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The Medical Informatics Program at the National University of Singapore

Abstract: The Medical Informatics Program at the National University of Singapore was established in September 1996 with a $4 million joint funding from the National Science and Technology Board and the Ministry of Education. The primary aims of the research program are to undertake upstream basic research in medical informatics and to build a critical mass of medical informatics expertise to meet long-term research goals and to effect technology transfer to the health sector of Singapore. Research projects fall into five groups: Clinical Decision Systems, Health Information Systems, Biomedical Datamining Systems, Medical Education Systems and Medical Networking, Applications Development and Integration Systems.

Keywords: Education, Clinical Decision making, Data Mining

Introduction

In September 1996, the National University of Singapore (NUS) established a Medical Informatics Program (MIP) to focus on upstream basic research into the tools and techniques that will enhance the understanding, communication and management of information in medical practice, education and research. Funded by a $4 million (S$ 6.6 million) grant from the Singapore National Science and Technology Board and the Ministry of Education, the campus-wide research program is highly multidisciplinary, coordinating medical informatics research in the medical, science and engineering faculties.

The missions of the MIP are:

1. To undertake upstream basic research in medical informatics;
2. To lead midstream projects to develop, incubate and prototype cutting-edge, market-driven applications by forming strategic partnership with the healthcare and IT industries;
3. To build a critical mass of medical informatics expertise to meet long-term research goals and to effect technology transfer to the health sector of Singapore;
4. To provide the leadership role for consensus building in medical informatics technology and policy in Singapore.

Current research at the MIP is undertaken by five groups:

- Clinical Decision Systems Group from the Department of Information Systems and Computer Science;
- Health Information Systems Group from the Department of Electrical Engineering;
- Biomedical Datamining Systems Group from the Centre for Information-Enhanced Medicine;
- Medical Educational Systems Group from the Department of Community, Occupational and Family Medicine;
- Medical Networking, Applications Development and Integration Systems Group from the Department of Information Systems and Computer Science.

This paper describes the research directions and projects undertaken by the five MIP research groups. Additional information is available from the MIP website at http://mip.nus.edu.sg.

Clinical Decision Systems Group

The Clinical Decision Systems Group comprises an international research team working on advanced frameworks and techniques for automated decision making in medicine. By integrating decision-theoretic and artificial intelligence paradigms, this research group aims to develop theoretically sound decision support techniques that can be easily and routinely used by healthcare providers, practitioners and users.

Currently, the group is working on three major projects that focus on establishing a comprehensive framework for complex medical decisions. Relevant information from distributed sources is integrated to provide decision recommendations in a timely manner.

Project 1: A General Framework for Dynamic Decision Analysis in Medicine

This project extends the expressiveness, efficiency and interface of a general dynamic decision modelling framework called DynaMoL (for Dynamic decision Modelling Language), initially developed by the group's principal investigator at the MIT Laboratory for Computer Science, Cambridge, USA. The resulting framework generalises most existing decision modelling comparing diagnostic test and treatment strategies, health policies, drugs or treatment efficacies and medical technologies [1-3].

Project 2: Automated Decision Formulation from Multiple Medical Knowledge Sources

This project develops techniques for automated construction and analysis of dynamic decision models in medicine. Such tools effectively retrieve, translate and integrate information from multiple sources to support various decision modelling tasks. These sources include multiple domain experts and distributed, on-line databases and repositories [4].

Project 3: Time Critical Dynamic Decision Modelling in Medicine

This project investigates methodologies and builds computer-based tools for managing complex decisions under limited resources. Such techniques take into account the dynamic nature of the problem, the uncertainties, the preference of the decision-makers as well as the time-criticaly of the problems so that the decision models are just right in size to offer timely recommendations for effective actions.

Health Information Systems Group

Health Information Systems help in collecting, retrieving, organising and analysing patient data and knowledge. The major technical challenge in this area is to harness available technology for effective use of the systems. Relevant core technologies aim to support timely care to alleviate sickness, improve diagnostic accuracy and to facilitate clinical and administration operations, e.g. reduce unnecessary waiting time in hospital visits and surgical schedules.

The research aim of this group is to build the foundation and infrastructure to support innovation diffusion in the healthcare setting, focusing on the following areas:

- Advanced techniques in human-computer interface;
- Rapid-prototyping methods for medical experts systems;
- Intelligent generation and management of electronic medical records.

Project 1 : Expert Clinical Interface

The objectives of this project are :

- to study and experiment with an intelligent, process-driven approach for implementing a human-computer interface;
- to design and implement a smart user-interface that a physician can use during the clinical process of diagnosis, therapy and order entry;
- to conduct a pilot trial to evaluate the efficacy of the smart card interface in the clinical setting;
- to experiment with and evaluate the effectiveness of input devices like pen-pads, voice digitisation and recognition.

Project 2: Large Scale Network of Medical Expert Systems

The objectives are:

- to develop a state–of-the-art systems for the automated acquisition of medical knowledge bases;
- to use the knowledge acquisition system to develop a large-scale network of clinical expert systems that will be used in a variety of healthcare applications;
- to develop multimedia expert systems in several medical areas (e.g. tropical skin disease).

Project 3: Intelligent Generation and Management of Electronic Medical Records

The objectives are:

- to formulate a theoretical, computational model for the Electronic Medical Record (EMR) and derive generalised rules for its management and manipulation;
- to use the model and knowledge based techniques to generate multi-faceted, medical records based on a natural language specification;
- to develop and evaluate a pilot system for the automatic "on-the-fly" generation and management of EMRs.

The research results will have both general and regional significance. In particular, the upstream research findings will complement and support, in the long term, the National Computer Board's IT2000 Health Care Cluster projects and the Ministry of Health IT in Health Care plans on deployment and integration of distributed Electronic Medical Records.

Biomedical Datamining Systems Group

The research work of this group will mainly focus on developing a mental health informatics system, which will comprise:

- Developing a mental health patient interview user interface, data storage to be part of the system and also store the data into a server based database, which is for re-

mote access and research;
- Linking the symptoms with the currently available DSM-IV rules to diagnose the disease;
- Developing useful datamining tools in two aspects: first verifying and enhance existing DSM-IV rules, second helping diagnostics using these rules;
- Developing and integrating new tools to visualise interviewed data and datamining the results in different views in the system.

According to the system framework and assumed targets, three separate instruments are now available:
- A questionnaire user interface (SCAN) is a set of instruments, which is used for recording patient's interviewed symptoms and aiming at assessing, measuring and classifying the psychopathology and behaviour associated with the major psychiatric syndromes of adult life;
- A diagnostic tool (Recorder Holder) using DSM-IV rules that have been coded in a database system and Prologue searching engine is then used to infer possible diseases for a given set of symptoms;
- A datamining tool known as Bayesian Applet is a Java applet showing the diagnostic logic of the American Psychiatric Association Diagnostic and Statistical Manual version IV.

At present, these facilities are implemented only for Boolean variables. Multivalued discrete variables are under implementation.

Current work of the project involves:
- Converting SCAN into a web-based medical record UI for mental health systems;
- Linking diagnostic rules in Recorder Holder with symptoms recorded in SCAN;
- Exploring and implementing more powerful and more efficient model algorithms;
- Developing new tools to visualise interview data and datamining result.

Medical Education Systems Group

Basic research into new educational paradigms and strategies is a major focus in medical informatics research and development. To learn and practice medicine effectively, medical students and physicians must have rapid access to the information which could range from simple text to the contents of large and complex medical knowledge bases made available over a wide array of storage media – paper records, CD-ROMS, Internet discussions groups, World Wide Web sites, etc. The available information may be in the form of text, image, sound, video or combinations of two or more media. Medical students and physicians must also be able to apply the retrieved facts and heuristics in honing their clinical skills in medical diagnosis and therapy planning. Hence, the research agenda of the Group is to develop new paradigms and tools that will update learning and knowledge as well as promote and sharpen clinical problem-solving strategies for better patient management in the training of medical students and the continuing education of practising physicians.

This group will focus on 3 projects:

Project 1: Goal-based Techniques for Clinical Problem Solving

There is considerable evidence today that the knowledge and skills possessed by experts are highly-situate and case-base, especially in the medical domain. Students will learn effectively more by doing than by passive observation or reading. 'Learning by doing' provides for deeper engagement in the learning process and superior retention and transfer of knowledge. In recent years, researchers at the Institute for Learning Sciences at the North-Western University have found that the use of such a goal-based approach gives students a better opportunity to acquire clinical diagnostic and problem-solving skills in a highly context-rich learning environment. The project will test the cognitive reasoning and techniques of the goal-based approach to the clinical management of upper GIT bleeding.

Project 2: A Generic Virtual Reality Authoring System for Medical Applications

The educational potential of virtual reality has hardly been tapped because the technology is still relatively new and mostly running on expensive workstations. The recent availability of PC-based VR systems has opened up a new realm for medical education research in which the user can explore 3D environments using divergent logic. However, we expect many medical educationists would be deterred from engaging VR systems actively in developing computer-based medical learning and training applications due to lack of computing experiences. This project is to design a generic VR authoring system that would allow a medical content specialist with minimal computer experience to be able to construct a specific VR tutoring package. Such a systems shell would, in fact, become a laboratory for virtual reality – the Virtual Laboratory [5].

Project 3: Intelligent Search and Retrieval System for Network-based Health Information

A plethora of health information resources exists today on the Internet. The NUS Cyberspace Hospital (http://ch.nus.sg), launched on 1 May 1995 as the first medical website in the World Wide Web, has provided a one-node access to some of the best medical websites in the world through URL links. To take advantage of the global resources of medical information that

have been identified by the Cyberspace Hospital, the project will develop a medical information retrieval system with the following research goals: (i) to identify and classify databases for major medical disciplines, (ii) build a semantic meta-layer over these databases to permit seamless and transparent searching and browsing of these databases, (iii) make use of the UMLS to codify medical databases as well as to rely on the UMLS metathesaurus to build intelligent search systems over these databases, (iv) integrate the resource into a globally accessible repository of medical information as an experimental resource [6,7].

Medical Networking, Applications Development and Integration Systems Group

A careful planning and adaptation of medical informatics can result in better resource (including expertise) and information sharing among the diverse and distributed healthcare providers. This will lead to better-informed decisions and more affordable and effective health care. The key for successful medical informatics lies in the easy-to-use, integrated implementation of applications. Most of the healthcare systems are islands of automation that have deployed partial and disparate systems addressing different elements of the problem. They are difficult to integrate for collaborative use by healthcare providers in large communities.

One way of achieving integrated medical informatics is through a network centric, standards-based development framework. Hence the research aim of this group is to investigate key issues pertaining to the building blocks of next-generation medical informatics applications. These applications are expected to involve processing, retrieval and transportation of medical data, which are multimedia. They support interactive collaborative work and telepresence, such as telemedicine, tele-consultation and diagnosis, and the like. The issues addressed by this group are central to the broad technical objectives and to integrating, in the long term, all research efforts proposed in the MIP initiative.

The group is working on the following projects:

Project 1: Medical Informatics Network Testbed (MINT)

This project aims to establish a high-speed backbone network testbed as part of the research infrastructure for the MIP. A new scalable ATM multicast service and audiographics and audio visual conferencing service will be developed to support group communication. The multicast scheme is to be based on a working prototype developed at the National University of Singapore. An object-oriented Open Medical Application Development Environment (OMADE) will also be developed to facilitate collaborative medical application development and to ensure cross-platforms interoperability. OMADE will enhance Corba in its capability of handling multimedia data as well as quality of service. The eventual aim of the project is to integrate MINT as part of the national high-speed information infrastructure-Singapore ONE [8].

Project 2: Distributed Medical Image Processing and Interpretation System

This project is designed as a showcase application for OMADE. The application will allow on-line submission of medical images for automated analysis and interpretation at a powerful server. This application is particularly useful in cases where the images are observed routinely or where diagnosis could benefit from a quantitative approach to avoid inter- or intra-observer variability. We also support teleconsultation if a second opinion on the interpretation is desirable. Potential technical contrib-utions include 3D models for object recognition and data fusion techniques for combining different image processing algorithms and analysis results.

Project 3: Medical Multimedia Rapid Prototyping Framework

The research objective of this framework is to provide support for data responsive medical systems which are able to 'understand' the incoming medical data (in the form of video image still image, sound and text), decide what actions to take based on the content of the data and carry out the appropriate actions in a timely manner. Examples of such systems include applications for coma patient monitoring and posture correction. The potential technical contributions of this project include fast and accurate image processing routines that can 'understand' time-critical medical multimedia data 'intelligent' host process scheduler that ensure timely responses to time-constraint medical data; and the incorporation of a distributed processing mode in medical multimedia systems [9, 10]

Significance of the Medical Informatics Program

Singapore is a centre for medical research and services, as well as a centre for computer and information technology in the Asia Pacific. To remain competitive in the face of rising healthcare costs and rapid computer technology advancements, Singapore needs to attain core competence in the area of medical informatics in order to attract international collaborations and investments in this field.

The upstream research focus of the Medical Informatics Program aims to establish a centre of excellence in medical informatics. This will complement the development and deployment tasks of the National

Computer Board and the Ministry of Health and provide the expertise and new technologies in medical informatics that best suit the local and regional contexts [11]. Increasingly, research institutions and companies from outside Singapore are keen to seek collaboration in R&D opportunities in medical informatics. These parties are interested in extending their own work and developing new technologies in the Asia Pacific region. Foremost in their minds is the question of the availability of a centre of excellence in medical informatics in Singapore to provide the expertise and infrastructure for R&D collaboration.

We see the need for Singapore to attain core competence in medical informatics based on the following reasons:

1. A critical mass of local experts in medical informatics is needed to effectively employ existing and new medical informatics technologies. Experience with many imported medical informatics applications from overseas vendors often involves substantial efforts to customize with suboptimal results. As globalization of medical informatics becomes pervasive, local or regional collaboration on customizing and/or development of such applications will become very important;
2. The opportunity for developing a medical informatics industry in Singapore is becoming increasingly attractive. Besides facilitating cost-effective local health care services, our expertise and research products can be exported to regional countries. Such a strategic research and development area could attract multinational companies to set up medical informatics R&D centres in Singapore or to invest in locally developed technologies for regional and international deployment;
3. Our available expertise and infrastructure in medical informatics would also influence the investment decisions of multinational companies (MNCs) in related areas of medical informatics and /or computer technologies. Many MNCs in health care and pharmaceutical products have begun to set up regional R&D centres in Singapore recently. High-value added expertise and services such as computer-based comparison of short-term and long-term drug efficacies and diagnostic test and treatment protocols will be sought after. Availability of such expertise locally would add to the investment incentives of the MNC [12].

The aims of the MIP are to develop core expertise in medical informatics that will:

1. understand the fundamental issues and long-term challenges in the field;
2. spearhead the directions of general or regional-based objectives and advances in medical informatics;
3. facilitate technology transfer to local and regional midstream R&D and/or commercial applications and;
4. most importantly, train the next generation of medical informaticians in Singapore and the Asia-Pacific region.

A strong track record of basic research in medical informatics is essential for Singapore to attract international collaborations and investments in this field.

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