Ethics and Biomedical Informatics: a Research Experiences for Undergraduates Program at the University of Tennessee at Chattanooga

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Abstract – The University of Tennessee at Chattanooga (UTC), in collaboration with biomedical researchers and healthcare practitioners from the University of Tennessee: College of Medicine Chattanooga and Erlanger Health System, has conducted the first iteration of a three-year Research Experiences for Undergraduates program on Biomedical Informatics, with a special emphasis on ethics as related to the student projects. This paper discusses goals and structure of the program, the specific bioinformatics projects begun in the first year of the program, the details of the ethical emphasis and activities, results of initial program assessments, and plans for the remaining years of the program.

Keywords: Biomedical Informatics, Computer Ethics.

INTRODUCTION

Potential impact of research activities in the area of bioinformatics on the practice of medicine is great. These impacts include enhanced and supported decision making and data mining tools for clinicians and biomedical researchers, new computing resources for biomedical research platforms and telemedicine, and new protections against potential security breaches, which can lead to improvements in patient privacy and safety. Because of the ethical implications of all of these areas, the new Research Experiences for Undergraduates program at UTC, in addition to technical student projects, has added a special emphasis on ethics. The ethics activities include lectures, combined with a heavy emphasis on discussion of current events related to ethics in Biomedical Informatics and computer fields. One of the primary goals of the ethics component was to introduce fundamental theory and practices on the ethical and social issues facing the healthcare and biomedical research industry as it adopts information technologies to provide safer, faster health care service with lower cost, while preserving patient privacy, and eliminating the possible consequences of misuse of personal medical information.

COMPUTERS AND BIOMEDICAL INFORMATICS

Advances in sensor technology, processing speed, high-speed networking, and massive digital storages are being incorporated into today's healthcare practice and biomedical research. Tremendous amounts of biomedical data are captured and recorded in digital format during daily clinical practice, medical research, and education. Biomedical informatics research [1], an interdisciplinary research area that focuses on acquisition, transmission, representation, retrieval, and analysis of biomedical data and knowledge, can be used to address many critical issues [1] facing our health care system, biomedical research and education today. For instance, biomedical informatics research and its applications hold great promise to improve quality of health care [2, 3], reduce medical errors [4], provide safer care at a lower cost [5], and advance biomedical research [6, 7]. Furthermore, the unique characteristics and challenges of biomedical data (e.g., large volume, heterogeneous, and semantic-rich) provide a tremendous opportunity for

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bringing together researchers and practitioners from diverse disciplines that seek to understand the fundamental principles and design strategies in computing systems, and leverage those understandings to build real-world, high-impact biomedical computing systems. Given the proliferation in the past five years of conferences, journals, and requests for proposals (RFPs) related to biomedical informatics and related applications, it appears that there is a strong and sustainable demand for globally competitive U.S. researchers and practitioners in biomedical informatics. The area of Biomedical Informatics research is interdisciplinary in nature and it involves many fields in Computer Science and Engineering, such as data mining, machine learning, information retrieval, computer vision, graphics, information security, privacy, and networking systems.

THE REU PROGRAM

The UTC Research Experiences for Undergraduates (REU) Site on Biomedical Informatics will sponsor 10 undergraduate students per summer in each of three summers (2012, 2013, and 2014). The first iteration of program was in summer of 2012, and lessons learned will be used to improve the program in future years. The duration of each summer program is nine weeks, beginning in June. The main goal of this program is to provide an opportunity for a diverse group of talented undergraduate students to participate in the interdisciplinary research projects on Biomedical Informatics. The main objectives of the program are to introduce students to the theoretical foundations and practical applications of Biomedical Informatics research; to train students in research and communication skills, such as literature review, novel approaches to solve open problems, creative and independent thinking, experimental design and interpretations, and effective oral and written communications; to stimulate students' interests in Computer Science (CS) research by exposing students to the intellectual excitement in CS and Biomedical Informatics research activities and professional development; and to encourage students to pursue graduate studies and research careers in CS by a wide variety of means, such as participating in professional meetings and field trips, career advisement and seminars, social events, and field trips. Our targeted student participants include those typically underrepresented in STEM fields, such as women, African American, and Hispanic students). Our targets for each year are to recruit a minimum of four students from underrepresented groups and at least five from other institutions, especially undergraduate students from institutions with limited research programs. The UTC CS faculty team running this program includes two female and one African American faculty members.

The project timetable is as follows: Each year from January to March, we conduct highly organized and aggressive recruitment for the REU program to choose a diverse group of qualified students. This includes targeted advertising to universities with a high proportion of students in under-represented groups, and personal outreach to women's professional and pre-professional groups. Potential participants must submit applications by March 31st and the list of participants is finalized by May 1st each year. The summer program is conducted from June to August. On the first day of the REU program, we have a one-day orientation which includes a welcome presentation from faculty mentors, a campus tour, and introduction to the research project areas. During the remaining four days of the first week and first day of the second week, we have an accelerated short course that introduces the concepts, techniques, and important algorithms for REU projects. During the remaining four days of the second week, we guide the students in conducting proper literature surveys and assist the students in selecting their summer research projects. Once the projects are identified, the students prepare proposals for their research projects. In the second week, we also conduct daily ethics lectures and group discussions to educate students on ethics in CS with a focus on ethical issues specific to Biomedical Informatics. Starting in the third week, the students present their proposed research plans. The faculty mentors, graduate student assistants, and other REU participants provide comments to aid the students in focusing their work and scoping projects so that significant results can be achieved in the nine-week duration of the program. The REU students then refine their research plans and conduct the project implementation full-time from the third week to the end of the eighth week of the summer program. To ensure the quality and progress of the project and to enhance the faculty-student interaction and communication, a variety of activities, such as faculty and graduate student office hours, weekly individual meetings, weekly group meetings, career mentoring, a seminar series, professional meeting attendance, self-training, social events, and field trips, are conducted. The ninth and final week of the program is devoted to project delivery, which includes writing the comprehensive project report, making group presentations and the final project demonstration. REU students who make significant results are encouraged to submit their reports to peer-reviewed conferences and journals. To ensure the continuance of the research experiences, we encourage successful REU students to continue their projects during

the subsequent Fall and Spring semesters. Faculty mentors from the summer REU program continue to supervise these projects during the following school year.

STUDENT PROJECTS

All of the research projects in our REU summer program share the theme of Biomedical Informatics and span several exciting areas of inquiry. The projects are intellectually stimulating and give students an opportunity to meaningfully participate in leading-edge research directly applicable to the current practice of medicine, primarily in Emergency and Rehabilitation areas.

For the 2012 instantiation of the program, the projects were organized into two major thrust areas: (1) Investigation of new computer algorithms for user-centered decision support and knowledge discovery from complex biomedical data; and (2) Research on large-scale network computing platforms and telemedicine systems to facilitate biomedical information collection, management, exchange, and analysis.

The first project in area 1 is entitled "Computer-aided Diagnoses for Acute Coronary Syndrome with Data-Mining Techniques." In this project, REU Fellow Albert Thornton explored different data-mining techniques, such as decision trees, neural networks, and logistic regression to determine the potential risk of patients presenting in the Emergency Room with chest pain having Acute Coronary Syndrome (ACS). The term ACS involves the spectrum of cardiac disease ranging from unstable angina to non-ST-elevation Acute Myocardial Infarction (AMI) to ST-segment elevation AMI. All the techniques were compared to one another, as well as to other forms of data-mining methods. This REU Fellow further discussed a relatively new method of predictive modeling called boosted regression trees and how it could benefit the medical field. Other information supplied included software used and a base study of methods with which the author conducted his research. [8] This project is continuing during the current academic year using internal UTC research funding.

The second project in the algorithm area is "Medical Imaging Indexing and Search". In this project, REU fellow Chyeeka Brown proposed a multi-modal approach to the indexing, search, and retrieval of medical images through the use of canonical correlation analysis (CCA) and explicit semantic analysis (ESA). By using Terrier to extract and quantize textual features of an image and ImageTerrier to extract and quantize the visual features of an image, she then used CCA to put these features in the same vector space and find the pairs of textual and visual features with the highest correlations. After determining which visual words are related to which textual words those terms are then used in textual form to create a semantic concepts index by using ESA. [9]

The third project in the first area is titled "Granger Causality and Robust Time Series Data Mining." In this project, REU Fellow Don Humphreys investigated the methods and results for benchmarking three causality algorithms, while generating complex multivariate graphical models. The goal of the experiment was to general random feature causal graphical models and time series, and then measure the accuracy of the causality algorithms in reproducing those graphical models using only the time series data. [10]

The final project in area 1 is "Data Visualization for Clinical Decision Support," by Christopher Lenk. This work had as its goal a comprehensive, integrated, intuitive, and web-based data visualization tool for multimodal physiological data, to be used by health professionals with limited technical background and knowledge of computer science. In order for the application to be useful to non-technical personnel, the web-based system was required to avoid complex graphs and have an intuitive user interface. The proof of concept of this project successfully visualized multimodal data, visualized biomedical data, and created intuitive visualizations. [11]

The first project in the second area is entitled "Xbox 360 and Kinect-Based Motion Sensing for In-Home Rehabilitation." In this project, REU fellows Chelsea Lewis and Joshua Skelton were teamed to work on a project that aimed to provide an efficient and cost effective computer-aided rehabilitation system that patients can use within their own homes. The human motion data captured by the Xbox Kinect is indexed and retrieved to determine whether the patient is performing prescribed physical therapy exercises correctly. The focus of this project was to find an efficient method of evaluating patient performance based on captured motion data in order for doctors to monitor their patients' rehabilitation. [12] By allowing patients to perform rehabilitation in their own homes without requiring medical personnel to be present, this work has the potential to greatly decrease the cost of physical rehabilitation compared to traditional on-site paradigms.

The second set of projects in area 2 is entitled "Smartphone-Based Activity Monitoring". The objective of these projects is to research into new algorithms and software to detect and classify the physical activity for long-term lifestyle and healthcare monitoring using smartphone platforms, such as iPhone and/or Android. Physical activity is one of the leading health indicators to measure the mobility level, latent chronic diseases and aging process in patients. A smartphone is an ideal platform to monitor physical activity since it is usually carried by the user most of the time and it could measure the activity passively and automatically in a non-intrusive fashion. Three sub-projects were part of the 2012 summer program under this general umbrella. Specifically, REU fellow Ariel Keller worked on the task of Android-based fall detection [13]; REU Fellow Jeffrey Cox developed iPhone-based walking speed estimation [14] ; and REU Fellow Travis Ringstaff investigated new feature extraction algorithms for human activity classification. [15]

The third project in the biomedical information area is entitled "Smart Vision Techniques for Managed Home Care". The aim of this research is to investigate a new software system for pervasive home monitoring using smart vision techniques. In-home activity monitoring can provide useful information to doctors in areas such as behavior profiling, and preventive care. It can also facilitate in emergency detection and remote assistance. REU Fellow Jackson Goodwin developed solution uses an inexpensive webcam and a computer program to analyze posture using techniques such as foreground detection and ellipse fitting. [16]

While all of the projects during the 2012 summer program made significant progress in producing proof of concept, most will be continued in future summers to produce more complete algorithms and/or products ready for application in a home or health-care environment. Three of the 2012 students have continued with their research projects during the current school year.

EMPHASIS ON ETHICS

One of the things that distinguishes this program from other undergraduate research programs with a purely technical focus is the emphasis on ethics included from the conception of the REU proposal. Biomedical Informatics is an interdisciplinary area that encompasses aspects of Computer Science, Medicine, Biology and Healthcare. The utilization of information and communication technologies in Biomedicine has changed the social picture in significant ways, while simultaneously leading to tensions with regard to traditional ethical practice, particularly given the global context of its application. Ethics education in Biomedical Informatics struggles to keep pace with the rapid changes in technology. A standard approach for teaching students about ethics has been to rely on the application of the ACM and IEEE Codes of Ethics using case studies packaged in a modular format and prepared for introduction into existing courses. The issue is that while, in theory, certain standards of practices can be codified for general applicability to any research or professional project, in practice, the ever-changing material dealt with by scientists and engineers is precisely of the sort that pushes the limits of ethical guidelines. In particular, the increasing incidence of patient medical records being kept in electronic formats; the government's push (as part of health care reform) for a centralized record-keeping system that will allow doctors and hospitals to coordinate care, and to avoid duplication of tests and prescription of incompatible medications; the related concerns by privacy advocates; and the increasing sophistication of computer hackers, make ethics study particularly critical in the context of biomedical informatics.

One of the primary goals of this ethics component is to introduce fundamental theory and practices on the ethical and social issues facing the healthcare and biomedical research industry as it adopts information technologies to provide safer, faster health care service with lower cost, while preserving patient privacy, and eliminating the possible consequences of misuse of personal medical information. The goal of this portion of the program is to introduce and sensitize students to the ethical issues arising in the use of information systems and other computer-based tools in the delivery of health care. Ethical topics and questions significant to this research area include such topics as the extent to which biomedical researchers make a difference in the degree to which technology leads to morally desirable outcomes; the roles and limits of professional autonomy; the scope of a researcher's responsibility in terms of protection of patient confidentiality and approved use of medical data; and ethical uses of telemedicine and decision support tools in diagnosis and treatment. Even a partial list of potential topics is long and quite complex, and is related to issues in computer security, technological obfuscation, piracy, computer viruses, tracking devices such as RFID, biometric analysis and identification, genetic screening, open-source software (Linux, Java, the GNU public license software, to name a few), digital rights management, or form/function distinctions involved in liability, infringement, and other issues such as access control technology. Other related issues must also include

critical thinking and information literacy, including intelligent identification and selection of necessary data, recognition of potential biases or conflicts of interest in data sources, and the ability to identify missing or contradictory data, which must be addressed in order to successfully complete a complex project.

The first ethics activity at the beginning of the program was an ethics "diagnostic" survey, designed to assess students' level of awareness of their own ethical decision-making processes, what factors predominate in these decisions, and their attitudes regarding the appropriateness of emotional considerations, logical consistency, and role of reason in ethical decisions. This was followed by a discussion of ethics as a whole, meant to highlight students' unstated assumptions about their own, and others', ethical viewpoints. The remainder of the first day's ethical discussion centered around some of the more prevalent ethical viewpoints students are likely to encounter in the workplace, such as subjective relativism and rule utilitarianism. The majority of the remaining time dedicated to ethical issues, in the first week of the REU, was spent on discussion of current ethical issues in computer and medical applications. The goal of these discussions was not for students to all agree on an ethical stance for a particular issue, but that students learn to consider these issues in a thoughtful and deliberate manner, be able to describe and defend their ethical positions, and be able to understand others' perspectives, in order to form convincing arguments and persuade others to their viewpoints. The final class period devoted to ethics was spent identifying and discussing the ethical issues which the students expected to face in their projects for the rest of the summer. All of the formal ethical discussions occurred during the first week of the nine-week program, but additional opportunities for ethical discussion were part of field trips and other program activities.

At the end of the nine-week program, a survey was used to assess the impact of the ethics portion of the program. While the numbers involved are very small, the assessment results can still be used as indicators, and to suggest improvements for future iterations of the program. On the final survey, 67% of the participants indicated that they mostly, or completely, agreed that the program had helped them to better understand their own ethical viewpoints, and 78% mostly, or completely, agreed with the following statements:

- I am now better able to understand other's ethical viewpoints.
- I am now able to better recognize fallacies, *ad hominem* attacks, and appeals to emotion.
- I now understand better how ethical issues apply to computer projects.
- I now better understand how to evaluate information sources critically.
- I am now more aware of how internet/computer privacy issues have the potential to affect society.
- I feel that the ethical discussions were a valuable part of the REU experience.
- This portion of the program made me *think.*

On statements particularly related to the REU projects,

- Ethical issues are especially critical in medical applications.
- I now understand ethical issues that are relevant to my REU project.

89% of the respondents mostly, or completely, agreed.

In the section of the assessment survey that allowed for discussion responses, the students had several recommendations for improving the ethics portion of the REU. Specific suggestions as to topics included increased emphasis on falsifying results in research projects, more discussion on scenarios specifically related to bioinformatics, and more stress on the importance of protecting patient information and the consequences of not doing so. The major suggestion related to the logistics of the ethics portion was that after the strong emphasis on ethics in the first week that more ethical discussions should be included throughout the remaining weeks of the program, with special attention paid to the ethical issues related to the student's individual projects. These suggestions will be incorporated into the 2013 summer program.

FUTURE WORK

While we regard the first iteration of the REU at UTC to have been successful, based on the results of the students projects, the identified areas for continuing or future research, the number of students continuing with their work, and the positive reviews of the ethics portion of the program, we also see areas in which the program can be improved. Students appeared to be greatly moved, and motivated, by their visit to the Erlanger Stroke Center, in which they observed how hardware and software systems interact to aid in the removal of potentially deadly blood

clots from stroke victims. Including more such opportunities, and including them earlier in the program, could aid in the level of student understanding of the importance of their work, which could, in turn, affect their focus and motivation in completion of their research projects. Also, we will continue to seek funding to allow students to continue their projects throughout the school year, and encourage them to submit reports of their work to professional conferences.

Based on the student recommendations, the ethics emphasis will be continued throughout the entire nine weeks of the program, possibly as part of the weekly progress meetings. The students will also be helped to identify and refine ethical issues related to their particular projects, and required to include these issues, and how they were addressed, in their final reports.

CONCLUDING REMARKS

The successful first year of the UTC Research Experiences for Undergraduates program has laid the foundation for even more successful programs in the remaining years of NSF funding. Lessons learned will enable us to build on our accomplishments both in the technical projects and the ethical focus to enable students to not only participate in leading-edge research in Biomedical Informatics essential to the future practice of medicine, but to also gain a true understanding of the critical role of ethical considerations in their careers as computer professionals.

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