Protégé as Professor:
Development of an Intelligent Tutoring System With Protégé-2000

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Outline

• General requirements for a tutoring system in Pathology

• Practical aspects of Protégé integration into SlideTutor

• Further use of Protégé
Medical Training System Needs

- Large medical image libraries (VHL)
- Digital knowledge libraries (FMA)
- Knowledge structuring, sharing, utilizing to teach the decision-making process
- Very few good examples in medicine
- Reuse knowledge representation and acquisition in other fields: paradigms, methodology, ideas
- Create system that incorporates empirical knowledge and theories about how people learn
- Build system with reusable components
- Design adaptive, revisable system that can incorporate any new observations
Intelligent Tutoring System

- Systems that use AI formalisms to offer interactive computer-based instruction
- Represent and model knowledge
- Actively monitor and encode student’s progress through a problem/case, and/or across problems/cases
- Offer instruction and provide feedback that is adaptive, flexible, *individually tailored*
Intelligent Tutor System With Model Tracing

- Cognitive Tutor based on ACT-R theory of learning (Anderson, Corbett, and Koedinger)
  - **Expert Model** – problem solving and decision making cognitive domain
    - Declarative – “factual” knowledge
    - Procedural knowledge - how to do things
    - Proceduralized declarative knowledge in the rules (*step instructions*)
  - **Model Tracing** – every user action is checked against the Expert Model

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Intelligent Tutor System Structure

- 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 to intervene

Interface
- Canvas for problem solving
- Make goals visible

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Dermopathology as an ITS Domain

- 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
- Diagnosis more deterministic in Pathology when compared with other domains

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Dermopathology Domain

- Visual diagnostic
  - Use of the microscope
  - More precise, visual criteria for reasoning
  - Visual criteria depend on microscope power, can be hierarchically classified
Dermopathology Domain

- Visual diagnostic
- Study of expertise in microscopic diagnosis (Crowley et al., JAMIA 2003)
  - Identified reasoning steps, goals
  - Physical search, identification, hypothesis testing and refinement
  - Knowledge transformation from novice to expert
Dermopathology Domain

- Visual diagnostic
- Study of expertise in microscopic diagnosis
- Dermopathology domain algorithms
### Visual Features

- Few neutrophils and eosinophils
- Eosinophils in interstitium of reticular dermis in company with lymphocytes (usually in conjunction with interepidermal vesicle)

### Diagnosis

- Bullous pemphigoid
- Porphyria cutanea tarda
- Varicella zoster
- Lichen sclerosus et atrophicus
- Pemphigoid gestationis (one manifestation)
- Cicatricial pemphigoid
- Dermatitis herpetiformis
- Linear IgA dermatosis
- Acquired epidermolysis bullosa (one manifestation)
- Systemic lupus erythematosus
- Leukocytoclastic vasculitis
- Sarcoidosis
- Rheumatoid arthritis
- Sjögren's syndrome
- Acquired epidermolysis bullosa (one manifestation)
- Urticaria pigmentosa
- Bullous pemphigoid
- Herpes gestationis
- Acquired epidermolysis bullosa (one manifestation)
Medical Intelligent Tutoring Systems

(+) • Individualized instructional system
• Multiple paths for problem solving
• Multi-dimensional decision space
  – Expert, Student, and Pedagogic models

(-) • Large complex dynamic declarative knowledge
• Formalism of production rule knowledge representation is domain specific (N\times100 rules)
• Maintenance is difficult and time consuming
• Knowledge modification alters the rules
**SlideTutor Approach**

- Use KBS approach to separate static (declarative) and dynamic (procedural) knowledge

- Complicated domain structure exactly fits Protégé knowledge representation paradigm

- In KBS PSMs serve as its *reasoning part* that can be used by tutor procedural rule based expert system
SlideTutor Approach

- Protégé for declarative knowledge
- Jess Expert System as PSM base
- JessTab bridge (Eriksson, 2003), slightly modified
  - reflect hierarchical Protégé structure
  - work with multiple projects
- Separate abstract graph PMS algorithm and specific behaviour
Expert System KB Implementation

- Parametric design approach for classification problem solving (Motta, 1999):
  - find the solution class that best explains certain set of observables for unknown object
    - Solution = Domain KB - finite set of feature specifications
    - Observable = Case Representation - set of facts

- Extended
  - Redefined Feature to be an object with its own properties
    - Solution - \{f\{a \{v\}\}\}
    - Observable - (f, \{a, v\})
  - Added abstract Feature-Attribute-Value ontology
Feature Ontology

- Hierarchical Feature structure
- Feature – Attribute – Value independence
- Reused by Domain KB and Case Representation
Domain KB

- Hierarchical diseases representation with allowed multiple inheritance
- DISEASE has FEATURE_SPECIFICATIONs, built up from range of features, attributes and values – multiple disease paths
- FEATURE_SPECIFICATION can have any number of associated DISEASEs – multiple disease set for a particular path
- DISEASE can be extended by tests, UMLS content
- Reusable, not connected to any problem solving environment
Slide Representation

Visual Dimension

Feature Ontology

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Dynamic Solution Graph (DSG)

- Generates valid path through problem state based on combination of expert model ontologies, case and pedagogic knowledge within abstract PSM
- Dynamic – incremental problem state and valid next steps generation system
- DSG state depends on the order of input reasoning events
- Abstract, task-independent, allows any conceptually correct node, makes no decision
- Node type specific response to a triggered event encapsulated in the behavior structures
- DSG visualization (JGraph, www.jgraph.org)
Forward Reasoning and Negation

Graph View

Evidence Cluster

mucin

QUANTITY extensive

epidermolysis bullosa a...

dermatitis herpetiformis...

dermatitis herpetiformis

QUANTITY none

LOCATION reticular der...

linear IgA dermatosis

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Backwards Reasoning
Cluster Concept

- Evidence Cluster – integrated relation between the state of its elements and nodes outside the cluster
- Serves as disjunction element that forms the problem solving path
- Allows multiple pedagogic strategies for hypothesis formation:
  - Based on single piece of evidence
  - Consistent with all evidences
Protégé Advantages

- Redefine a knowledge role of shared procedures as a static knowledge
- Knowledge decomposition and inclusion (Feature, Domain and Case ontologies)
- Modularity and extensibility allows independent rules and models development
- Reusable domain for classification problem solving
- Domain neutral for many search - identification – interpretation reasoning systems
- More Protégé – more flexibility
Acknowledgements

- NLM 1 R01 LM007891-01 (Crowley, PI)
- Competitive Medical Research Fund of the University of Pittsburgh Office of Health Research (Crowley, PI)
- Rebecca Crowley, Pathology Informatics
- Katsura Fujita, Pathology Informatics
- Elizabeth Legowski, Pathology Informatics
- Ellen Roh, Dermatopathology
- Drazen Jukic, Dermatopathology