Biomedical Informatics

Biomedical Information and its use for Clinical Decision Making

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Domain
Biomedical Informatics concerns itself with the application of information processing techniques to the acquisition, storage, retrieval, sharing, representation, analysis, and optimal use of biomedical data and knowledge for problem solving and decision-making in medicine and health related disciplines. Biomedical Informatics is an interdisciplinary field involving computer science, biomedicine, probability, statistics, and decision sciences, which systematically applies computational methods to public health delivery, research and learning. Biomedical Informatics tools mostly include computers software and hardware; however the discipline also avails itself of health policies, clinical guidelines, and formal medical ontologies, networked through healthcare information and management systems.

Significance
Biomedical Informatics is increasingly relevant to health care education for a number of reasons. Most prominent among these are the following:

1 - Public health officials, government policy initiatives (e.g., HITECH), and the current economic landscape are driving an immediate need for health care professionals trained in Biomedical Informatics in order to improve efficiency, reduce operating costs, and maintain a sharp focus on quality and patient reported outcomes. Biomedical Informatics is the most promising tool for physicians, hospitals and health systems to improve those metrics through the efficient and effective use of health information technology. Biomedical Informatics lowers operating costs, and improves efficiency at all levels of the health delivery system.

2 - Health researchers are dealing with a deluge of biomedical data that they must of collect, curate, inventory, annotate, store, analyze, represent, share, and exchange. Biomedical Informatics addresses this challenge in the most optimal manner. But Biomedical Informatics does more: by enabling quick integration of research and clinical data, it maximizes research efficiency and overcomes delays and obstacles along the translational research path. Biomedical Informatics is essential to health research.
The accuracy of a clinician’s diagnosis depends on the way in which s/he gathers and interprets available information, a traditionally somewhat subjective process. Biomedical Informatics tools are invaluable in helping clinicians build a more objective argument for a particular diagnosis based on their interpretation of “the facts”, that traditional clinical decision-making and differential diagnosis allows for. Clinicians rely increasingly on medical informatics tools whenever engaging in clinical decision-making and differential diagnosis, or whenever they use information gathered from patients’ medical history, physical and mental examinations to suggest a list of possible causes of disorders and suitable treatments. Biomedical Informatics helps save lives.

Purpose
Students who take this course will have the opportunity to acquire core competencies in a key discipline supporting general medical practice. As a whole, the course is meant to prepare future health researchers to perform at the highest level of standards in their intended clinical and research functions, and to help them reach their future policy and management decisions with a higher degree of effectiveness and efficacy.

Intended Audience
Graduate students in the fields of Medicine, Nursing, Dentistry, Pharmacy, and Public Health

Textbooks

Biomedical Informatics: Computer Applications in Health Care and Biomedicine
Edward H. Shortliffe & James J. Cimino

Health Informatics: A Patient-Centered Approach to Diabetes
Barbara M. Hayes & William Aspray
Cambridge, MA. MIT Press, ©2010

Course Outline
This course proposal comprises two modules and case studies:
• Part 1 - *Biomedical Informatics Fundamentals* introduces recurring themes in the field of Biomedical Informatics

• Part 2 - *Biomedical Informatics Applications* provides a rigorous introduction to the most representative applications in the field of Biomedical Informatics

• Six cases studies reinforce the theoretical frameworks and illustrate the fundamentals concepts underlying the development and use of Biomedical Informatics applications. Moreover, each case study exemplifies opportunities and challenges inherent to the development of Biomedical Informatics solutions.

The course modules are organized as follow:

**Introduction:**
Computer in Medical, Pharmaceutical, Nursing, and Public Health Education

**Part 1 - Biomedical Informatics Fundamentals**

**The Computation Framework in Biomedical Informatics**
Computer Architecture; Software; Networks; Real-Time Data Acquisition; Signal Processing; Security.

**Storage and Use of Medical and Biomedical Information**
Medical Data Types; Uses of Medical Data; Pragmatic & Logistical Issues with Traditional Medical Records; The Structure of Medical Data; Decision Making in Data Collection & Selection.; Computerized Collection of Medical Data.

**Health Information Systems Design**
Engineering information systems to support health care delivery; Practical issues in System design, Implementation, and Evaluation.

**Computational Medical Informatics & Natural Language Processing (NLP)**
Processing Structured Data, NLP Techniques; NLP Grammars, Syntax, Semantics, & Pragmatics; Issues in Clinical and Biological Language Processing.

**Biomedical Imaging & Structural Informatics**
Digital Image Generation, Manipulation, Management, & Integration; Structural Imaging Energy Sources, Reconstruction Methods, & Dimensionality; Two & Three Dimensional Image Processing; Qualitative & Quantitative Approaches to Anatomy Characterization; Functional Imaging.

**Healthcare Information Technology Standards**
Data Interchange Standards (DICOM, ASTM, Health Level 7 & RIM, MEDIX, etc.); NCPDP standards; Medical Information Bus (MIB); ANSI X12 & X12N; ADA Standards; HIBC Standard; EDIFACT Standards; XML, SBML, TMA-DE, MAGE-ML; Controlled Vocabularies.

**Human Performance in Technology Mediated Settings**
Health Information Systems as Cognitive Artifacts; Human Factors; Usability & Learnability; Information Processing & Information Processing Under Conditions of Risk & Stress: Situational Awareness, Cognitive Load and Critical Errors; Human Computer Interaction (HCI); Medical Cognition and Distributed Cognition in Medical Practice.

**Biomedical Informatics Ethics**
Appropriate Use; Privacy, Confidentiality & Data Sharing; Clinical & Research Data; Public Health, Managed Care, & Clinician-Patient Ethical Challenges in Biomedical Informatics; Legal and Regulatory Issues in Biomedical Informatics.

**Part 2 - Biomedical Informatics Applications**

[1] **Electronic Health Record (EHR) Systems**
The EHR as an electronic information repository; The EHR Functional Components; Capturing, Displaying, Querying, & Monitoring Patient Data.

**Case Study: 3 HIPAA-compliant EHR Systems**
- This case study showcases 3 HIPAA-compliant EHR Systems for small and midsize practices, all certified under the Office of the National Coordinator for Health IT meaningful use program, and the Certification Commission for Healthcare IT: EClinicalWorks™, NextGen™, and MDTablet™. These EHR systems illustrate both the commonality of goals each strives to attain, and the fact that distinctions among systems are found in the advanced capabilities each seek to prioritize. The last system, MDTablet™, offers students a good example of the recent integration of EHR capabilities with the mobility of hand-held tablet computers.


**Case Study: DXplain™**
- This case study showcases DXplain™, a decision support system that uses a set of clinical findings (signs, symptoms, laboratory data) to produce a ranked list of diagnoses that might explain (or be associated with) the clinical manifestations. DXplain provides justification for why each of these diseases might be considered, suggests what further clinical information would be useful to collect for each disease, and lists what clinical manifestations, if any, would be unusual or atypical for each of the specific diseases. Decision support systems do not offer definitive medical consultation and should not be used as a substitute for traditional diagnostic decision-making.
Healthcare System Management & Integration; Store & Forward Tele-Health; Real Time Tele-Health; Remote Patient Monitoring.

Case Study: JABSOM TRI’s CDMP
- This case study showcases the UHM Telemedicine Research Institute’s Chronic Disease Management Program (CDMP), developed under the direction of Sven-Erik Bursell at UHM John A. Burns School of Medicine. CDMP is a web-based open-source software that aggregates data from a variety of sources including EHR systems, laboratories, home-based remote monitoring devices, smart phones, and facilitates communication through a patient portal and the patient centered medical home. It is currently implemented in five community health centers in Hawaii, and over 100 sites across 24 mainland states – primarily with the Indian Health Service. CDMP also comprises a prototype cell phone application that provides lifestyle decision support to patients with diabetes.

[4] m-Health: Tele-Health New Frontier
Mobile Devices: The Next revolution in Health Care; Mobile Point of Care (MPOC); Security and Privacy in Mobile Healthcare: Protecting Healthcare Data in the Cloud; Deploying Wireless Patient Tracking in EDs; m-Health Special Topics: Optimizing Care Delivery, Diagnostics Tools, Drug Quality Verification, Surveillance & Monitoring.

Case Study: Lifeguard®, MDTablet™
- This case study showcases the NASA Ames/Stanford National Biocomputation Center's Lifeguard System. Lifeguard, developed under the directions of Dr. Kevin Montgomery at Stanford University School of Medicine. Lifeguard® is a real-time mobile monitoring device used with astronauts at NASA that is now being adapted for home use. As a wearable, small, and unobtrusive device, Lifeguard is used for remote monitoring of patients’ physiology. The system combines a series of lightweight medical sensors, base computer (Tablet PC), secure wireless network architecture, and software for data storage, display and analysis.

[5] Imaging Systems
Imaging Systems in Medicine: diagnosis, treatment, assessment, and prognosis; Imaging technology: Radiography, Magnetic Resonance Imaging (MRI), Fiduciary Markers, Nuclear medicine, Photo acoustic imaging, Breast Thermography, Tomography, Ultrasound; Maximizing imaging procedure use; Creation of three-dimensional images; Compression of medical images; Non-diagnostic imaging; Archiving and recording; Medical Imaging in the Cloud; Imaging in pharmaceutical clinical trials; Shielding.

Case Study: The UH JABSOM Magnetic Resonance Image Processing Core
The Neuroscience and Magnetic Resonance Research Program is using a dedicated 3-Tesla scanner to conduct research that clearly demonstrates the important role of imaging systems in medical research. The following studies were selected as particularly informative in this context: Brain Activation in Patients with Early HIV Dementia; Early Brain Development after Prenatal “Ice” Exposure: A Longitudinal MR Study, RGR-
based Motion Tracking for Real-Time Adaptive MR Imaging and Spectroscopy; PING - Creating a Pediatric Imaging Neurocognition and Genomics Data Resource; Neuroimaging to Assess the Effects of Therapy in Children with Acute Lymphoblastic Leukemia; Impact of Marijuana Exposure on Brain Maturation: Translational Neuroimaging; Factors for enhanced neurotoxicity in methamphetamine abuse and HIV infection.

[6] Bioinformatics
Translational bioinformatics: the convergence of molecular bioinformatics, biostatistics, statistical genetics and clinical informatics; Sources of Biological Data: DNA Sequences, Amino Acids Sequences, DNA Microarrays; Data Driven Challenges: System Data; Sequences Data, 3-D Structures Data, Expression Data; Computational tools for Bioinformatics; Fundamental Computational Algorithms; Fundamental Applications in Bioinformatics; The Implications of Bioinformatics on Clinical Informatics.

Case Study: FragAnchor, a GPI-Anchored Protein Prediction Tandem System

- This case study showcases FragAnchor, a GPI-Anchored Protein Prediction Tandem System (NN+HMM) developed by Dr. Guylaine Poisson from the UHM computer Sciences Dept. FragAnchor is based on the tandem use of a Neural Network predictor and a Hidden Markov Model predictor. The Neural Network is used to select the potential GPI-anchored sequences and the Hidden Markov Model classifies the selected sequences according to four different levels of precision (highly probable, probable, weakly probable, potential false positive). The Hidden Markov Model proposes also up to three possible locations for the anchor/cleavage site.

Conclusion: A Translational Value
The tangible benefits Biomedical Informatics brings to the medical enterprise should be compelling enough to ensure that the discipline becomes fully integrated with all parts of the traditional medical curriculum. However, because the very set of methodologies lying at the core of the discipline provides a foundation for the crossing of translational barriers, Biomedical Informatics is destined to become indistinguishable from the medical culture. Mastering the fundamental aspects of Biomedical Informatics is invaluable not only in improving patient outcomes, maximizing efficiency, cutting costs, and expanding access to affordable care, it also ensures that future clinicians will have the skills to conduct effective translational research and become key partners within translational medicine teams.