Clinical Applications of Big Data

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Outline

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  – Pre-Hospital Syndromic Surveillance
  – Chronic Disease Prediction with Genomic Data
  – Computational Image Classification
The Challenge

• Systems to enhance **practice of medicine**.
  – Physician-driven clinical challenges.
  – Deliver safer and more efficient care.
  – Enable decision support at the bedside.

• **Strategic importance** to the UMMC and UMSOM.
  – Enhance access to biomedical knowledge.
  – Strong theoretical basis in Computer Science.
Big Data - Clinical Decision-Making

• The practice of medicine.
  – “Medical practice” is “medical decision-making”.
  – This is the defining skill of all physicians.

• “Diagnostic gap” in computations systems.
  – Many computational advances in healthcare.
    • Administrative, workflow, imaging, devices, etc.
  – Few advances in bedside clinical decision support.
    • Some success with alerts, calculators, and order sets.
    • But no computationally-enabled clinical decision support.

There are no practical systems to help doctors make clinical decisions.
Big Data - Challenges

- Accumulating data faster than we can analyze.
  - Clinicians require immediate access to 2-5 million facts.
  - Medical knowledge doubling every 5 years.
  - Clinical data doubling every 1-2 years.

- Analytical challenges.
  - Dimensionality, heterogeneity, interdependency, complexity.
  - Uncertainty, nonmonotonic, nondeterministic.

- Traditional statistical approaches to big data.
  - Efficiency and accuracy problems.
  - A priori models limit ability to find hidden patterns.
Big Data - Sources

• Department of Veterans Affairs repository (VINCI).
  – 15 years of clinical data from 150 hospitals and 800 clinics.
  – 20 million patients, 6 million currently active.

• Million Veteran Program (MVP).
  – Genomic sequences and markers, correlated with VINCI.

• Electronic Maryland EMS Data System (eMEDS).
  – Assessments, treatments, and dispositions for 400,000 priority medical EMS calls annually.

• GENEVA Consortium.
  – Secondary analysis of clinical and demographic data with high-dimensional genomic markers.
Big Data - Approach

• Semantic analysis.
  – Provide context and meaning to the clinical data.

• Machine learning.
  – Reduce intractable amounts of clinical data into a moderately-sized repository of medical facts.

• Pathophysiology.
  – Organize clinical knowledge according to physiologic relationships and evidence-based guidelines.

• Human factors.
  – Incorporate an understanding on the nature of clinical expertise in decision making.
Big Data - Areas of Research

• Dimensionality reduction.
• Biological enrichment (domain information).
• Discovery of relationships with genomic data.
• Knowledge extraction from unstructured text.
• Validation approaches.
• Rare event discovery.
Research Projects

• Knowledge Representation and Reasoning (KRR)
  – Disease, critical event, and treatment efficacy prediction.

• Patient Safety in Emergency Medicine
  – Identify patient safety indicators in emergency medicine.

• The Nature of Clinical Expertise
  – Elucidate the clinical decision-making process.

• Pre-Hospital Syndromic Surveillance
  – Risk analysis for obscure syndromes and toxidromes.

• Chronic Disease Prediction with Genomic Data
  – Genomic prediction models in pre-symptomatic individuals.

• Computational Image Classification
  – Cellular communications and surgical safety.
Research Projects - KRR

• Restructure data for bedside decision support.
  – Disease prediction.
  – Critical event prediction.
  – Treatment efficacy prediction.

• Focus on a small group of chronic diseases.
  – CAD, DM, CKD, COPD, AD, Prostate + Pancreatic CA.
  – Complex and multifactorial.
  – Leading causes of morbidity and mortality.

• Strategic collaborations.

• New computing facilities at the Baltimore VA.
Research Projects - KRR Clinical Narratives

• Semantic framework for clinical decision support.
  – Apply text analytics to clinical narratives.
  – Establish relationships between extracted terms using domain-specific medical ontologies.
  – Infer additional facts using OWL reasoner with clinical rules.

• Initial results.
  – Extract evidence-based risk scores from clinical narratives.
    • TIMI Risk Score for Acute Coronary Syndrome.
    • San Francisco Syncope Rule.
  – Great than 90% accuracy.
Research Projects - Patient Safety

• Patient safety is an essential health care challenge.
  – Reporting, analysis, and prevention of medical errors.

• Safety challenges in emergency medicine.
  – 100 million annual visits.

• Safety events difficult to measure.
  – Events resulting in harm just the “tip of the iceberg”.
  – Need to identify “submerged” events.
    • Near misses and events that did not result in harm.
    • Hard to find with self-reporting & with a priori models.
Research Projects - Clinical Expertise

• The nature of clinical expertise in decision making.
  – Information requirements (what, when, why).
  – Clinical guidelines, clinical prediction rules, online resources.
  – Effect of time pressure and patient acuity.
  – Impact of workflow and social interactions.
  – Inter-operator variability.

• Elucidate the clinical decision-making process.
  – Observational studies, simulations, and surveys.

• Use results to help with decision-support systems.
  – Empathic and user-driven approach to development.
  – Vetting and credentialing of decision-support systems.

“People Learning” --- not just “Machine Learning”
Research Projects - Genomic Prediction

• Chronic disease prediction with genomic markers.
  – Leading causes of M&M.
  – Obscure patterns of inheritance.
  – Prediction in presymptomatic individuals = early intervention.

• Initial results.
  – Cluster models to combine relevant clinical and genomic features.
  – New genotype score comparable to clinical risk scores.
  – Demonstrated improvements in risk prediction using domain knowledge and feature selection.
  – Identified new genomic relationships using collaborative filtering and cosine similarity.
Research Projects - Syndromic Surveillance

• Early detection of disease outbreaks.
  – Biologic terrorism, disasters, or natural causes.

• Monitoring of pre-clinical data.
  – Electronic Maryland EMS Data System (eMEDS).
  – Complement with data from social media.

• Machine learning approach.
  – Identify obscure syndromes and toxidromes.
  – Predict hospital utilization requirements.
Computational Image Classification

- We experimented with image classifier techniques using machine learning algorithms.
- We developed a new approach to extract and map image features to biological characteristics.
  - Extracted image features from smooth muscle images.
  - Characterized cell-to-matrix interactions.
- We also applied this approach algorithm to laparoscopic surgery videos.
  - Identified critical surgical activities.
  - Recognized potentially unsafe actions.
Research Overview

Projects

- Knowledge Representation & Reasoning
- Patient Safety
- Genomic Risk Prediction
- Syndromic Surveillance

Computational Health Intelligence Platform

- Semantic Analysis
- Machine Learning
- Evidence-Based Guidelines & Physiologic Relationships
- Nature of Clinical Expertise

Big Data

- VINCI/MVP
- GENEVA
- eMEDS
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