INFSCI 2480: Adaptive Information Systems

User Models for Adaptive Hypermedia and Adaptive Educational Systems

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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

Intelligent ES \( \bigcap \) Adaptive ES
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

Concept 1
Concept 2
Concept 3
Concept 4
Concept 5
Concept N
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

- Concept 1
  - yes
  - yes

- Concept 2
  - yes
  - yes

- Concept 3
  - yes

- Concept 4
  - no
  - no

- Concept N
  - no

- Concept 5
  - no
Weighted overlay model
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
Indexing content with concepts
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.

Troubleshooting step plus hypermedia support information, custom-selected for a specific technician within a specific work context.
## Domain model example

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>Principles of Operation</th>
<th>Removal Instructions</th>
<th>Testing Instructions</th>
<th>Illustrated Parts Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reeling Machine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonar Data Computer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonar System</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

CONCEPT
Reeling Machine
- Reviewed
- Hands-on
- Reviewed

CONCEPT
Sonar Data Computer
- Simulation
- Hands-on
- Hands-on + Certified
- Preference
- Reviewed

CONCEPT
Sonar System
- Certified
- Hands-on
- Reviewed

ROLE
Theory of Operation
- AT2 Smith
- AD2 Jones

ROLE
Removal Instructions
- AT2 Smith
- AD2 Jones

ROLE
Testing Instructions
- AT2 Smith
- AD2 Jones

ROLE
IPB
- 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 they think that the system is not reflecting their 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.
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