Chapter 5.7
Computational Methods and Tools for Decision Support in Biomedicine:
An Overview of Algorithmic Challenges

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ABSTRACT

The automation of diagnostic tools and the increasing availability of extensive medical datasets in the last decade have triggered the development of new analytical methodologies in the context of biomedical informatics. The aim is always to explore a problem's feature space, extract useful information and support clinicians in their time, volume, and accuracy demanding decision making tasks. From simple summarizing statistics to state-of-the-art pattern analysis algorithms, the underlying principles that drive most medical problems show trends that can be identified and taken into account to improve the usefulness of computerized medicine to the field-clinicians and ultimately to the patient. This chapter presents a thorough review of this field and highlights the achievements and shortcomings of each family of methods. The authors' effort has been focused on methodological issues as to generalize useful conclusions based on the large number of notable, yet case-specific developments presented in the field.

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INTRODUCTION

Contemporary and future methods of healthcare delivery will be exploiting new technology, novel sensing devices and a plethora of modes of information generated by distributed data sources. This raw data is inevitably increasing in volume and complexity at a rate faster than the ability of primary healthcare providers to access and understand it. Several countries are currently considering issues of integrated personalised healthcare and the application of 'intelligent' data mining methodologies in providing medical decision support to the clinician (and the individual), using principled pattern recognition methodologies.

Within such an environment, the domain of medical imaging, with its various structural (CT, MRI, U/S) and functional (PET, fMRI) modalities, is probably on the top of the list with respect to the amount of raw data generated. Most of these modalities are explored in other chapters of this volume. Even though image inspection by human experts enables the accurate localization of anatomic structures and/or temporal events, their systematic evaluation requires the algorithmic extraction of certain characteristic features that encode the anatomic or functional properties under scrutiny. Such imaging features, treated as markers of a disease, can subsequently be integrated with other clinical, biological and genomic markers, thus enabling more effective diagnostic, prognostic and therapeutic actions. It is the purpose of this chapter to address issues related to the decision making process, to trace developments in infrastructure and techniques, as well as to explore new frontiers in this area.

The Medical Informatics Revolution

During the last decades we are witnessing a gradual shift in the medical field. Medical professionals are increasingly being supported by advanced sensing equipment. These instruments provide objective information and assist in reducing the margin of error in diagnosis and prognosis of diseases. Detailed imaging techniques provide accurate anatomic and/or functional maps of the human body, and advanced signal processing methods performing biosignal and biochemical analyses are now largely automated, faster and increasingly accurate. In the broader medical research field, larger datasets of patients including multiple covariates are becoming available for analysis.

Figure 1 outlines the information flow in a medical decision support system. At an initial stage, a large amount of data is collected from various sensors and pre-processed. This data is accessibly stored in a structured format and fused with other information, such as expert knowledge. At a higher level, patterns are sought in the full dataset and translated in an intelligent way to produce meaningful and helpful reasoning. This output supports healthcare professionals during their prognostic, diagnostic and other decision making tasks. At the end of this process, feedback to the system in the form of expert evaluation or validity of analysis can be incorporated to improve performance.

This relative data abundance has resulted in a corresponding explosion of scientific papers referring to thorough statistical analysis with data mining and pattern classification techniques. New findings are more easily made available to the scientific community through the internet and cheap processing power aids the development of complex models of diseases, drugs, and effects.

In this context the field of medical informatics emerges as the intersection of information technology with the different disciplines of medicine and health care. It deals with the resources, devices, and methods required to optimize the acquisition, storage, retrieval, analysis and use of information in health and biomedicine (VanBemmel & Musen, 1997). Medical informatics tools include not only computers but also clinical guidelines, formal medical terminologies, and information, communication and decision support systems. It is by now evident that medical informatics do not

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