Supporting acquisition of visual diagnostic expertise:
Case-Based Training to Intelligent Tutoring

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University of Pittsburgh School of Medicine
Center for Pathology Informatics
Interests

- Knowledge representation
- Education
- AI applications in Education
- Human Computer Interaction
- Intelligent Multimedia Interfaces
- And also ... Virtual Slides
Overview

• How do we build effective educational systems that incorporate new technologies such as Virtual Slides?

• Two examples from our laboratory that take very different approaches. Both of these systems are very early examples!

• Both grounded on results of our empirical work describing the development of expertise in this domain – How does this work help inform system design?

• Virtual Slide Set - A case-based system for authoring and presentation of Virtual Slides

• SlideTutor - An intelligent tutoring system

• Demonstrations

• Future Questions
Approach

- Medical education is “stuck” in time and space and content (Friedman, 2000)
- Apprenticeship model is increasingly hard to sustain
- Many environments, new pressures, need to cover more material in less time
- Create computer-based methods for training
- Make environments realistic – Virtual Slides
- Identify where students have problems and where traditional approaches have failed
- Look to other fields for ideas
- Evaluate the results of our work
A Study of Expertise in Visual Diagnosis
Motivation

- Understand a difficult diagnostic task that requires multiple kinds of skills
- Investigate how pathologists develop the ability to classify complex visual patterns
- Apply findings to the design of image-based computer training systems
**Background**

- Numerous previous studies of expertise in medical domains that are not primarily visual (Patel, Bordage)
- Several previous studies of expertise in radiology and dermatology (Lesgold, Kundel, Norman)
- No previous studies of expertise in microscopic diagnosis
- Microscopic diagnosis may be quite different
Methods

- Think-aloud protocols
- Videotape collected from the microscope
- Determine accuracy – specific and categoric
- Code processes (operators) and content (knowledge states) using process coding scheme - 48 codes
- Identify errors using error coding scheme - 8 codes
- Measure times to important events
- Aggregate and compare codes and times for level, or case
- ANOVA, Scheffe tests to measure differences
Cases & Subjects

- Standardized set of cases in breast pathology
- 10 Novices – just finished year 2
- 10 Intermediates – 2\textsuperscript{nd} and 3\textsuperscript{rd} year residents
- 8 Experts – Attending pathologists with >10 years experience
Data Collection
**Standardized Case Set**

<table>
<thead>
<tr>
<th>Case</th>
<th>Gold Standard Diagnosis</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Infiltrating Ductal Carcinoma</td>
<td>Focal lesion of poorly differentiated cancer adjacent to biopsy site and scar.</td>
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<tr>
<td>2</td>
<td>Ductal Carcinoma in Situ (DCIS)</td>
<td>Widespread solid and cribriform in-situ carcinoma present throughout majority of sample.</td>
</tr>
<tr>
<td>3</td>
<td>Infiltrating Lobular Carcinoma</td>
<td>Widespread classical type infiltrating lobular carcinoma. Scant adjacent normal tissue.</td>
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<tr>
<td>4</td>
<td>Lobular Carcinoma in Situ (LCIS)</td>
<td>Small focus of LCIS with retrograde extension in otherwise normal breast.</td>
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<tr>
<td>5</td>
<td>Fibroadenomas, Sclerosing Adenosis and Intraductal Papilloma</td>
<td>Multiple focal lesions, including sclerosing adenosis - a benign lesion that shares some visual features with cancer.</td>
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<td>6</td>
<td>Paget’s Disease</td>
<td>Nipple with focal area of intra-epidermal Paget’s disease. No underlying carcinoma.</td>
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<tr>
<td>7</td>
<td>Adenomyoepithelioma</td>
<td>Small circumscribed lesion with uniform features.</td>
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<tr>
<td>8</td>
<td>Atypical Papilloma</td>
<td>Large lesion with numerous atypical features</td>
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</tbody>
</table>

Crowley et al. JAMIA, in press
An example protocol: An expert diagnosing DCIS

Expert E7:

3 Okay let’s look at low power
4 I think the tissue is breast
5 I recognize some normal
6 Here is in situ carcinoma
7 I have to find out if there is any invasion

→ identify-anatomic-location
→ statement-of-hypothesis
→ set-goal-identify
An example protocol:
An intermediate diagnosing DCIS

Intermediate I5:

20 and some of the ducts that are expanded with small cells
4 with focal, possibly central, area of necrosis.
5 So just scan this slide around and try to determine some
focal areas that I want to concentrate and focus on.
6 Now I’m looking at some of the ducts that are expanded.
25 And some of these ducts, they also have holes,
26 and these are sort of punched-out holes,
27 very uniform, which...
29 So at this magnification, I think it is a DCIS.
Overall accuracy

Accuracy

Novice | Intermediate | Expert
---|---|---
Specific | Category

Accuracy chart showing the overall accuracy for Novice, Intermediate, and Expert categories.
### Aggregated Process Differences

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<th>Intermediate Mean</th>
<th>SD</th>
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Crowley, Naus, Stewart & Friedman, in press
## Task Errors

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<th>Description</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Expert</th>
<th>Statistics</th>
<th>Pairwise Comparison</th>
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<td>Number of cases / Total (%)</td>
<td>Number of cases / Total (%)</td>
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Crowley, Naus, Stewart & Friedman, in press
Intermediates detect but cannot accurately classify
Task Analysis Latencies

Crowley, Naus, Stewart & Friedman, in press
# Lessons learned

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<thead>
<tr>
<th>This is a multi-step process requiring three different sets of skills and several minutes.</th>
<th>Model these processes using a model-tracing approach.</th>
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<tbody>
<tr>
<td>Searching the slide is a difficult first step.</td>
<td>Connect the model to a virtual microscope; Include rules for searching and magnification use.</td>
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<tr>
<td>Uncertainty and error in identification of visual features</td>
<td>Require the student to explicitly relate image features to diagnostic criteria. Give feedback.</td>
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<tr>
<td>Rapid pattern matching is preceded by explicit inference.</td>
<td>Make these explicit reasoning steps visible to the student, require that they argue for and support their diagnosis in a graphical reasoning interface.</td>
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Two systems that incorporate virtual slides

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<tr>
<th></th>
<th>SlideTutor</th>
<th>Virtual Slide Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Paradigm</td>
<td>Intelligent Tutoring System</td>
<td>Computer-Assisted Instruction</td>
</tr>
<tr>
<td>Domain</td>
<td>Dermatopathology</td>
<td>Domain-Neutral</td>
</tr>
<tr>
<td>Audience</td>
<td>Residents/Fellows</td>
<td>Medical Students</td>
</tr>
<tr>
<td>Development Strategy</td>
<td>Long term Research Project</td>
<td>Iterative Development/ Deployment Cycle</td>
</tr>
<tr>
<td>Web Access</td>
<td>Client/Server Application downloaded and updated with Java WebStart</td>
<td>Use from any Java enabled browser (currently Windows only)</td>
</tr>
<tr>
<td>Knowledge Base</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Authoring Privileges</td>
<td>Controlled</td>
<td>Open</td>
</tr>
<tr>
<td>Authoring Requirements</td>
<td>Minimal</td>
<td>Maximal</td>
</tr>
<tr>
<td>Individualization</td>
<td>Maximal</td>
<td>Minimal</td>
</tr>
</tbody>
</table>
Design and development of an Intelligent Tutoring System in Pathology
Intelligent Tutoring Systems

- Systems that use AI formalisms to offer interactive computer-based instruction
- “Learning by doing” +
- Represent knowledge
- Actively encode student’s progress
- Offer content based on systems model of student
- Offer instruction and hints based on systems model of student
- Provide feedback about how the student is learning
- Adaptive, flexible, *individually tailored* instruction
Alot like a Ballroom Dance Lesson

- Learning by Doing
- Student leads
- Right step?…teacher follows
- Wrong Step?…teacher corrects
- Lost?…teacher leads but only for a moment
- Production Rule Systems and Probabilistic Models
Collect data on what student does
Make predictions on what student knows
Provide data for pedagogic decision making

Student Module

Expert Model

- Allow correct steps
- Correct errors
- Give hints on next step

Pedagogic Knowledge

- Case sequence
- When to intervene
- How much to intervene
- How to intervene

Interface

- Canvas for problem solving
- Make goals visible
- Provide metaphors and novel notations
Dermatopathology as a Domain for an ITS

- Extremely difficult
- Residents have little time to learn
- False positives and false negatives; errors associated with significant impact to patient
- Some areas are highly algorithmic, seemed straightforward to model with rule system
- Some areas not so straightforward to model with rule system
Tools and Standards

- Web-deployed using Java WebStart
  http://java.sun.com/products/javawebstart/
- Jess – Java Production Rule System, abstract PSMs
  http://herzberg.ca.sandia.gov/jess/
- Protégé-2000 Ontology/WME editor
  http://protege.stanford.edu/index.html
- IBROW Standards Classification Problem Solving
- FIPA Agent Standards
  http://www.fipa.org/specs/fipa00001/XC00001J.html#_Toc8186403
- Xippix ImagePump Software
  http://www.xippix.com/index.html
Tutor Architecture
Current Slide Authoring Tool

Authoring Tool Bar - freehand shapes and rectangles

Virtual Microscope Interface

History of previous fields

Current Location

Load new slide

Where should the student start?

Shape List and Authoring Tags

Save to Protégé Slide Representation

Shapes defined by polygons and incorporated into located observables

Current View: x=21760, y=0, scale: 1.0

IMAGE PATH: E:\images\20020703D002.tif

SLIDE NAME: 20020703D002

INIT SETTINGS:

CURRENT SHAPES:

- Polygon
- Boundary
- Authoring Tag

MESSAGES:

View change at 21760, 0, 1.0
View change at 22272, 0, 1.0
View change at 23296, 0, 1.0

SAVE TO KB

STATUS: Slide 20020703D002 has NOT been saved.
Demonstration

- Protégé-2000 Knowledge Base
- Slide Tutor Student Interface
- Slide Tutor Authoring Tool
Future Questions

- Is immediate feedback a good thing? Or should we let students make mistakes?
- What are the tradeoffs among expressiveness, validity, predictive value, and run-time speed of various student modeling options?
- What kinds of interventions help students learn faster?
- What kinds of interface metaphors and mechanisms foster a deep understanding of the process?
- Should we teach Pathology breadth-first, or depth-first?
- Do different students need different feedback?
Virtual Slide Set - Research

Goals

- Develop a web-based system for authoring and presenting virtual slides in case based context
- Support Medical School Courses that include a Pathology Component
- Create methods for individualization, personal preferences and different views of the data
- Integrate our system with existing Online educational system at University of Pittsburgh to give students a single gateway
- Iterative design, development and deployment across multiple courses
- Evaluate using traditional survey, observation, and log-file methods
Virtual Slide Set - Approach

- Case-based learning
- WWW – JVM - no other special needs
- Empty vessel for communication
- Use-neutral; applicable to many different educational settings
- Teach microscopic skills but in a clinical context
- Rich text – image annotation
Virtual Slide Set – System Design

Client

Applet

Web Server

Virtual Slide Servlet

Java Beans

ImagePump Servlet

ImagePump Server

Oracle DB Server
Relational Design

Table Design of Virtual Slides
Virtual Slide Set – Demonstration
Virtual Slide Set - Progress

- Host Defenses Course, 2002
  - Prototype system
  - Single Laboratory Session on Neoplasia
  - 72 MS-I students working in pairs on five cases
  - 74 MS-I students with microscopes seeing same five cases
  - Response universally enthusiastic

- GI Course, 2002
  - Presentation layer deployed
  - Cirrhosis Self Study Module
  - All students responsible for working through material on their own

- Neuroscience Course, February 2003
  - First expected use of authoring system with NS instructors
  - First expected use of Discover, Guide and Annotate preferences
Virtual Slide Set - Response

- Evaluation limited to a single course
- No significant differences between groups for confidence with identifying features, perceived effect on identifying questions or solidifying concepts in lecture
- Significant difference in students' predictions about reviewing cases as Vslides as opposed to traditional slides
- Many interesting and useful comments
  - "I didn’t have to waste my time focusing"
  - "Awesome. I can do it alone and when I feel like it"
  - "Annoying to use – would rather use a microscope. Difficult to watch screen and wait for image to adjust"
  - "Reviewing the material in a clinical case put the info in context"
- More complete evaluation planned using log file analyses, surveys and observation
Future Questions

- How do we integrate Virtual Slides into developing on-line educational resources?
- What do we need to do to get instructors with no expertise in IT or informatics to contribute their instructional content, create annotated slides, etc.?
- How do we make Vslide sites so that they can be individualized and used for multiple purposes, and in multiple contexts?
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- National Library of Medicine Training Grant T15-LM07059 (*empirical studies*)
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- Yukako Yagi, Pathology Informatics
- Charles Friedman, CBMI
- Michael Becich, Pathology Informatics