Medical Informatics-
the uncle of Bioinformatics

Dr. Adrian Mondry
Bioinformatics and Medical Informatics - tools for the biosciences.

A short introduction to the disciplines.
Definition of “Bioinformatics”

• Bioinformatics is a collection of statistical methods for dealing with large biological data sets.
  - a statistician.

• Bioinformatics is the marriage of Computer Science and Molecular Biology.
  - the chair of a computer science department.

• Bioinformatics is the application of machine learning to biological data.
  - an artificial intelligence researcher.

• Bioinformatics is sequence alignment.
  - a statement made during an attempt to figure out what project to fund

• Bioinformatics is command line unix.
  - a system support worker at a biotech company.

• Bioinformatics is the funding stream for the next millennium.
  - a college dean.
Aim of “Bioinformatics”

• Research, development, or application of computational tools and approaches for expanding the use of biological, medical, behavioral or health data, including those to acquire, store, organize, archive, analyze, or visualize such data.
What other applications are there for “Bioinformatics”
The Central Dogma of Molecular Biology and Bioinformatics

Genetic information is stored in the chromosomes in form of desoxynucleic acid sequences- DNA. These are transcribed into RNA sequences and then translated into protein sequences.
Structural and functional Genomics

Protein structure determination (X-Ray, NMR, electron cryo-microscopy etc.), protein structure modeling and prediction, computational proteomics (protein sequencing via mass spectrometry);
Gene expression analysis, gene annotation, genetic and biochemical pathway construction and analysis.
Computational Genomics

Sequence analysis and gene identification, large scale database construction and data mining, scientific visualization of genomic information, computational analysis of biochemical and genetic networks, computational statistical and population genetics (e.g. linkage analysis), macromolecular modeling (classical and quantum molecular dynamics, Monte Carlo, conformation analysis etc.).
Systems Biology

The challenge is to develop mathematical models that incorporate biological data gathered from experiments in conjunction with computational techniques for massively parallel computing to model these complex interacting systems i.e. the living cell in terms of all its constituent molecules.

\(^{\text{TM}}\) and a H.263 decompressor are needed to see this picture.
Distributed computing in Biomedicine

The aim is to help establish the advanced computational infrastructure and technical expertise needed to address the computationally demanding and challenging problems below. This includes cluster computing, data management and mining over massive data storage facilities, Grid computing etc. as well as developing optimized algorithms in computational biology.

**GridBlast: Solution Architecture**

**Grid Middleware (GLOBUS)**

**CLIENT/REMOTE MACHINES**

**COMPUTE/DATA GRID**

**Queries, Executables, Databases**

**Results**
Definition of “Medical Informatics”

• **Simplistic:** Computer applications in medical care.

• **Complicated:** The study, invention, and implementation of structures and algorithms to improve communication, understanding and management of medical information.
Aim of “Medical Informatics”

• 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 focus on the structures and algorithms necessary to manipulate the information separates Medical Informatics from other medical disciplines where information content is the focus.
Correlation of “Bioinformatics” and “Medical Informatics”

Medical Informatics and Bioinformatics are both subsets of one and the same field of science:

“Information technology in the life sciences”

Medical Informatics is the older discipline
Bioinformatics is the more fashionable discipline
A historical perspective (1): from thought to action

- The question: Can human reasoning be explained in terms of formal processes was raised in the middle ages.
- G.W. von Leibnitz tried to develop a calculus to simulate human reasoning.
- The first practical application of automatic computing for medicine was Herrman Hollerith’s data processing system for the 1890 US census.
A historical perspective (2): the digital age

- Hospital information systems, from the 1960s onwards.
- Assisting the physician’s decision-making: “expert systems”.
- Integrating images into medical practice.
- Giving the physician access to specialized knowledge databases.
- Giving the public access to medical information.
Medical Informatics as basic science

In this view, development and evaluation of new methods and theories are a primary focus of activity.

These core concepts in turn have broad applicability in the health and biomedical sciences.

The informatics subfields are therefore best regarded as application domains for a common set of concepts and techniques from the field of medical informatics.
Application driven science

- Work in medical informatics is motivated totally by the application domains that the field intends to serve.

- Thus, the basic research activities in the field generally result from the identification of a problem in the real world of health or biomedicine for which an informatics solution is sought.

A given applications area is motivated by the needs of that area, to which it attempts to contribute a solution to problems.

Thus, the need for an application may motivate basic research in order to find these solutions.

For this, medical informatics draws on, and contributes to, a wide variety of component disciplines.

Example of “Medical Informatics”

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Projects in Medical Informatics

**Virtual Bone:**
Finite Element Model using human bone as template.

• **Aims:**
  - amelioration of current diagnostic tools for osteoporosis
  - Integration of laboratory data for modeling of (patho-)physiological states
  - Modeling of drug effects
  - Modeling of gait disturbances and biometry for prosthesis construction

• **Putative collaboration partners:**
  - NKFS: clinical data
  - NTU: bone collection, gait analysis
  - TU/e MaTe: scanning, FEM
Medical Decision Modeling:
Medical decision modeling integrating clinical guidelines and individual patient data.

- **Aims:**
  - Decision aid for diagnosis and treatment.
  - Customizing existing decision aids to the individual patient’s specific needs.
  - Use of multiple knowledge base.
  - Automated integration of best current evidence into existing guidelines and diagnosis/treatment algorithms.

- **Collaboration partner:**
  - NUH-EDTU: clinical setting, “testbed”
Projects in Medical Informatics

Overall Design of the Expert System in EDTU
Evidence Based Medicine Tools:
Online tools to further the use of an evidence based approach to clinical practice.

• Aims:
  ▪ Automatically updating download site for CAT libraries for PDA use.
  ▪ Online decision aid for ultrasound based intrauterine growth monitoring.

• Collaboration partners:
  ▪ NUH- EBM committee: “testbed”
  ▪ NUH- OG: clinical data growth monitoring
Achievements (1): “CAT” search engine by Dong Peng

- A CAT is a short fact sheet detailing very up-to-date medical knowledge as an answer to a specific practical question.

- Meta search engine allows to browse established CAT libraries in various places worldwide from a single interface.

- Work in progress: refinement of search strategies to include more external databases, accept more formats, allow download to PDA.
Achievements (2): Redefining IUGR by Liu Pengbo

- Intrauterine Growth Restriction is an alarm signal during pregnancy, and thus should be diagnosed with good sensitivity and specificity.

- Using a computer simulation of ultrasound measurements, it could be shown that the definition of IUGR as $\frac{dz}{dt}$ allows for safe diagnosis of IUGR independent of gestational age.
Achievements (3): Adaptation of bone to load by Wang Zhengyuan

- Bone reacts to external forces by changing its internal architecture to optimize stability for a given situation.
- This essentially positive capacity can become dangerous when the force is followed by inadequate adaptation because nature did not “program” the possibility for adequate reaction.
Achievements (4): Medical image registration based on Image Rotation Perspective by Wang Zhengyuan

A large number of medical treatments need to take into account information from various imaging techniques.

It is important to make sure that the different images can be compiled in a way that gives the doctor the most precise knowledge about spatial details.

Fig. 2 An example of a normalized IRP with rotation from zero to $2\pi$ and amplitude from zero to 1. As rotation goes from zero to $\pi$, it drops to a trough and then goes up to a peak. The latter half simply repeats the former half. If the image is rotated at $\theta$, its new IRP will start at $\theta$ of the original one. By analyzing the two IRPs, the rotation can be calculated.

$$IRP(i) \triangleq \sum_{i=1}^{N} \left[ P_i(x_i, y_i) \otimes \overline{e} \right]$$
The Future of “Medical Informatics”

The focus on the structures and algorithms necessary to manipulate the information separates Medical Informatics from other medical disciplines where information content is the focus…