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Research and Education

The Evolving Biomedical Informatics Programs in Taipei Medical University

1. Introduction

Computer literacy has been an important issue to the medical students in Taipei Medical University (TMU). However, not until 1995 did this 40-year-old university start to realize the benefit of applying information technology to clinical care. True multidisciplinary research/education programs in medical informatics are among the latest developments in TMU's rapid expansion during the past six years. The number of faculties and graduate programs doubled in the process of expanding from an independent medical college to a university that consists of five medically-related colleges.

In 1995, a team of IT engineers and physicians were assembled to form the Center for Biomedical Informatics (CBI). Besides studying computer applications in biomedicine as its name indicated, it was also responsible for the design and deployment of the campus computer network. Starting relatively late, it was able to take advantage of the latest network technology and install ample optic fibers for the campus. A high-speed ATM (Asynchronous Transfer Mode) network was installed as the backbone and a Fast Etherswitches were used to link to most of the desktop PCs. The backbone was later upgraded to Gigabit Etherswitches. Thanks to the flourishing IC and PC industries in Taiwan, since 1996, we were able to allocate at least one networked PC to every teacher and employee at very affordable prices. Intensive training was given to all users to familiarize them with the networked environment. Crucial applications and information were put on the school's website to attract more usage. This arrangement proved to be one of the most important steps to transform a conservative medical college to an innovative e-campus in which faculties and students are eager to harness the power of information technology.

Although computers and information systems were generally available in the business sector, computerization of hospitals and clinics was not prevalent in Taiwan until 1995 when the National Health Insurance (NHI) agent went into operation. With a 300-billion NT annual budget (about 9 billion US dollars), the NHI covers almost all of the twenty-three million people in Taiwan and has become the single largest payer for most of the healthcare expenses. For the purpose of quality control and cost containment, it demanded that all claims be submitted electronically. This decision led to the rapid computerization of all 670 hospitals and more than 80% of the 17,000 clinics in Taiwan. The dramatic change, in turn, called for much more medical informatics research and attracted many more IT professionals into the healthcare industry.

Between 1995 and 1998, CBI played a major role in helping to computerize our campus and the two university teaching hospitals. However, we still felt a need to provide specialized training programs for this emerging multi-disciplinary domain. After several years of preparation, TMU started the first graduate program of medical informatics in Taiwan under the Graduate Institute of Medical Informatics (GIMI) in 1998. The establishment of this program turns out to be as challenging as it is rewarding to the school. The final approval for GIMI by the Ministry of Education made medical informatics one of the academically recognized disciplines in Taiwan, which also started the trend of multidisciplinary research and training in medical schools around the country.

Besides education and research works, GIMI also oversees the IT departments of the two university teaching hospitals, namely Taipei Medical University Hospital and

Wanfang Hospital. These two hospitals have a total capacity of 1000 acute inpatient beds and 1.6 million outpatient visits a year. Capitalizing on the resources provided by this rich clinical computing environment, GIMI's faculty and students were able to undertake a wide variety of applied research ranging from building electronic health records, managing/analyzing medical images to building knowledge-based systems for clinical decision support.

The evolution of the medical informatics program took another turn in the year 2000 when the draft of the complete human genome was released. The fast-growing biotechnology industry demanded more computational power and innovative algorithms for genomics and proteomics research. GIMI responded to this development with a new bioinformatics curriculum and a new center dedicated to bioinformatics research in 2001. This center, dubbed Bioinformatic Computing Center or BCC, gathered scholars from biochemistry, computer science, biostatistics, mathematics, clinical medicine and medical informatics. Together, they identified crucial problems in genomics and proteomics that can be dealt with by computational methodologies. Developing data mining techniques for microarray analysis and building neural networks for protein-protein interaction prediction were among the first batch of projects in this center.

The current biomedical informatics education and research programs in TMU are supported by GIMI, CBI, BCC and scholars from outstanding research institutes within or outside of our campus. It took time to orchestrate cooperation among highly-specialized inter-disciplinary people, but the rewards are very much worthwhile.

2. Education

TMU consists of five colleges with a total of 4500 undergraduates and 500 graduate students. GIMI offers a series of undergraduate-level courses related to computer applications in biomedicine for all the colleges, as well as a full set of graduate-level curriculum for its own fifty-four Master students and four Ph.D. students. In GIMI, most of the course work is often completed within the first school year. Research projects and theses writing occupies most of the time in the years that follow. Generally speaking, a Master student would need two years and a Ph.D. student five years to complete his degree while a thesis is required for all degrees. A proposal defense is required before a student proceeds to his research for thesis. This approach greatly reduces the chance of having an unqualified thesis at the final oral defense.

The GIMI graduate students came from a diverse range of undergraduate training backgrounds. Among them, approximately 25% were computer-related while the remaining 75% were medical professionals. Half of the GIMI medical professionals were physicians, most of them board-certified specialists, including neurosurgeons, gastroenterologists, nephrologists, oncologists, dermatologists, ophthalmologists, psychiatrists, etc.. The heterogeneous student composition is crucial to the way our faculty conducts its classes. There are often intriguing questions and arguments raised by students that stir stimulating debate from very different perspectives.

We have designed a highly flexible curriculum to accommodate students from such diverse backgrounds, and with different career plans. A Master student must complete twenty-four credit hours of coursework before proceeding to the thesis defense. Generally speaking, a credit hour is equivalent to sixteen hours of class per semester. Together with adjunct faculty members from other TMU colleges and outstanding institutions in Taiwan, we offer an eighteen credit hour core course complemented by sixty-nine credit hours of elective courses. In order to complete all of the required credit hours, a Master student must take at least six credit hours of the elective course work, in addition to the core course. A Ph.D. student is on a different scheme and requires a total of only eighteen credit hours before thesis defense. The core course is composed of classes like seminars, healthcare information systems, introduction to medical informatics, introduction to biomedical engineering, database management systems and medical decision making (Table 1). The elective courses cover topics in four major

Table 1. Core courses in the Graduate Institute of Medical Informatics

Course	Credit Hours
Healthcare Information Systems	2
Medical Informatics	4
Database Management Systems	2
Graduate Seminars	4
Biomedical Engineering	2
Practical Training - Healthcare Information Systems	2
Medical Decision Making	2

research areas, namely medical decision support, biomedical signal processing, bioinformatics and knowledge discovery in medicine. Although most of our students came with at least basic computer and medical knowledge, two sets of complementary courses, namely basic computer course and basic medical course, are organized into the elective courses for students with different academic backgrounds. Students from a non-medical background are suggested to take the basic medical course with classes such as medical terminology and physiology. On the other hand, the basic computer course, which covers classes such as programming language and algorithms, is recommended to all students without formal computer science training.

3. Research

GIMI is committed to advancing medical care and biomedical research through the use of innovative information technology. A campus-wide Gigabit Ethernet and ATM network connecting the colleges, two university teaching hospitals, as well as two supporting centers (CBI and BCC), provides GIMI with a wealth of resources for biomedical informatics research. In the past six years, our students and faculty have conducted a wide range of research projects. Most of their efforts fit into the following areas: medical decision support, knowledge discovery and data mining, eLearning and eHealth, national Health Information Network project and Distributed Computing in Bioinformatics. Examples of research projects in these areas are described below.

3.1 Medical Decision Support:

One of our long-term projects is to develop a distributed multi-domain medical decision support system on the Web. This system will support multiple knowledge base (KB) maintenance in a distributed fashion, that is, multiple groups of users can collaborate on the Internet to maintain different KBs. The resultant "cluster" of knowledge bases can be used to support different kinds of medical decisions independently, or they can work in tandem to support "multi-domain" decisions. For example, a KB for autoimmune disease can be used to support diagnostic decisions in the autoimmune diseases domain. It can also be used in conjunction with a generalized blistering disease KB to support difficult diagnostic decisions for autoimmune diseases with generalized blisters (e.g. Bullous Systemic Lupus Erythematosus).

A Web-based probabilistic knowledge platform called PIEW (Probabilistic Inference Engine on the Web) is currently available for this purpose (Figure 1). It is equipped with a dictionary editor, a knowledge frame editor, a Bayesian calculator and a consultation interface for decision support. Two knowledge bases were developed and tested on this platform; one is to help diagnose generalized blistering diseases, while the other was designed to help diagnose autoimmune diseases [1]. "Multi-domain" inference will soon be implemented using our newly developed approximation algorithms for KBs with different knowledge domains.

3.2 Knowledge Discovery and Data Mining

We are working on several clinical databases with neural networks and various data mining techniques to uncover hidden associations among variables. For example, a national Traumatic Brain Injury (TBI) database with more than 50,000 patients was used to investigate factors contributing to the treatment strategy and outcome of patients with TBI [2]. Another example is the 400GB per year national health insurance database that stores health claims of over 300 million outpatient visits and 8 million inpatient stays a year. This database is now anonymized and released for research purpose. A plethora of questions are

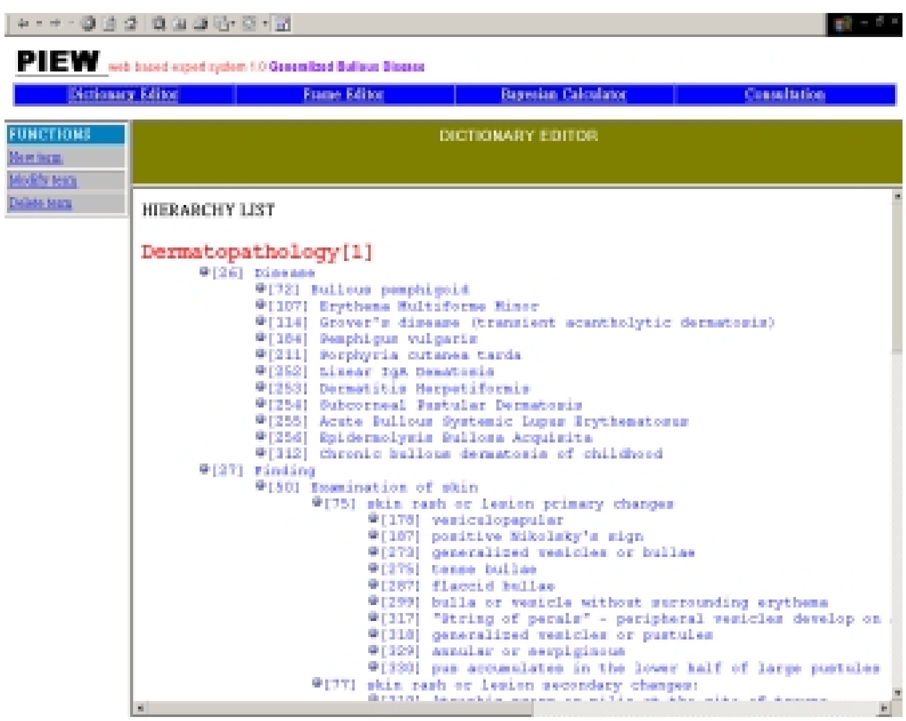

Fig. 1. A screen snapshot of the Dictionary Editor in PIEW. Eleven non-infectious generalized blistering diseases are listed in the data dictionary.

being asked against this huge database using customized data mining software tools developed by our faculty members. Interesting reports are now being published in areas such as drug-drug interactions and physician practice patterns. Neural networks are also heavily used to analyze ECG patterns to predict the risk of myocardial infarction in one of our faculty members' research [3].

3.3 eLearning and eHealth

In light of the fast development of broadband technology and the Internet, Web-based distance learning and its implications in medical education were investigated. One of the most ambitious projects would be the Virtual Medical Campus (VMC) campaign initiated by theTMU and two other leading medical schools in Taiwan. VMC set out to provide a multi-center, multi-disciplinary information infrastructure for medical education and research. In VMC, virtual libraries, classrooms, laboratories, and teaching hospitals are all connected to a multi-modality, broadband and ubiquitous information network. All multimedia objects (including image, text, sound, video and 3D models) and their associated metadata are stored in a heterogeneous, ultra-high capacity data warehouse. Clusters of high-performance graphics workstations will provide enough computing resources for intensive 3D animation and even real-time simulation. With the vision of VMC in place, we have continuously developed component projects to fill in the big picture. Examples include a Virtual Microscope for Pathology and Histology that uses streaming images to teach pathology and histology [4], a Visible Parasite Web site for teaching medical parasitology [5], a Virtual Clinical Pathology Conference Web site that provides high resolution clinical and pathology images for special cases [6], and a Medical Multimedia Resource Locator project for storing multimedia objects.

On the eHealth side of the research, our vision is to build a Virtual Health Community (VHC) that represents an information infrastructure for the general public to access all consumer health information, as well as personal health records securely and conveniently [7, 8]. VHC is also covering related services, ranging from online patient support groups, online pharmacy, tele-consultation to online bookstores. The purpose of VHC is to harness the power of the virtual community, while providing a one-stop-shopping environment for consumer health and wellness needs on the Internet (Figure 2).

Fig. 2. The Virtual Health Community provides a one-stop shopping for personal health and wellness needs.

3.4 National Health Information Network

The Health Information Network (HIN) is one of the most important medical informatics projects directly supported by the Ministry of Health with an annual budget of several million US dollars. It covers a range of research projects that built a health information infrastructure for all hospitals in Taiwan to facilitate secure exchange of patient information. GIMI students and faculty members play a major part in the HIN project by leading one of its critical segments, the MIEC (Medical Information Exchange Center) [9, 10]. There are six component projects under MIEC, namely "Mechanisms for information exchange among heterogeneous healthcare information systems", "Development of patient-centered information retrieval systems", "Development and deployment of physician workstations in a clinical setting", "Information presentation for electronic patient records", "Extranet clinical information systems" and "Secure medical information link everywhere-SMILE". Undertaking these projects has brought us to the issue of standards such as HL7 and DICOM, as well as security issues similar to those raised by HIPAA (Health Information Portability and Accountability Act) in the United States. In the course of resolving these issues, GIMI also helped found HL7 Taiwan – one of the first official health information standards development organizations in this country.

3.5 Distributed Computing in Bioinformatics

By utilizing PC farms and Peer-to-Peer distributed computation, we are actively developing smart algorithms for genetic and proteomic search/ prediction. With the help of staff from BCC, we were able to devote a significant proportion of our students and faculty to bioinformatics research. A number of data mining techniques are now being reformulated to accommodate distributed computing and are being applied to microarray and proteomic data analysis. Some distributed genetic algorithms for choosing the fittest neural networks are being developed for prediction of specific protein-protein interactions. Molecular biology research groups from within and outside the TMU campus are collaborating with our bioinformatics team to unlock more protein functions and biological pathways for diseases such as asthma and atopic dermatitis.

3.6 Others

Some of our students and faculty are also involved in research topics such as biomedical signal processing and evidence-based medicine. As a young and energetic research institute in TMU, new areas are continuously being explored and new issues debated. This helps GIMI stay innovative and creative.

4. Future

As a new and exciting area in our country, medical informatics is becoming one of the most important academic disciplines in medical schools, while also attracting attention of IT industry leaders. Three major factors can be identified that were responsible for the dramatic change observed in the past few years: knowledge-based economy initiative, national health insurance policy and the rapid development of biotechnology. A knowledge-based economy initiative was proposed to the government last year that resulted in significant budget allocations to areas that can "create profit from knowledge itself". Health-care was considered an area that can potentially contribute to this initiative due to its heavy use of patented technologies and its direct link to the lucrative pharmaceutical market. A national conference concluded that medical informatics, with its strategic use of information technology, should be heavily invested to further the knowledge-based economy of healthcare.

The second factor is the national health insurance policy which began in 1995. It started as a fee-for-service type of reimbursement and has gradually transformed into a hybrid model that mixes Capitation and Integrated Delivery Systems. As described in the first section, NHI single-handedly forced the computerization of most healthcare organizations in Taiwan, because it accepted only electronic claims. Its continuing accumulation and selective release of anonymized electronic claim data, and its sinuated rules for claim rejections, contributed greatly to the study of healthcare information systems. The emphasis of quality of care in the coming years may again trigger another wave of research and implementation of electronic health record systems.

The third factor is the rapid development of biotechnology and bioinformatics. Reignited by the announcement of a draft of the human genome map from both the public (Human Genome Project) and the private (Celera) sectors in the year 2000, biotechnology is becoming one of the most important topics of the century. The wide implications of technologies, such as Genetically Modified Organisms (GMO) and human cloning further sparks a global debate of what can be done and what should be done. Controversy aside, biotechnology industry could become the largest segment of the worldwide market in the future and no country wants to be left behind in this cut-throat competition of research and development. This brings us to a point where medical informaticians need to decide whether bioinformatics is something worth pursuing or not. In GIMI, we recognized that the multi-disciplinary nature of bioinformatics has its similarity to medical informatics and there are many techniques/ experiences that can be borrowed from previous accomplishments in the field of medical informatics. On the other hand, no medical informatician is readily a bioinformatician by training. We need to incorporate more expertise from molecular and cellular biology, mathematics and biostatistics into this area. By doing so, we are making medical informatics a much more complete scientific field, since almost every medical problem is now also a genetic problem. In this country, the significance of medical informatics is becoming more eminent by the awareness raised by biotechnology and bioinformatics.

Prestigious medical schools around the world are starting to realize the clear benefit of having multidisciplinary programs, such as medical informatics and bioinformatics. In TMU, we are fortunate enough to have evolved from a small team of physicians and IT professionals into a flourishing bio-medical informatics program with scholars from many different disciplines. The next challenge would be to have medical informatics and bioinformatics researchers work towards a common goal. We believe that the convergence of medical informatics and bioinformatics will eventually bring us to the next generation of personalized healthcare, where information from the cellular level is integrated with clinical information for the optimal care of each patient.

References

1. Chang YJ, Shiue HS, Li YC, Liu HN. A web-based dermatopathological diagnostic decision support system for non-infectious generalized blistering diseases. In: Proceedings of the American Academy of Dermatology 59th Annual Meeting. Washington D.C., United States; 2001.
2. Li YC, Li L, Chiu WT, Jian WS. Neural Network Modeling for Surgical Decisions on Traumatic Brain Injury Patients. International Journal of Medical Informatics 2000;57:1-9.
3. Yang TF, Devine B, Macfarlane PW. Use of artificial neural networks within deterministic logic for the computer ECG diagnosis of inferior myocardial infarction. Journal of Electrocardiology. 1999;27:188-93.
4. Surgical pathology teaching slides under virtual microscope. Taipei medical university. Available at: http://pathology.tmu.edu.tw/. Accessed Sep 1, 2001.
5. Parasitology electronic atlas. Taipei medical university. Available at: http://parasite.tmu.edu.tw/. Accessed Sep 1, 2001.
6. Virtual Clinical Dermatopathology Conference. Taipei medical university. Available at: http://cpc.tmu.edu.tw/. Accessed Sep 1, 2001.
7. Virtual Health Community. Taipei medical university. Available at: http://www.vhc.org.tw/. Accessed Sep 1, 2001.
8. Wu JS, Li YC, Jian WS. Consumer Health Information Website in Taiwan. J Formos Med Assoc. 2000;99:663-6.
9. Li YC, Kuo HS, Jian WS, Tang DD, Liu CT, Liu L, et al. Building a Generic Architecture for Medical Information Exchange among Healthcare Providers. International Journal of Medical Informatics. 2001;61:241-6.
10. Liu CT, Long AG, Li YC, Tsai KC, Kuo SS. Sharing patient care records over the World Wide Web. International Journal of Medical Informatics 2001; 61:189-205.

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