INFSCI 2480: Adaptive Information Systems

User Models
for Adaptive Hypermedia
and Adaptive Educational Systems

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<table>
<thead>
<tr>
<th></th>
<th>Search</th>
<th>Navigation</th>
<th>Recommendation</th>
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<td>Semantics / Metadata</td>
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<td>Social</td>
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Adaptive systems

Classic loop user modeling - adaptation in adaptive systems
Intelligent vs. Adaptive

1. Intelligent but not adaptive (no user model!)
2. Adaptive but not really intelligent
3. Intelligent and adaptive
3 Dimensions of User Models

- What is being modeled (nature)
- How this information is represented (structure)
- How the models are constructed and maintained

What is Being Modeled?

- User knowledge of the subject
- User interests
- User goals
- User background
- User individual traits
How to Model User Knowledge

• Scalar model
  – The user knowledge level is modeled as one value
  – Example: MetaDoc, CAT

• Structural model
  – What kind of knowledge?
    • Declarative, procedural, episodic
  – How it relates to expert knowledge?
    • Overlay model -> Bug mode -> Genetic model
Overlay Model of Knowledge

• Domain model
  – The whole body of domain knowledge is decomposed into set of smaller knowledge units
  – A set of concepts, topics, etc

• User knowledge model (aka student model)
  – Overlay of the Domain model
  – Student knowledge is measured independently for each knowledge unit
Vector vs. Network Domain Models

• Vector - no relationships

• Precedence (prerequisite) relationship

• is-a, part-of, analogy
  – Wescourt et al, 1977

• Genetic relationships
  – Goldstein, 1979

More power
Vector model
Network model

Concept 1

Concept 2

Concept 3

Concept 4

Concept N

Concept 5
Simple overlay model

Concept 1
   yes
Concept 2
   yes
Concept 3
   yes
Concept 4
   no
Concept N
   no
Concept 5
   no
Simple overlay model
Weighted overlay model

Concept 1
10

Concept 2
7

Concept 3
4

Concept 4
3

Concept N
0

Concept 5
2
Student Modeling Approaches

• Ad Hoc (1-100)
• Heuristic and rule-based (qualitative)
• Simple statistical (Bush, Atkinson)
• Probabilistic and Bayesian (BN, D-S…)
• Fuzzy
• Neural networks
• Combine approaches and layered models
How to do Course Sequencing

- Needs a Domain Model
- Uses classic or weighted overlay model
- Needs indexing of learning material with domain model
- May also need a learning goal (also based on domain model)
Indexing teaching material

• Types of indexing
  – One concept per ULM
  – Indexing of ULMs with concepts

• How to get the ULMs indexed?
  – Manual indexing (closed corpus)
  – Computer indexing (open corpus)
Simple case: one concept per learning activity

- Random selection if there are no links - Scholar
- Links can be used to restrict the order
MasteryGrids Interface:
one *topic* per learning activity
Indexing content with concepts

Concepts

Concept 1

Concept 2

Concept 3

Concept 4

Concept N

Concept 5

Examples

Example 1

Example 2

Example M

Problems

Problem 1

Problem 2

Problem K
Simple goal model

• Learning goal as a set of topics
More complicated models

- Sequence, stack, tree
Sequencing with models

- Given the state of UM and the current goal pick up the best topic or ULM within a subset of relevant ones (defined by links)
- Special cases with multi-topic indexing and several kinds of ULM
- Applying explicit pedagogical strategy to sequencing
Maintaining Overlay Models

• Adaptive educational systems use problems, questions, and other evaluation activities to model student knowledge

• If a page is read, an example is browsed, or a problem is solved, knowledge of all involved concepts increases (example: jWADEIn)
  – Links could be used to propagate knowledge

• If problem is not solved, the system needs to allocate “blame” for involved concepts
  – Links could be helpful to avoid noise
Models in SIETTE
Models for interactive problem-solving support and diagnosis

- Domain model
  - Concept model (same as for sequencing)
  - Bug model
  - Constraint model
- Student model
  - Generalized overlay model (works with bug model and constraint model too)
- Teaching material - feedback messages for bugs/constraints
Bug models

• Each concept/skill has a set of associated bugs/misconceptions and sub-optimal skills
• There are help/hint/remediation messages for bugs
Do we need bug models?

• Lots of works on bug models in the between 1974-1985

• Bugs has limited applicability
  – Problem solving feedback only. Sequencing does not take bugs into account: whatever misconceptions the student has - effectively we only can re-teach the same material
  – Short-term model: once corrected should disappear, so not necessary to keep
Constraint Model: SQL-Tutor

- Domain model: Set of constraints (procedural, evaluation knowledge); Student model: Bug model
Models for example-based problem solving support

• Need to represent problem-solving cases

• Episodic learner model
  – Every solution is decomposed on smaller components, but not concepts!
  – Keeping track what components were used and when - not an overlay!

• ELM-PE and ELM-ART - only systems that use this model
Multi-Aspect Models in ADAPTS - an adaptive IETM
What’s in adaptive content?

ADAPTS dynamically assembles custom-selected content.
<table>
<thead>
<tr>
<th>Concept</th>
<th>Principles of Operation</th>
<th>Removal Instructions</th>
<th>Testing Instructions</th>
<th>Illustrated Parts Breakdown</th>
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<tbody>
<tr>
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<td>Sonar Data Computer</td>
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<tr>
<td>Sonar System</td>
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User model

• Characterizes user ability at each element of the domain model
  – Size of model is bounded by domain
  – Weights on different types of elements account for learning styles and preferences
  – Can be time sensitive

• Constrains the diagnostic strategy
### User model example

<table>
<thead>
<tr>
<th>Concept</th>
<th>Role 1: Theory of Operation</th>
<th>Role 2: Removal Instructions</th>
<th>Role 3: Testing Instructions</th>
<th>Role 4: IPB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reeling Machine</td>
<td>Reviewed</td>
<td>Hands-on + Certified</td>
<td>Preferred</td>
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<tr>
<td>Sonar Data Computer</td>
<td>Simulation</td>
<td>Hands-on</td>
<td>Reviewed</td>
<td></td>
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<tr>
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<td>Certified</td>
<td>Hands-on</td>
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- **AT2 Smith**
- **AD2 Jones**
Adaptive content selection

• Information is custom-selected for a user
  – Level of detail offered depends upon who the user is (i.e., his level of expertise)
  – Selected at a highly granular level, e.g., for each step within a procedure

• Performance-oriented training is presented as part of content
Interest Modeling

- User interests are typically modeled by overlay models as well
- Keyword model of user interests (profile)
  - Learned about it in user profiling lecture
  - User profile is a *keyword overlay*
    - “sub-symbolic” model
- Concept-level model of user interests
  - Concept overlay
Domain Models

• A domain model is required for interest modeling
  – Traditional domain model for interest modeling in educational context
  – A taxonomy of interest areas for non-educational areas

Example:
Domain model for adaptive News system
Overlay Model of Interests

- For each domain concept or taxon an overlay model stores estimated level of interest
Benefits of Concept-Level Overlay Interest Modeling

• The ability to use formal ontologies
  – Developed for a range of reasons
  – Pushed by the Semantic Web

• Links allow spreading activation

• *Understandable* by the users
  – Could be initialized and edited by the users
  – Can be used for explaining personalization
Ontological Interest Modeling

- Interests are deduced from the content of “interesting documents”
- Needs manual or automatic document to ontology matching

Spreading Activation

- Evidence of user interests can be propagated along the links
- Spreading activation over the model may be used for more reliable modeling and to deal with sparsity

Initializing and editing models

• Concept-level models are *understandable* by end users since they appeal to their own conceptualization of the domain
• Users can initialize a model or edit it if she thinks that the system is not reflecting her interests
• Editing keyword-level models produces poor results (Ahn YourNews study)

Explanations

- The presence of concepts or topics allows to better explain why a specific item is recommended to the user.

Personalized access to scientific publications: from recommendation to explanation
Dario De Nart, Felice Ferrara, Carlo Tasso, 2013
Overlay model and content indexing

• The use of overlay models requires content to be related to domain concepts/topics, this is known as *content indexing*

• A range of indexing approaches exist in AH
  – Simplest case: Nodes *are* concepts
    • InterBook, ELM-ART, ISIS-Tutor
  – Indexing *nodes* with concepts
    • InterBook, ELM-ART, ISIS-Tutor, AHA
  – Indexing *fragments* with concepts
    • MetaDoc, AHA, PT
Generalized overlay models

• The overlay approach is quite generic, many aspects could be modeled as “generalized overlays”

• What has been learned so far
  – Knowledge modeling with overlays
    • Domain model - network of concepts
    • User model – weighed overlay of the domain model indicating concept knowledge
  – Interest modeling with overlays
    • Domain model – topic ontology
    • User model – overlay of the ontology indicating topic interests
Generalized overlay model for user goals and stereotypes

- **Goals**
  - Domain model: a set of possible goals, tree of goals
  - User model: on overlay of this set/tree showing probabilities that the user has one of these goals

- **Stereotypes**
  - Domain Model: a set or a taxonomy of user stereotypes
  - User model: on overlay of this DM showing probabilities that the user belongs to one of these stereotypes
Indexing with generalized model

• goals are nodes
  – HYPERFLEX
• content fragments are indexed with goals
  – PUSH
• nodes are indexed with user’s tasks
  – HYNECOSUM:
• nodes are indexed with stereotypes
  – EPIAIM, Anatom-Tutor, C-Book