INFSCI 2480: Adaptive Information Systems

Adaptive Navigation Support

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Where we are?

<table>
<thead>
<tr>
<th></th>
<th>Search</th>
<th>Navigation</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content-based</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semantics / Metadata</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A Part of Adaptive Hypermedia

• Hypermedia = Pages + Links

• Adaptive presentation
  – content adaptation

• Adaptive navigation support
  – link adaptation
Adaptive hypermedia technologies

Adaptive presentation

Adaptive navigation support

Adaptive multimedia presentation

Adaptive text presentation

Adaptation of modality

Canned text adaptation

Direct guidance

Adaptive link sorting

Hiding

Adaptive link hiding

Disabling

Adaptive link annotation

Removal

Adaptive link generation

Map adaptation

Inserting/removing fragments

Altering fragments

Stretchtext

Sorting fragments

Dimming fragments

Canned text adaptation

Natural language adaptation
Adaptive navigation support: goals

- **Guidance: Where I can go?**
  - Local guidance ("next best")
  - Global guidance ("ultimate goal")

- **Orientation: Where am I?**
  - Local orientation support (local area)
  - Global orientation support (whole hyperspace)
Adaptive navigation support

• Direct guidance
• Restricting access
  – Removing, disabling, hiding
• Sorting
• Annotation
• Generation
  – Similarity-based, interest-based
• Map adaptation techniques
Example: Adaptive annotation

1. Concept role
2. Current concept state
3. Current section state
4. Linked sections state
What can be adapted: links

- Contextual links (“real hypertext”)
- Local non-contextual links
- Index pages
- Table of contents
- Links on local map
- Links on global map
## Link types and technologies

<table>
<thead>
<tr>
<th></th>
<th>Direct guidance</th>
<th>Sorting</th>
<th>Hiding</th>
<th>Annotation</th>
<th>Map adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextual links</td>
<td>OK</td>
<td></td>
<td>(disabling)</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>Non-contextual links</td>
<td>OK</td>
<td>OK</td>
<td>?</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>Table of contents</td>
<td>OK</td>
<td></td>
<td>?</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>OK</td>
<td></td>
<td>?</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>Local map</td>
<td>OK</td>
<td></td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Global map</td>
<td>OK</td>
<td></td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
</tbody>
</table>
Some Popular ANS Mechanisms

• Relevance-based navigation support
  – Expresses link relevance to user interests
  – Mechanism is similar to adaptive search, but interface is different

• Prerequisite-based navigation support

• Progress-based navigation support

• A mechanism is different from an interface
  – Same mechanism, different presentation
Relevance-based navigation support

- **Sorting**
  - HYPERFLEX, 1993
- **Annotation (icons)**
  - Siskill & Webert 1996
- **Annotation (font)**
  - ScentTrails 2003
- **Annotation (icons) + Sorting**
  - YourNews, 2007
Evaluation of Relevance-based AND using sorting

- HYPERFLEX: IR System
  - adaptation to user search goal
  - adaptation to “personal cognitive map”
- Number of visited nodes decreased (significant)
- Correctness increased (not significant)
- Goal adaptation is more effective
- No significant difference for time/topic
Syskill & Webert vs. ScentTrails

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Content-Based Link Annotation in YourNews
InterBook: Prerequisite-based navigation in ET

• “Knowledge behind pages”
• Structured electronic textbook (a tree of “sections”)
• Sections indexed by domain concepts
  – Outcome concepts
  – Background concepts
• Concepts are externalized as glossary entries
• Shows educational status of concepts and pages
Sections and concepts

Textbook

Chapter 1

Section 1.1

Section 1.2

Section 1.2.1

Section 1,2,2

Chapter 2
Sections and concepts

Domain model

- Concept 1
- Concept 2
- Concept 3
- Concept n
- Concept m

Textbook

- Chapter 1
  - Section 1.1
    - Section 1.2.1
    - Section 1,2,2
  - Section 1.2
- Chapter 2
Indexing and navigation
3.1.3 The annotated textbook

To make the textbook "more intelligent" and to connect it to the glossary, we have to let the system know what about each section of the textbook is. It is done by indexing the textbook sections by domain model concepts. For each unit, a list of concepts related with this unit is provided (we call this list spectrum of the unit). For each involved concept, the spectrum of the unit can represent also the role of the concept in the unit. Currently we support two roles: each concept can be either an outcome concept or a background concept. A concept is included in the spectrum as an outcome concept if some part of this page presents the piece of knowledge designated by the concept. A concept is included into the spectrum as a prerequisite concept if a student has to know this concept to understand the content of the page. Indexing is a relatively simple but powerful mechanism, because it provides the system with knowledge about the content of its pages: the system knows which concepts are presented on each page and which concepts have to be learned before starting to learn each page. It opens a way for several adaptation techniques.
Glossary view

Action

The action is the part of the production which specifies the changes to the goal and other actions to take should the production fire.

This concept is introduced on these pages:
- 1.1.2 Production Rules in ACT-R
- 1.6.2. The Action Side of Productions
- Action

Knowledge about this concept is required for:
- 1.1.3 Production Rule Format
- 1.1.5 ACT-R's Action Side
- Section 1.6: Writing Productions
- 1.6.3. Tutor Exercises on Writing Productions
- Section 1.7: Creating a Production System
- 1.7.2. Example Production with Goals
- 2.1.3. The Top Level Rule
Navigation in InterBook

- Regular navigation
  - Linear (Continue/Back)
  - Tree navigation (Ancestors/Brothers)
  - Table of contents

- Concept-based navigation
  - Glossary (concept -> section)
  - Concept bar (section -> concept)
  - Hypertext links (section -> concept)
Adaptive navigation support

• Adaptive annotations
  – Links to sections
  – Links to concepts
  – Pages

• Adaptive sorting
  – Background help

• Direct guidance (course sequencing)
  – Teach Me
User modeling

• Overlay student model for domain concepts
• Knowledge states for each concept
  – unknown (never seen)
  – known (visited some page)
  – learned (passed a test)
• Information for sections
  – visited/not visited
  – time spent
• Information for tests: last answers
Adaptive annotation

• Educational status for concept
  unknown
  ✔ known
  ✔ learned

• Educational status for sections
  ✗ not ready to be learned
  ✔ ready to be learned
  ◉ suggested
Adaptive annotation in InterBook

1. State of concepts (unknown, known, ..., learned)
2. State of current section (ready, not ready, nothing new)
3. States of sections behind the links (as above + visited)
Backward learning: “help” and “teach this”
ELM-ART: Lisp ITS on WWW

- Model: adaptive electronic textbook
  - hierarchical textbook
  - tests
  - examples
  - problems
  - programming laboratory

- Navigation Support
  - Uses both progress-based and prerequisite-based navigation support
ELM-ART: Navigation Support

All tasks in the last exercises were solved correctly. However, you should work at some more tasks.

Exercises

Is the character string a number?
-6.0e+4

- Yes
- No

Is the character string a number?
1

- Yes
- No
### Learner Model:

<table>
<thead>
<tr>
<th>Page</th>
<th>Link-Status</th>
<th>% learned</th>
<th>User Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Datatypes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atoms (exercises solved)</td>
<td>The system suggests to work at this section.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-Atom (with exercises)</td>
<td>You successfully worked at this page.</td>
<td>100 %</td>
<td>already known</td>
</tr>
<tr>
<td><strong>Numbers</strong> (with exercises)</td>
<td>The system assumes the content of this page is known to you already.</td>
<td></td>
<td>already known</td>
</tr>
<tr>
<td>Lists (exercises solved)</td>
<td>You successfully worked at this page.</td>
<td>100 %</td>
<td>already known</td>
</tr>
<tr>
<td>Nested Lists (exercises solved)</td>
<td>You successfully worked at this page.</td>
<td>100 %</td>
<td>already known</td>
</tr>
<tr>
<td>Empty List, NIL, and T (with exercises)</td>
<td>The system suggests to work at this page.</td>
<td>0 %</td>
<td>already known</td>
</tr>
<tr>
<td>Tests on Data Types</td>
<td>Working at this page is not yet recommended.</td>
<td>0 %</td>
<td>already known</td>
</tr>
</tbody>
</table>

[Back to current page (Datatypes)]
Effects of Prerequisite ANS

- Reduces navigation efforts
- Reduces repetitive visits to presentation and problem pages
- Educational goal achieved faster
- Increases learning outcome
- Adaptive annotation encourage non-sequential navigation
- Make system more attractive for students
Where is the Magic?

- No magic: Knowledge behind material
- Knowledge about domain (subject)
- Knowledge about documents
  - Simple concept indexing
- Knowledge about students
  - Learning goal model
  - Overlay student model
- Straightforward techniques of user modeling and adaptation
Adaptive Hypertext: The Secret

- Adaptive hypertext has knowledge “behind” the pages
- A network of pages like a regular hypertext plus a network of concepts connected to pages
Hyperspace structuring

- Concept-based hyperspace
- No imposed structure
- Hierarchy
- ASK approach - conversational relationships
Progress-Based Mechanism

• The idea of the mechanism to express the progress of user knowledge/experience
  – With domain concepts
  – With content pages

• Possible interfaces
  – Removing links to well-known concepts (AHA)
  – Annotating links to concepts and pages (InterBook, Inspire, QuizGuide, NavEx)
Progress-Based Hiding

• Adaptive course on Hypertext (De Bra)
• Hiding “not ready” links
• Hiding obsolete links to support content
• Small-scale evaluation
• No significant differences
• Students are not comfortable with disappearing links
Progress-Based Annotation
What Size of “concept”? 

• How much domain knowledge should a concept cover? 
• Two practical approaches 
  • Topic-based student modeling 
    – Large topics, one per ULM/page 
  • Concept-based student modeling 
    – Small concepts, many per ULM/page
Topic-based Student Modeling

• Benefits
  – Easier for students and teachers to grasp
  – Easier for teachers to index content
  – Clear interface for presentation of progress

• Shortcomings
  – The user model is too coarse-grained
  – Precision of user modeling is low
Topic-Based ANS: QuizGuide

Question 1

```c
main()
{
    int i = 0;
    if (7 % 2)
        i *= 2;
    else
        i++;
}
```

What is the final value of `i`

`i = ________`
QuizGuide: Topic-level Adaptive Annotations

- Target-arrow abstraction:
  - Number of arrows – level of knowledge for the specific topic (from 0 to 3). *Individual, event-based adaptation.*

- Color Intensity – learning goal (current, prerequisite for current, not-relevant, not-ready). *Group, time-based adaptation.*

- loops (while)
  - Quiz1
  - Quiz2

- increment decrement

- compound assignments
  - Quiz1

- logical expressions
  - Quiz1

- loops (do while)
  - Quiz1
  - Quiz2

- conditionals (if else)
QuizGuide: Influence on Motivation

- Adaptive navigation support increased student's activity and persistence of using the system.

- Within the same class QuizGuide session were much longer than QuizPACK sessions: 24 vs. 14 question attempts at average.

- Average Knowledge Gain for the class rose from 5.1 to 6.5.
QuizGuide: Success Rate Increase

- One-way ANOVA shows that mean success value for QuizGuide with ANS is significantly larger than:
  $F(1, 43) = 5.07$ (p-value = 0.03).
A Deeper Look
Concept-based Student Modeling

• Benefits
  – The user model is fine-grained
  – Precision of user modeling is good

• Shortcomings
  – Harder for students and teachers to grasp
  – Harder for teachers to index content
  – Presentation of progress is harder to integrate into the system interface
Concept-Based ANS: NavEx

Example 3.3

```c
#include <stdio.h>

main()
{
    float interest_rate; /*
    interest rate in percents */
    int capital; /*
    This is a preprocessor command. System
    header file stdio.h will be inserted there during
```
Indexing Examples in NavEx

• Concepts derived from language constructs
  – C-code parser (based on UNIX lex & yacc)
  – 51 concepts totally (include, void, main_func, decl_var, etc)

• Ask teacher to assign examples to lectures
  – Use a subsetting approach to divide extracted concepts into prerequisite and outcome concepts
Increased Motivation

- The increase of the amount of work for the course
ANS vs Recommendations

• Relevance-based ANS vs. recommendations
  – Same engine, different interface
  – In-context guidance vs. ranked list

• More sophisticated ANS vs. recommendations
  – ANS can display simultaneously several aspects of importance/interest/relevance
  – Ranking used in recommendation approaches can only display only one dimension