Trends in Computer-Based Medical Systems

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ABSTRACT

The 25th IEEE International Symposium on Computer-Based Medical Systems, held June 20-22, 2012 in Rome, Italy, has been a forum for discussing the latest developments in the field of computational medicine, biomedical informatics, and related disciplines. The Symposium has covered a broad range of issues in several areas with accepted submissions gathered into one general track, addressing general questions of computational biomedicine, and twelve special tracks, each focused on a particular related sub-theme. Three keynote speakers have presented an overview of recent research and developments in their particular subareas of mining clinical data for biomedical research, multivariate and multiscale analysis of biomedical signals, and oncology image analysis.

Keywords

Computer-based medical systems, machine learning, pattern recognition, bioinformatics, health informatics, data mining, knowledge discovery, ontologies, grid and cloud computing, image processing, database.

1. INTRODUCTION

The 25th IEEE International Symposium on Computer-Based Medical Systems was held in the "Campus Bio-Medico" University of Rome, Italy, in the period from 20th to 22nd of June 2012 [1,2]. Since its first edition a quarter of a century ago in 1988 the Symposium has been witnessing the rapid evolution of the computer techniques and devices available for medical systems, and has been providing an international forum for discussing the latest developments in the field of computational medicine, biomedical informatics and related disciplines.

The Symposium covers a broad range of issues in the following areas: software systems, network and telemedicine systems, web-based delivery of medical information, medical databases and information systems, knowledge discovery, data mining, pervasive health systems and services, biomedical signal, image and video processing and analysis, decision support systems, medical devices with embedded computers, e-Health, medical robotics, computer-aided diagnosis, and bioinformatics. Furthermore, the 2012 Symposium has focused on sixteen topics of different scale that were considered of large relevance, from more generic themes such as software and systems and learning-based biomedical information systems to more specific topics such as image processing for ophthalmology and endoscopic image processing and analysis.

Symposium contributions have been selected from 228 manuscripts submitted by 755 authors from 50 countries. After the reviewing procedure, which has involved 210 program committee members and 54 external reviewers, we have selected 72 long papers thus having 31.6% acceptance rate for this category. Besides, 44 short papers have been selected including both research and application oriented contributions.

Furthermore, the Symposium has been the occasion to discuss other three themes devoted to a broad audience since three keynote speakers gave contributions on data mining for biomedical research, multivariate and multiscale analysis of biomedical signals, as well as biomedical cancer image analysis.

In the following we overview we main topics covered in the Symposium by the regular and the three keynote speakers.

2. SYMPOSIUM MAIN TOPICS

The main topics described in the following correspond to the Symposiums' programme, which has been divided into a general track, distributed over four sessions, and twelve special tracks.

2.1 Software, systems and data management

The application of software and systems as well as data management in biomedicine has dramatically increased over the last decades, with many solutions applied both in research and in practice. Nevertheless, there are many issues deserving research attention dealing with still open topics, related to a various set of applications, such as calibration, databases, patient records and so on.

2.2 Learning-based biomedical information systems

The vast amount of data generated by biomedical devices, or retrieved from archives, motivates the development of tools that are able to handle, analyze and make use of it in a computer-supported fashion.

However, the automatic extraction of useful information from these sources remains a challenging task because the data are of deeply heterogeneous nature (texts, images, time-varying signals,

omics data, etc.) as well as the processes involved (computer-aided patient data monitoring and anomaly detection, automatic anatomy delineation and lesion detection from images, finding inconsistencies in clinical reports, etc.).

To this aim, information systems based on automatic learning techniques have become a popular and effective way for facing such issues. These systems can pursue different objectives, such as pre-selection of patient data to be examined, serving as a second reader or working as a tool for training and education of specialized medical personnel. Currently, the development of learning-based systems applicable to different working scenarios is a major issue.

2.3 Signal and image processing

Signal processing plays a broad role in the development of medical devices and in the analysis of physiological signals, where signal analysis has been widely applied in patient monitoring, diagnosis and prognosis, as well as physiological investigation and in some therapeutic settings. Medical imaging is the technique and process used to create images of the human body for clinical purposes or medical science. It is part of biological imaging and incorporates radiology, nuclear medicine, endoscopy, and microscopy. Accepted contributions have covered the area of instrumentation, image acquisition, modeling and quantification, enhancement and interpretation.

2.4 Processing and managing medical data streams

Many applied computing researchers coming from different areas (data mining, machine learning, intelligent data analysis, pattern recognition, fuzzy logic, databases, etc.) are designing new approaches or adapting some of the traditional algorithms to data streams. On the other side, many physicians are addressing the need to integrate streaming medical data into decision support systems.

2.5 Bioinformatics: towards personalized medicine from omics data

The study of biological systems regards the basic biological elements (e.g., proteins, genes and metabolites) as well as the interactions among such components (e.g., protein interactions, genetic interactions). It combines the application of computational methods to experimental data with the exploitation of biological and life science knowledge. Raw experimental data need to be preprocessed with specific algorithms and may be annotated with semantic information and prior knowledge, e.g. extracted from ontologies. Analysis is usually performed by using data mining or statistical methods that allow to extract behavior and information. Computational methods lead also to building accurate models of such systems and that give feedback to the scientist to perform new experiments or to refine current ones. Omics data play a central role in modern biology and bioinformatics and include genomics, proteomics and interactomics data, to cite a few.

The maturity and experiences of the collaboration among biologists and computer scientists brings today to additional interests on integrating omics data with clinical data, e.g. for pharmacogenomics studies. The combined use of genomics, proteomics, and clinical data will thus improve healthcare management and is the basis for personalized medicine. Tools and databases used for genomics and proteomics studies should be able to furnish input to clinical practice, enabling the so-called from-bench-to-bed paradigm.

2.6 Ontologies, terminologies and language processing

Biomedical Ontologies provide a crucial framework for handling and coping with an exponential growth in the volume of biological data, generated by high-output technologies and fuelled by advances in biotechnology. However, these Ontologies have developed in a largely uncoordinated way, often reflecting mere relations of 'association' between concepts, and primarily serving the purposes of information extraction from on-line biomedical literature and databases. In recent years, a great deal has been learned about the criteria which must be satisfied if an ontology is to allow true information integration and automatic reasoning across data with information derived from different sources.

2.7 Grid and cloud computing in biomedicine and life sciences

Life sciences researchers routinely deal with large data to be analyzed by applications that need considerable computing power, including advanced parallel and distributed infrastructures, Managing these data and optimizing the applications for these architectures is one of the challenges that must be tackled. Bringing together and correlating data among different and heterogeneous data sources will allow inference of new knowledge from these databases. There is a tremendous potential for end-users in many fields of life sciences, to routinely conduct large-scale computations on distributed resources by using a combination of distributed middleware and virtualization technologies.

Grid for the Life Sciences is an environment that allows sharing of resources, in which heterogeneous and dispersed health data as well as applications can be accessed by all users as a tailored information providing system according to their authorization.

Cloud computing is emerging as a model for enabling convenient, on demand network access to a shared pool of configurable resources that can be rapidly provisioned and released with minimal management effort or service provider interaction.

Institutions and medical professionals who frequently do not have enough storage and computing resources can manage their biomedical information through applications built on top of these types of services, accessing advanced computing infrastructures that they could not afford otherwise. While many companies, like Google, IBM, Amazon, and Microsoft, were early adopters of cloud computing, its application to biomedicine has been only recently proposed, mainly for bioinformatics applications, while in contrast, applications in medical informatics have been infrequent.

2.8 Intelligent patient management

Over the past three decades there has been a rapidly growing interest by Governments and healthcare providers, of most industrialised countries, to improve access and the quality of healthcare. The motivation for such research has been generated by many factors relating to the changing demographics in populations for example the increasing proportion of the elderly

in the population and increased longevity, improved medical technologies and rising health aspirations by the general population. At CBMS 2012, we considered the latest research in modeling patient care and resources within a healthcare system using intelligent computational and modeling techniques.

2.9 Collaboration and technology-mediated communication in healthcare

Communication, Teamwork, Interaction and Mobility are terms we have come to associate with healthcare work. Communication can be synchronous or asynchronous, coupled and often mediated by multimedia technology. The challenge of co-ordination and supporting co-operation in these work settings is an on-going problem for designers and developers. Co-ordination of information among teams and between institutional settings is critical for efficient and effective healthcare delivery.

In this economic climate, we are especially challenged to find more efficient and effective methods of delivering services. We are provoked to provide novel approaches to help to control disease and maintain a healthy population. Different technologies have the potential for hospitals, teams, and individuals to reconfigure their traditional practices in new and effective ways.

2.10 Emerging smart technologies for personalised healthcare

The current technology and communication developments, and the increasing willingness of people to be involved in making decisions about their health or disease, have been paving the way for advances in the area of personalised healthcare.

The uncertainty and complexity within this area require smart solutions and systems, which are capable to interpret context-specific information concerning the patient and his/her environment.

2.11 Informatics challenges of patient centric health and social care

Policy makers around the world emphasize the integration of health and social care in their National eHealth Strategies. However, health care differs from social care as services are different, they are usually regulated under different laws, care records are constructed differently using different terminology and meaning and there are still many unexplored research issues to make this integration happen. A fundamental goal is the shift from organization-centric to patient-centric care to allow for a holistic care service that can be supported by technology.

2.12 Systems and services for quality enhancement of healthcare provisioning

Owing to the increasing healthcare costs across the world, most Governments and leading technology companies are focusing and investing in the area of improving healthcare quality provisioning, and are interested in systems that conduct quality assessments or audits. The escalating demand for improving the quality of healthcare provision has influenced both the public and private health sectors demanding results and ideas of how to improve quality of healthcare provisioning in different paradigms. Research for this special session can draw from various disciplines.

2.13 Brain imaging

Recent technology has enabled neuroscientists to see inside the living brain. Such brain imaging methods help neuroscientists to understand the relationships between specific areas of the brain and what function they serve, to locate the areas of the brain that are affected by neurological disorders as well as to develop new strategies to treat brain disorders.

2.14 Image processing for ophthalmology: challenges in retinal analysis and related fields

During the last decade, retinal image analysis has been making steady progress towards applications in clinical practice. Various research and commercial software tools have emerged for screening, lesion detection and quantification, and biomarker discovery. A mounting volume of data and annotations is becoming accessible to research groups, and several public repository of test data have appeared on the Internet. With steadily increasing computer-aided support, the eye is even more than before a window on the whole human body. Retinal image analysis is maturing as a field, building on foundational years of work on automated detection and representation of retinal landmarks and lesions alike.

2.15 Endoscopic image processing and analysis

Medical endoscopy is the process whereby an optical instrument is introduced into one or other of the body tubes or cavities so that the organs of the body may be directly inspected. The application of this technology has permitted to tackle with the digestive tract examination, which has now become painless and simple with the aid of Wireless Capsule Endoscopy (WCE). WCE is a revolutionary, patient-friendly imaging technique that enables non-invasive visual inspection of the patient's digestive tract, especially small intestine. By continuously imaging and transmitting the patient's gastrointestinal tract, the capsule can store thousands of endoscopic images for medical diagnosis. However, the time-consuming task of reviewing the endoscopic data is a burden for the physicians, stimulating researches for different applications, such as real-time redundant image elimination system to reduce the number of near-reduplicate images generated in the near-time period, and stream processing for automatic discrimination of images related to a certain disease, e.g. ulcer or colonic polyps. In general, image processing in endoscopic images could potentially help to save time, lower the cost for colonoscopy procedures, and reduce the risk of complications.

3. INVITED KEYNOTES

Besides the submissions related to the aforementioned sixteen topics, the Symposium offered also keynote speeches from recognized scientists providing a deep insight into three topics of large interest:

- Prof. Nada Lavrac (Jožef Stefan Institute, Ljubljana, Slovenia) gave a contribution about Advances in Data Mining for Biomedical Research, first outlining standard approaches to data mining, with the emphasis on subgroup discovery which proves to be an effective tool for data analysis in medical applications [3]. The core of the talk was devoted to relational data mining and inductive logic programming, which have a great

potential for biomedical research, including recent approaches to semantic data mining with enable the use of domain ontologies as background knowledge used in data analysis. The use of such techniques and tools has been illustrated on a number of biomedical applications;

- The speech of Prof. Sergio Cerutti (Politecnico di Milano, Milan, Italy) dealt with Multivariate and Multiscale Analysis of Biomedical Signals [4]. The MMM-paradigm (i.e. multivariate, multiorgan and multiscale) allows to describe the behavior of several complex systems, such as the cardiovascular or central nervous ones, that often provide us with very informative signals showing strong linear and non linear interactions with other biological systems. Such an approach to physiological studies emphasizes where the genesis of their complexity is potentially allocated and how it is possible to detect information from it, through a proper processing of the available data. No doubt that processing signals from multi-leads of the same system (multivariate), from the interaction of different physiological systems (multiorgan) and integrating all this information across multiple scales (from genes, to proteins, molecules, cells, up to the whole organ) could really provide us with a more complete look at the overall phenomenon of cardiovascular or central nervous system complexity, in respect to the one which is obtainable from summing up its single constituent parts. In this speech, such an innovative approach has been discussed, by providing examples relative to cardiovascular system and central nervous system in different time and spatial scales, in studying different organ involvements (like in sleep, relaxation, depression and multiple organ disfunction). It is believed that this paradigm will contribute to a more holistic vision of physiopathology, by considering patient as a whole not simply as the sum of his/her constituent parts. Medical diagnosis a well as a modern concept of preventive medicine which has to take care also of healthy population could largely profit by this methodological and technological approach;
- Dr. Julia Schnabel (University of Oxford, Oxford, UK) presented a talk about Biomedical Cancer Imaging Analysis, which is becoming increasingly integrated into clinical workflow [5]. As imaging technology is becoming more and more sophisticated, providing volumetric, multi-modality and dynamic acquisitions, the large amount of spatiotemporal data available poses increasingly challenging problems for the radiologists, oncologists, and other clinicians involved in cancer treatment, calling for automated, robust and accurate image analysis solutions. One aspect of interpreting such data correctly is the problem of patient motion, due to different scanning systems, patient movements, or respiratory motion. Her speech focused over a range of image analysis tools for multi-modal and dynamic image motion correction, in particular for lung cancer and colorectal cancer.

4. CONCLUSIONS

The area of computer-based medical systems has been evolving over the past decade. Beside the traditional (yet also evolving over the years) topics related to imaging, computer-aided diagnosis, medical software and systems, bioinformatics, intelligent patient data processing, signal processing, telemedicine, the recent editions of the conference include a broader range of covered CBMS subareas: ontologies, text mining, patient centric and personalized healthcare, distributed and cloud computing among others. We foresee a further broadening and reshaping of the conference scope due to fertilization of the core CBMS areas and new trends in Health Informatics, Artificial Intelligence in Medicine and other related areas. We believe that we can help this process by bringing together/collocating in time and space the key scientific events in the field, including but not limited to IHI, AIME and CBMS conferences.

We invite prospective authors to contribute to the next CBMS edition that will be held in Porto, Portugal on 22-24 June 2013 (http://cbms2013.med.up.pt).

5. ACKNOWLEDGMENTS

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