Guest Editorial Introduction to the Special Issue on Citizen Centered e-Health Systems in a Global Healthcare Environment: Selected Papers From ITAB 2009

I. Introduction

THIS special issue is based on selected papers presented in the International Special Topic Conference on Information Technology in Biomedicine, held in October 2009, in Larnaka, Cyprus (http://www.cs.ucy.ac.cy/itab2009/). The event was technically cosponsored by the IEEE Engineering in Medicine and Biology Society and sponsored by the University of Cyprus, Cyprus, the Cyprus University of Technology, Cyprus, and the University of Ioannina, Greece. It marked the continuation of the previous eight successful conferences held in Prague in 1997, in Washington DC in 1998, in Amsterdam in 1999, in Virginia in 2000, in Birmingham in 2003, in Ioannina in 2006, in Tokyo in 2007, and in Shenzhen in 2008. ITAB 2010 was held in Corfu, and ITAB 2011 will be held in Istanbul, Turkey.

The overall objective of ITAB 2009 was to cover the state of the art in Information Technology Applications in Biomedicine, under the theme "Citizen centered e-health systems in a global healthcare environment". In total, 147 papers were presented, with 37 papers on e-health systems, m-health systems, and telemedicine systems; 52 papers in *Biomedical Signal Processing and Analysis*; 28 papers in *Biomedical Image Processing and Analysis*; 12 papers in *Bioinformatics and Computational Biology*; 6 papers in *Systems Biology and Modeling Methodologies*; and 12 papers in *Diagnostic and Therapeutic Systems*. In addition to these, 42 papers were presented by students and a student paper competition took place. Furthermore, five special sessions were organized with 35 papers presented on the following topics: LinkSCEEM HPC Life Sciences Meeting, Computational Intelligence in Medical Imaging (CIMI 2009), Information Technology for Patient Safety (ITPS 2009), Multitype Content Repurposing and Sharing in Medical Education, and Computational Methods in Orthopedic Biomechanics and Rehabilitation (COMOR 2009).

The program featured seven keynote presentations by distinguished colleagues. The first keynote was given by Prof. L. Kun, Senior Research Professor of Homeland Security National Defense University/IRMC, Washington DC, on "Global health transformation through true interoperability." The second keynote was given by Prof. Y.-T. Zhang, Chinese University of Hong Kong, Hong Kong, on "Cardiovascular health informatics: Sensing and imaging plagues in arteries." The third keynote was given by Mr. K. Kokkinos, General Manager of IBM Cyprus, Cyprus, on "Paving the path towards e-health for Cyprus public healthcare ecosystem." The fourth keynote, was given by Prof. M. Akay, Arizona State University, Tempe, AZ, on "A low cost and effective electronic medical record system for developing countries." The fifth keynote was given by Prof. N. Saranummi, VTT Technical Research Centre of Finland, Finland, on "Personal health record and value-based healthcare." The sixth keynote was given by Prof. R. Allen, University of Southampton, Southampton, U.K., on "Signal processing in patient assessment and care: from hospital to home", and the seventh keynote was given by Prof. G. Eysenbach, University of Toronto, Canada, on "Medicine 2.0 – new opportunities and challenges in the provision of health information and e-Learning."

The aim of this special issue is to provide a snapshot of emerging technologies in biomedical informatics focused on "Citizen centered e-health systems in a global healthcare environment," based on selected papers presented in ITAB 2009. A special issue call was announced and 65 papers were received. All the received papers went through the peer-review process of the IEEE Transactions. From the submitted papers, 20 were accepted for publication, organized under the topics of *Biosignal Processing and Analysis, Cardiovascular Monitoring, EHR and Remote and Home Monitoring, Decision Making, Medical Imaging, Bioinformatics*, and *e-Learning*, with two, three, five, four, four, one, and one papers, respectively. These papers are briefly presented in the following section.

II. Papers in this Special Issue

A. Biosignal Processing and Analysis

The paper by Karagiannis *et al.* [1] investigates the performance of empirical mode decomposition (EMD) on ECGs. Synthetic ECG signals corrupted with white Gaussian noise are employed and time series of various lengths are processed with EMD in order to extract the intrinsic mode functions (IMF). The identification of IMFs with high-level noise and their subsequent exclusion is done statistically. Simulation results reveal that a decrease of processing time is accomplished with the introduction of a preprocessing stage, prior to the application of EMD. Furthermore, the variation in the number of IMFs according to the type of the preprocessing stage is studied as a function of signal-to-noise ratio and time-series length. The application

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of the methodology is tested with real ECG signals from the MIT-BIH ECG library.

Murata *et al.* [2] propose a noninvasive system capable of monitoring the biological condition of a driver and issuing warnings during instances of drowsiness. More specifically, their system manages to detect individuals driving under the influence of alcohol by measuring biological signals. Frequency-time-series analysis is used in an attempt to distinguish between normal and intoxicated state of a person as the basis of the sensing system.

B. Cardiovascular Monitoring

The paper by Stylianides *et al.* [3] introduces a novel, open-source middleware framework for communication with medical devices and an application using the middleware named intensive care window (ICW). The middleware enables communication with intensive care unit bedside installed medical devices over standard and proprietary communication protocol stacks. The ICW application facilitates the acquisition of vital signs and physiological parameters exported from patient attached medical devices and sensors. Moreover, ICW provides run time and post analysis procedures for data annotation, data visualization, and data query and analysis. The ICW application can be deployed as a standalone solution or in conjunction with existing clinical information systems providing a holistic solution to inpatient medical condition monitoring, early diagnosis and prognosis.

Sufi and Khalil [4] demonstrate an innovative technique that performs real-time classification of cardiovascular disease (CVD). By using this, the emergency personnel or the hospital can automatically be notified via SMS/MMS/email when a life-threatening cardiac abnormality of the CVD-affected patient is detected. The system uses data-mining techniques, such as attribute selection and expectation-maximization-based clustering, run on a hospital server, to generate a set of constraints for representing each of the abnormalities. Then, the patient's mobile phone receives these set of constrains and employs a rule-based system that can identify each of abnormal beats in real time. Experimentation results on 50 MIT-BIH ECG entries reveal that the proposed approach can successfully detect cardiac abnormalities with an average accuracy of 97%. It is expected that this may help to building an efficient telecardiology diagnosis system.

The paper by Pecchia *et al.* [5] investigates the discrimination power of short-term heart rate variability (HRV) for discriminating normal subjects versus chronic heart failure (CHF) patients. Pecchia *et al.* analyze 1914.40 h of ECG of 83 patients of which 54 were normal and 29 were suffering from CHF with New York Heart Classification (NYHA) I, II, and III. Time and frequency analysis is performed in order to extract HRV features. In order to assess the discrimination power of HRV features, the authors designed a classifier based on the classification and regression tree (CART) method. The best subset of features for subject classification includes RMSSD, total power, high-frequencies power, and the ratio between low- and high-frequencies power (LF/HF). The best possible results achieve specificity and sensitivity of 89.7% and 100%, respectively. The proposed method allows a fully human-understandable description of classification procedures, in terms of intelligible "IF . . . THEN . . ." rules.

C. EHR and Remote and Home Monitoring

Cunningham *et al.* [6] propose a home-based tool designed to monitor and assess peripheral motor symptoms. An evaluation of the tool was carried out over a period of ten weeks on ten people with idiopathic Parkinson's disease (PD). Participants were asked to use the tool twice daily over four days, once when their medication was working at its best ("ON" state) and once when it had worn off ("OFF" state). Results show the ability of the data collected to distinguish the "ON" and "OFF" state and also demonstrate statistically significant differences in timed assessments. It is anticipated that this tool can be used in the home environment as an early alert to a change in clinical condition or to monitor the effects of changes in prescribed medications used to manage PD.

The paper by Huang *et al.* [7] proposes a method for the automatic analysis and classification of report data from patients suffering from chronic pain. The method is based on a machine-learning approach, which is used to analyze self-reporting data collected from the integrated biopsychosocial treatment, in order to identify an optimal set of features for supporting self-management. In addition, a classification model based on supervised-learning classifiers is proposed to differentiate the treatment stages. The results show a multilayer perceptron classifier has the best classification performance on an optimized subset of questions, which consists of ten questions. Its overall classification accuracy and AUC are 100% and 1, respectively.

Chen and Akay [8] propose that the use of electronic health records (EHR) in clinics for developing countries could help to increase the efficiency and efficacy of these clinics. Even though some EHR systems have been developed for developing countries, they lack customizability. This paper covers some background information about EHR systems, how they are used in developed countries, and how FileMaker could be used to rapidly deploy EHR systems in clinics and hospitals of developing countries. An existing EHR database developed by Banner Alzheimer's Institute serves as a proof-of-concept that FileMaker is a viable EHR solution.

Rybynok *et al.* [9] propose that in most emergency situations, health professionals rely on patients to provide information about their medical history. However, in some cases, patients might not be able to communicate this information, and in most countries, an online integrated patient record system has not been adopted yet. Therefore, in order to address this issue, the on-going project MyCare Card (MyC2, www.myc2.org) has been established. The aim of this project is to design, implement, and evaluate a prototype patient held EHR device. Due to the wide range of user requirements, the device, its communication interface and its software have to be compatible with many common platforms and operating systems. Thus, this paper is addressing one of the software compatibility matters—the cross-platform GUI implementation. It introduces a portable object-oriented GUI framework, suitable for a declarative

layout definition, components customization, and fine model-view code separation. It also rationalizes the hardware and software solutions selected for this project implementation

The paper by Liao *et al.* [10] explores a sensor fusion method applied within Smart Homes used for the purposes of monitoring human activities in addition to managing uncertainty in sensor-based readings. A three layer lattice structure is proposed, which can be used to combine the mass functions derived from sensors along with sensor context. The proposed model can be used to infer activities. The Dempster–Shafer theory of evidence can incorporate the uncertainty derived from the sensor errors and the sensor context, and subsequently, infer the activity using the proposed lattice structure. Results show that this method can detect a toileting activity within a Smart Home environment with an accuracy of 88%.

D. Decision Making

Maglogiannis *et al.* [11] present a Web application that exploits GRID infrastructures for distributed data processing and management of DNA microarrays (cDNA, Affymetrix, Illumina) through a generic, consistent, and computational analysis framework. The platform (named as GRISSOM) performs versatile annotation and integrative analysis tasks, through the use of third-party application programming interfaces, delivered as Web services. In parallel, by conforming to service-oriented architectures, it can be encapsulated in other biomedical processing workflows, with the help of workflow enacting software, like Taverna Workbench, thus rendering access to its algorithms, transparent, and generic. GRISSOM aims to set a generic paradigm of efficient metamining that promotes translational research in biomedicine, through the fusion of grid and semantic Web computing technologies.

Lambrou *et al.* [12] propose that conformal predictors (CPs) are machine-learning algorithms that can provide predictions complemented with valid confidence measures. In medical diagnosis, such measures are highly desirable, as medical experts can gain additional information for each machine diagnosis. A risk assessment in each prediction can play an important role for medical decision making, in which the outcome can be critical for the patients. Several classical machine-learning methods can be incorporated into the CP framework. In this paper, a CP is proposed that makes use of evolved rule sets generated by a genetic algorithm (GA). The rule-based GA has the advantage of being human readable. The proposed method is applied to two real world datasets for medical diagnosis, one dataset for breast cancer diagnosis, which contains data gathered from fine needle aspirate (FNA) of breast mass, and one dataset for ovarian cancer diagnosis, which contains proteomic patterns identified in serum. The results on both datasets show that the proposed method is as accurate as classical techniques, while it provides reliable and useful confidence measures.

Iakovides *et al.* [13] propose that medical decision making can be regarded as a process, combining both analytical cognition and intuition. It involves reasoning within complex causal models of multiple concepts, usually described by uncertain, imprecise, and/or incomplete information. Aiming to model medical decision making, they propose an approach based on cognitive maps and intuitionistic fuzzy logic. The new model, called intuitionistic fuzzy cognitive map (iFCM), extends the existing FCM by considering the expert's hesitancy in the determination of the causal relations between the concepts of a domain. Furthermore, a modification in the formulation of the new model makes it even less sensitive than the original model to missing input data. To validate its effectiveness, an iFCM with 34 concepts representing fuzzy, linguistically expressed patient-specific data, symptoms and multimodal measurements, was constructed for pneumonia severity assessment. The results reveal its comparative advantage over the respective FCM model by providing decisions that match better with the ones made by the experts. The authors claim that the generality of the proposed approach suggests its suitability for a variety of medical decision-making tasks.

Alexandrou *et al.* [14] present an innovative software environment that provides an integrated IT solution concerning the adaptation of healthcare processes (clinical pathways) during execution time. The software comprises a healthcare process execution engine assisted by a semantic infrastructure for reconfiguring the clinical pathways. During the execution of clinical pathways, the system reasons over the rules, and reconfigures the next steps of the treatment. A graphical designer interface is implemented for the definition of the rule set for the clinical pathways adaptation in a user-friendly way.

E. Medical Imaging

Loizou *et al.* [15] introduce the use of multiscale AM–FM texture analysis of multiple sclerosis (MS) using MR images from the brain. Clinically, there is interest in identifying potential associations between lesion texture and disease progression, and in relating texture features with relevant clinical indices, such as the expanded disability status scale (EDSS). Their study explores the application of 2-D AM–FM analysis of brain white matter MS lesions to quantify and monitor disease load. To this end, MS lesions and normal appearing white matter (NAWM) from MS patients, as well as normal white matter (NWM) from healthy volunteers, were segmented on transverse T2-weighted images obtained from serial brain MR imaging scans (0 and 6–12 months). The findings suggest that AM–FM characteristics succeed in differentiating 1) between NWM and lesions; 2) between NAWM and lesions; and 3) between NWM and NAWM. A support vector machines (SVM) classifier succeeded in differentiating between patients that, two years after the initial MRI scan, acquired an EDSS ≤ 2 from those with EDSS > 2 (correct classification rate $= 86\%$). The findings of this study provide evidence that AM–FM features may have a potential role as surrogate markers of lesion load in MS.

Tsiaparas *et al.* [16] propose a multiresolution analysis for texture classification of atherosclerotic tissue from B-mode ultrasound. Four decomposition schemes, namely the discrete wavelet transform (DWT), the stationary wavelet transform (SWT), wavelet packets (WP), and Gabor transform (GT), as well as several basis functions, are investigated in terms of their ability to discriminate between symptomatic and asymptomatic

cases. Selected features are subsequently input into two classifiers using SVM and probabilistic neural networks (PNN). WP analysis and the coiflet 1 produced the highest overall classification performance (90% for diastole and 75% for systole) using SVM.

Belaid *et al.* [17] present a phase-based level set method for segmenting ultrasound images. Belaid *et al.* introduce a new speed term based on local phase and orientation defined in terms of the monogenic signal. The approach uses Cauchy kernels for implementing quadrature filters for feature extraction. Segmentation results on 20 ultrasound images indicate that the proposed approach can perform well in noise and also in capturing low contrast boundaries.

Aristokleous *et al.* [18] propose a method, which monitors geometric features extracted from 3-D virtual models of the carotid artery bifurcation. 3-D models were created from cross-sectional MRI images. Geometric features, such as bifurcation angle, ICA angle, planarity angle, asymmetry angle, tortuosity, curvature, bifurcation area ratio, ICA/CCA, ECA/CCA, and ECA/ICA diameter ratios, were calculated for both carotids in two head postures: 1) the supine neutral position and 2) the prone sleeping position with head rotation to the right ($\sim 80^{\circ}$). The results obtained have shown significant geometric changes observed in most subjects with head posture, may also cause significant changes in bifurcation hemodynamics and warrant future investigation of the hemodynamic parameters related to the development of atherosclerotic disease, such as low oscillating wall shear stress and particle residence times.

F. Bioinformatics

Blazadonakis *et al.* [19] assess the issue of similarities at the biology level hidden underneath a given signature. They take into account the biological knowledge that exists among different signatures and use it as a means of integrating them and refining their statistical significance on the datasets. In this form, by integrating biological knowledge with information stemming from data distributions, they derive a unified signature that is significantly improved over its predecessors in terms of performance and robustness. The motivation behind this approach was to assess the problem of evaluating different signatures not in a competitive but rather in a complementary manner, where one is treated as a pool of knowledge contributing to a global and unified solution.

G. e-Learning

The paper by Kaldoudi *et al.* [20] discusses educational content and content repurposing in medical education, presenting different repurposing contexts. Furthermore, it proposes a novel approach to content repurposing via Web 2.0 social networking of learning resources. The proposed social network is augmented by a graphical representation module in order to capture and depict the relationships among different repurposed medical educational resources, based on educational resource "families'' and inheritance.

III. Concluding Remarks

Health services are facing a number of complex interacting and multifactor challenges, that according to a recent paper by Saranummi [21], include: 1) healthcare costs that are increasing as people grow older, that is more apparent in developed countries; 2) current lifestyles that contribute toward increased prevalence of chronic degenerative diseases; and 3) widely expanding coverage of the healthcare services based on new and innovative technologies. For addressing the aforementioned challenges, major changes need to take place for offering better services to the citizen [21].

To address the aforementioned issues from the information and communication technologies (ICT) perspective, the World Health Assembly (WHA), at its 58th session in May 2005, adopted resolution WHA58.28 establishing an e-health strategy for the World Health Organization (WHO). The resolution urged member states to plan for appropriate e-health services in their countries. It also recognized that a WHO e-health strategy would serve as a basis for WHO's activities in e-health [22]. WHO established the global observatory for e-health (GOe) that carried out a global survey for e-health. The key findings of this survey are [22]: 1) ICT is steadily integrated into health systems and services worldwide; 2) a consistent relationship was found between World Bank income groups and the introduction of e-health by countries. Countries in the high and upper middle income groups are more advanced in their e-health development than those in the lower middle, low-income groups; 3) member states are making concrete advances in building foundation policies and strategies for e-health at the national level, with the exception of e-health governance mechanisms; and 4) adoption of most enabling policies or strategies for e-health is low compared to the foundation actions reviewed.

In parallel with the WHO activities, the European Commission (EC), adopted the e-health action plan [23] in 2004, which covers a wide spectrum of e-health services, ranging from electronic prescriptions and health cards to new information systems that are targeting to reduce waiting times and errors to facilitate a more harmonious and complementary European approach to e-health [24]. The EC is moving toward a "European e-health area", coordinating actions and promoting synergies between related policies and stakeholders, so as to develop better solutions, prevent market fragmentation and disseminate best practices. Specific objectives are to apply an EHR architecture by supporting the exchange of information and standardization, to set up health information networks between points of care to coordinate reactions to health threats, to ensure online health services, such as information on healthy living and illness prevention, and to develop teleconsultation, ePrescribing, eReferral, and eReimbursement capabilities. The success of this venture requires that citizens', patients', and health professionals' requirements and involvement are considered in the implementation strategies and projects [25]. The EC holds every year a Ministerial conference on e-health for monitoring the progress of the implementation of e-health and ensuring the proper deployment of ICT in healthcare. During the most recent meeting held in Barcelona in March 2010 [26], the ministers issued a declaration that commits them

in enhancing quality and sustainability of healthcare systems, to make them to benefit from ICT deployment in the best interest of patients, healthcare professionals and society. The way of achieving these was summarized as: 1) political and strategic commitment; 2) building confidence and acceptance; 3) bringing legal and ethical clarity and ensuring protection of personal health data; 4) solving interoperability issues; and 5) linking e-health policy to competitiveness, innovation, and research as well as to cohesion and inclusion policies. In conclusion, they recognized the need for stronger synergies with policy areas like competitiveness, research, and regional development both at European and national levels. They also recognized the importance of involving all stakeholders, in the strategic planning, validation, and implementation of e-health.

The U.S. Senate passed the American Recovery and Reinvestment Act of 2009 (Recovery Act) that earmarked US$19 billion for health information technology spending, $17 billion of which is designated for incentive payments for EHR use. President Obama, in his joint speech to Congress, emphasized that he wants EHRs to be established for all Americans over the next five years [27]. According to [27] to date, only about 25% of the nation's 5000 hospitals have rolled out EHR systems, and only a small fraction of physician practices have done the same.

There is a huge and urgent need for the development, implementation, and deployment in everyday medical practice of e-health systems and services in support of the citizen. In this context and direction, ITAB conferences will continue contributing.

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