Training Next Generation Scientists in Interdisciplinary Computing: PBL

**Problem-Based Learning**

Define Problem → Analyze & Design → Make Impact

Enable Active Learning + Build PS Skill + EQ

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Bio-MIBLab Team

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Outline

- **Background**
  - Problem-based learning
- **Design of Curriculum**
  - Integrating PBL with technical specialty course
  - Delivering software tools for medical imaging problems
- **Outcome**
  - Deliverables
  - Making impact in science discovery and clinical practice
- **Discussion and Summary**

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  - Dr. Yan Xu
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Education Innovation

• Society Need:
  – Young Generations Capable of Taking Charge and Solving Problem
• Students’ Attending Colleges
  – Degree + Ability
  – Knowledge + Technical Skills
  – IQ + EQ
• Improving Teaching
  – Shifting from “Lecture-Centric” Knowledge Passing to “Student-Centric” Proactive Learning

What are the interdisciplinary challenges in BioMed?

Solutions: Ability, Skills, EQ through PBL

• Developer perspective: Hard in user-centric design (No time to understand domain application needs)
  ➔ Problem Driven
• Technical challenges in practice ➔ Problem Solving
  – Data integration, tool interoperability, knowledge
  – Language barrier, culture difference
• User perspective: computing illiteracy ➔ CompProg
  – No time/need to learn computing in depth
  – Computing tools/resources interfaces are NOT intuitive and visual

Success Starts with Education: Problem-Based Learning

Comparison of PBL with Lecture-Based Learning

<table>
<thead>
<tr>
<th></th>
<th>Lecture-Based Learning</th>
<th>Problem-based Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary agent</td>
<td>Instructor</td>
<td>Student</td>
</tr>
<tr>
<td>Dominant interactions</td>
<td>Instructor-to-student</td>
<td>Student-to-student</td>
</tr>
<tr>
<td>Knowledge sources</td>
<td>Single; dominant</td>
<td>Multiple; complementary</td>
</tr>
<tr>
<td>Learning styles</td>
<td>Dependent</td>
<td>Interdependent</td>
</tr>
<tr>
<td>Educational emphasis</td>
<td>Knowledge</td>
<td>Problem-solving</td>
</tr>
<tr>
<td>Pedagogical focus</td>
<td>Result-oriented</td>
<td>Process-oriented</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Summative</td>
<td>Formative</td>
</tr>
</tbody>
</table>

PBL in Medical Image Processing

Problem-Based Learning

Define Problem ➔ Analyze & Design ➔ Make Impact

• Use Real-World Biomedical Problem and Data
  – Students: form multidisciplinary team (1 BME & 1 ECE/CS)
  – Instructors: consist of domain experts and computational expert
• Propose and justify computational method selection
  – Conduct real literature critique in addition to basic theory
• Implement computation system
  – To be evaluated by real domain scientists (+ conference review)
The New PBL Process

Real World Problem

Problem Analysis/Requirements Collection (PARC)
- e.g. details, attributes of biological data, biological significance or questions to be answered via data analysis

Clinical Collaborators
- Using acquired knowledge, test and compare proposed techniques to solve the problem and coming up with a viable solution. Applying knowledge from PARC to present the solution in a user friendly manner.

Knowledge sharing

Knowledge Building (KB)
- Literature survey to learn the state of the art, identifying techniques to solve the problem, coming up with novel methods to enhance existing techniques and proposing new techniques for unsolved problems

Case Study 1: Analysis and Synthesis

Microtubule Dynamics

Microtubule Dynamics Measures Drug Therapeutics

- Taxol
- Cancer drug toxicity
- Microtubule dynamics changes

Problem Statement

- Microtubules bundle-ness stops cell dividing → cancer cell death
- Existing Manual Method
  - Measure length manually
  - Time consuming task;
- Automating Method
  - Dynamic quantification that are hard to calculate manually
  - Reduce subjectivity

Marcus, A. Giannakakou, P. et al. Cancer Res. 2005
Solution Work Flowchart

- **Problem Analysis/Requirements Collection (PARC)**
  - Match Filter
  - Otsu Threshold
  - Get FFT Mask
  - FFT
  - K-means
  - Tip Selection/Linking
- **Knowledge Building (KB)**
  - BW Label
  - PNA Tip Detection
- **Problem Solving (PS)**
  - -- Enhance MT structure
  - -- Get binary images
  - -- Remove noise caused by thresholding
  - -- locate tips, also gives information about isolated level
  - -- Only do FFT on possible tip locations, reduce calculation and reduce noise
  - -- Integrate temporal information
  - -- Obtain high activity regions
  - -- Find tips that are closed to high FFT region and isolated

Real World Problem

Automated Image Processing Results

- **Problem Analysis/Requirements Collection (PARC)**
- **Knowledge Building (KB)**
- **Problem Solving (PS)**

Credits: Christopher Alberti, Delano Billingsley, Jean-Philippe Villaréal (2007)
Course Outcome

- Software Tool
  - Microtubule Tracking for Cancer Drug Efficacy

- Peer Review Publication No.1

Publication No.2

**Automatic tip selection for microtubule dynamics quantification**

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Case Study 2: Analysis and Visualization of Tissue Imaging Mass Spec Data

1. Combining Proteomics/Metabolomics with Medical Image Processing
2. -omic with Molecular image analysis

**Brain Tissue (Septo-striatal) ➔ MALDI**

- Dr. Al Merrill’s Research on Lipidomics with Dr. Cameron Sullards, Dr. Frank Chen
Mathematics Algorithm Design

\[ X \approx WS \]

\[ X \in \mathbb{R}^{N \times 10} \quad W \in \mathbb{R}^{N \times 6} \quad S \in \mathbb{R}^{6 \times 10} \]

- S known:
  \[ X S^T (SS^T)^{-1} \approx W \]
- S unknown:
  \[ [W, S] = nmf(X) \]

Tissue Imaging Mass Spectrometry Tool

Outcome

- Software Tool
  - Tissue imaging mass spectrometry (LC-ESI-MS/MS)
- Peer Reviewed Publication
Case Study: PillCam

Credits: David McCann, Steve Conover (2007)

Case Study: Clinical MRI Diffusion Tensor Imaging


Dr. Hui Mao


Perfusion Image Quantification (DCE-MRI)

Molecular In Vivo Image Segmentation

Team: Cody Wortham, Florence Bonnafé (2007)
Dr. Shuming Nie, Lily Yang
Case Study: Next Generation Pathology

- Problems
  1. Poor contrast, Clutter
  2. No standard grading metric
  3. Large data size

- Solutions
  1. Segmentation
  2. Classification
  3. Speed up

Emory-GT Center
Next Gen Pathology
Multiplex QD Tissue Image Size (10X)

- 16 QD Channels Multiplex
- 40,000x24,000 Pixels/Tissue Slide (960 Million)
- 2 Bytes /Pixel/Channel

RCC_A
6 whole tissue

Meta Data: Multiscale Image

SRM Q=8
SRM Q=64
SRM Q=16
SRM Q=128
SRM Q=32
SRM Q=256
Original Image
Semantic Annotation

Extension of Web-Based System to Mobile Device

- Access antibody-stained profiling data and images via iPhone/iPad application
- Create and share image annotation knowledge anytime and anywhere

Antibody Browsing
Image Browsing
Annotation Sharing


Discussion: Observations

- Inspiring Student-Centric Learning
  - Is essential to Bio-Medicine & Possibly Other Fields
    - Real problem
    - Real team
    - Mentality
  - Is empowering domain scientists
    - Quantitative and computational thinking
  - Is a driver to new discovery
    - Student's creativity is enormous

Discussion

Surprising Outcomes of PBL

Publications Citable in ISI Conf. Database


Discussion: Challenges

- **Need: Multidisciplinary Faculty Team**
  - The Wallace H. Coulter Dept. of Biomedical Eng: 1997
    - A Truly Joint and Multidisciplinary Department between Emory Univ. Medical School and Georgia Tech College of Engineering
    - 40 Faculty Members, No.2 in 2007-2011 US News & Report
    - Easy NOW!

- **Need: TAs**
  - NOT Easy!

Summary

- Process is more important than handing over solution
- Integrating PBL with technical specialty course ➔
  - Training students in inter-disciplinary research with **skills** beyond technical knowledge
  - Gaining real-world problem solving **ability**
  - Gaining teamwork **EQ**

- Students ➔ Active Learning
- Mentors ➔ Increasing Faculty Interactions

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