2006-1403: INTEGRATION OF MEDICAL INFORMATICS INTO COMPUTER SCIENCE CURRICULUM

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Abstract

Biomedical informatics has been defined as the discipline concerned with the systematic processing of data, information and knowledge in medicine and health care. It is an interdisciplinary field based on computer science, information science, the cognitive and decision sciences, telecommunications as well as other fields. Because of the rich and diverse nature of medical information, it has created a fertile ground for innovations and applied research particularly from the prospective of computer science and information technology. Although medical informatics has been recognized as a standalone science, few colleges and universities with computer science programs have acknowledged medical informatics as a viable application and have recognized the importance of incorporating medical informatics courses into their curriculum. Also, there has been no unified approach as to how topics in medical informatics should be integrated into the curriculum. In this paper, we address the need to have a structured paradigm for embedding medical informatics courses in computer science programs in a way that allows students to achieve a multitude of knowledge and a high-level of proficiency which will ultimately enable them to apply their problems-solving skills in health and medicine. We define three main areas from which these courses are derived. First, methodologies for processing data, information and knowledge in medicine and health care are essential for analysis and management of clinical data in research and medical practice especially in administrative and clinical decision supports. Second, understanding the clinical workflow of a typical hospital information system is also crucial for the design of electronic medical record applications and hospital network topology. Finally, biometric applications invite computer scientists to fully employ their knowledge in artificial intelligence and security systems. We believe that our work may contribute as future guidelines for incorporating medical informatics as an optional track in computer science programs.

Introduction

In the past, Medical Informatics was considered as merely an area of application of computer science in healthcare. Today, Biomedical or Medical Informatics is an emerging discipline that can be defined as the study, invention, and implementation of structures and algorithms to improve communication, understanding and management of medical information. Its rapid growth is due in large to the explosion in data from all areas of medicine and biology as well as the exponential advancement in computer science and information technology. The end objective of biomedical informatics is the coalescing of data, knowledge, and the tools necessary to apply that data and knowledge in the decision-making process, at the time and place that a decision needs to be made. The emphasis on the structures and algorithms necessary to manipulate the information separates Biomedical Informatics from other medical disciplines where information content is in focus. While historically innovations in computer science and information
technology had found viable applications in medical data, computer scientists and IT professionals are venturing into the world of medical informatics in search of medical problems that can be tackled through novel methodologies that include data processing, analysis and recognition. This has created new opportunities to change medical practice and exposed the need to understand and manage information in the context of clinical care from the prospect of computer science, information and telecommunication technology. Today, more colleges are offering programs in Medical Informatics either as a special track in nursing or as a graduate program for nursing and/or other healthcare professionals [1]. Other Medical Informatics curricula target medically-oriented students of a wider range of health-related backgrounds, while providing a uniform foundation in the essentials of the field [2]. For most computer science graduates nowadays, Medical Informatics seems remotely far-fetched, distanced by knowledge in medicine and health science. We argue that computer science and IT students, with modest training in health and life science and some familiarization with the medical terminology, can be prepared to engage in this emerging field using their technical knowledge and problem-solving skills in their related discipline. In this paper, we address the need to have a structured paradigm for embedding medical informatics courses in computer science programs in a seamless way that allows students to achieve a multitude of knowledge and a high-level of proficiency which will ultimately enable them to apply their problems-solving skills in health and medicine. We identify three main areas from which these courses are derived; data processing and knowledge discovery, Clinical Database Management, and Biometry. To meet the educational objectives of Medical Informatics under each area, we designate three categories under which courses are classified within a curriculum; basic, core and specific. The basic courses reflect life and health science related courses that are essential for non-medical professions. The core courses are those that are usually embedded in every Computer Science and IT program but are imperative to Medical Informatics. Specific courses are those that are directly related to Medical Informatics and which serve as the building blocks for students skills and experience in the related field. At the end, we present a case study that demonstrates how computer science students can participate in medical informatics projects and research.

Data Processing and Knowledge Discovery

Methodologies for processing data, information and knowledge in medicine and health care are essential for analysis and management of clinical data in research and medical practice especially in administrative and clinical decision supports. Integrating medical knowledge and advances into the clinical setting is often difficult due to the complexity of the involved algorithms and protocols. Modern clinical decision support systems (CDSS) assist the clinician in applying new information to patient care through the analysis of patient-specific clinical variables. Many of these systems are used to enhance diagnostic efforts and include computer-based programs which provide extensive differential diagnoses based on clinical information entered by the clinician [3-4]. Other forms of clinical decision support systems, such as antibiotic management programs and anticoagulation dosing calculators, seek to prevent medical errors and improve patient safety [5-6]. Although many clinical decision support systems are now computer-based, some are relatively simple, with no inherently complex internal logic systems. More
complex systems include computerized diagnostic tools that may be useful as an adjunctive measure when a patient presents a confusing constellation of symptoms causing unclear diagnosis. Computer-assisted diagnosis can borrow a lot from novel artificial intelligence, expert systems and pattern recognitions techniques. Rule-based or knowledge-based CDSS will analyze and interpret patient health data based on standard medical information and evidence-based or medical best practice reasoning. Moreover, speech recognition and analysis systems can also provide a remedy for the labor-intensive process of patient-specific data entry. Other CDSS systems, both simple and complex, may be integrated into the point-of-care and provide accessible reminders to clinicians regarding appropriate management based on previously entered data. These systems may be most practical when coupled with computerized physician order entry and electronic medical records or EMR which will be discussed next. Finally, through their integration with practice guidelines and critical pathways, decision support systems may provide clinicians with suggestions for appropriate care, thus decreasing the likelihood of medical errors. For example, a guideline for the management of community-acquired pneumonia may include a clinical tool that, after the input of patient-specific data, would provide a recommendation regarding the appropriateness of inpatient or outpatient therapy.

### Basic Courses

1) Human anatomy and Physiology

### Core Courses

1) Expert System  
2) Pattern recognition and Artificial Intelligence

### Specific Courses

1) **Clinical and Administrative Support Systems**

   The course builds the foundations and the lifecycle of clinical information starting with information collection, processing (e.g., decision making) and recording. All aspects of clinical information use in inpatient and outpatient facilities. Special emphasis on the clinician’s work to support enterprise-wide health care delivery

2) **Knowledge Discovery and Data Mining**

   The course introduces concepts and strategies for design, development, and implementation of clinical data warehouses and repositories to enable their exploitation by knowledge discovery and data mining technologies. Various models of data warehouse and repository design and of various methodologies associated with data mining and machine learning. Applications made to healthcare organization.

### Clinical Database Management
Understanding the clinical workflow of a typical hospital information system is also crucial for the design of electronic medical record applications and hospital network topology. Electronic Medical Record (EMR), also termed computerized patient record (CPR) and patient health record (PHR), is a term used to describe computer-based patient medical record that mimics the structure of the traditional paper medical record such as charting, transcription, and even medical images. It enables physicians to run a paperless office, access patient data any given location, enter and store clinical notes and prescriptions. It also allows automatic scheduling of patients as well as accurate and complete processing of claims by insurance companies. The term has also become expanded to include systems which keep track of other relevant medical information. Although an EMR system has the potential to permit invasion of medical privacy, if security policies are monitored effectively EMRs are as secure as banking records, for example. There are two primary categories of the EMR; the "born digital" record and the scanned/imaged record. The "born digital" record, which is information captured in a native electronic format originally is information that may be entered into a database, transcribed from an electronic tablet or notebook PC, or in some other manner captured from its inception electronically. The information is then transferred to a server or other host environment, where it is stored electronically. The second category is records originally produced in a paper or other hardcopy form (x-ray film, photographs, etc.) that have been scanned or imaged and converted to a digital form. Understanding how all the complex and the diverse medical data, including text and images, are related is central to the design of the database architecture that houses the EMR as well as the access method. Methods of image processing and representation including standard compression techniques are essential to designing clinical image warehouse often referred to as PACS (Picture Archiving and Communications System). In addition, effective techniques for simultaneous visualization of different types of health data can be a life-saving factor especially in time-critical emergency situations.

**Basic Courses**

1) Medical Coding and Terminology

**Core Courses**

1) Database Management System  
2) Computer Graphics and Visualizations  
3) Medical Image Analysis and Processing

**Specific Courses**

1) **Databases and Data Modeling**

The course introduces concepts of data modeling, data architectures, and data administration. Study of various models with application to current health information projects.
2) **Analysis and Design of Health Information Systems**

The course addresses requirements, concepts, methods, and tools in analyzing, modeling, and designing health information systems with emphasis on clinical systems. Conformance to standards including HL7 and DICOM are also examined.

**Biometry**

Biometry or biometrics can also be considered a branch of medical informatics. It is defined as automatically recognizing a person using distinguishing traits, such as unique physiological or behavioral characteristic, not shared by any other individual, to positively identify an individual. Recently, more biometric features extracted from physical features (e.g. fingerprints, iris, etc…) have been found to be useful in being personal identification or the classification of the identity of an unknown individual with a vast number of applications ranging from bank security systems to airport security to securing access for electronic medical records. Biometric systems work by matching specific individual characteristics features to one recorded in a specific device's memory. The biometric features that are used can be broken into two categories. Topological traits are physiological characteristics which remain stable throughout the lifetime of a person (e.g. facial features, hand geometry, iris features). Behavioral traits are activities that a person does in a learned and consistent manner (e.g. voice verification, handwriting, Gait analysis and keyboard dynamics). The design of biometric systems for secured access of data requires knowledge of 1) how critical data can be coded for privacy and security and 2) how biometric features can be exploited to provide a more reliable measure of authentication in addition to traditional passwords. It is a

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<th><strong>Core Courses</strong></th>
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<td>1) Data Security and Encryptions</td>
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<td>2) Information and Coding Theory</td>
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<th><strong>Specific Courses</strong></th>
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<tr>
<td>1) <strong>Security and Privacy in Health Care:</strong></td>
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<td>The course discusses security and privacy issues such as HIPPA regulations, legislation, and accreditation standards unique to the health care field.</td>
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<td>2) <strong>Biometric Analysis</strong></td>
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The course discusses all aspects of biometric analysis including signature verifications, iris recognition, and gait analysis. The course also focuses on the matching algorithm process that leads to the final step of the decision making.

**Case Study**

A student project was conducted at the Computer Science department of the University of Texas at Brownsville. Three students were assigned to designing, building and implementing a biometric system for human identification using iris features. Although most current identification and authentication systems use more traditional biometric features, e.g. fingerprints, the human iris has been found to possess highly distinct features unique to each individual, and, hence, provides a good alternative resource for personal identification [7,8]. The main subsystems that are usually involved in any personal identification system that utilizes the human iris are: image data acquisition, iris localization and segmentation, feature extraction and decision making [9]. For image acquisition, 320x280 resolution images of the eye taken from 4 centimeters away using a near infrared camera was captured featuring the small details of the iris, typically 1cm in diameter, with a good level of illumination. Next, the iris was localized and segmented from the rest of the image using complex mathematical algorithms. The features of the iris were represented by a joint probability of a pair of pixel intensities in predetermined relative positions in the image, also called Gray-Level Co-Occurrence Matrix (GLCM). The decision to grant access to an unknown individual was based on correlating his/her iris with a database of stored individuals whose identity has been already authenticated.

In addition to the fact that students had the opportunity to apply their math, programming and software development skills to a biometric problem, which has a promising future in security access of electronic medical records, the accuracy of the developed system lead to the deployment of the system to authenticate students during access to the computer science lab. The students were recognized and awarded by the department.

**Conclusion**

In this paper, we presented our view of how to integrate MI programs in computer science curricula. We believe that our work may contribute as future guidelines to incorporate medical informatics as an optional track in our computer science programs. The explosion of medical and biological information has made it clear that innovative advances in storing, retrieving, and interpreting information are essential for health professionals and scientists. In such a multidisciplinary field that hinges greatly on innovations in computer science and information technology, physicians can no longer be expected to master comprehensively the technical tools involved. Instead, the creativity and the problem solving strategies of computer science graduates can be best employed if they are exposed to basic knowledge in health care.
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