Adaptive Educational Hypermedia: From Generation to Generation

Peter Brusilovsky
School of Information Sciences
University of Pittsburgh, USA

From Generation to Generation

UM  HT  ITS
WWW  1G AEH
WBE  2G AEH
3G AEH

Classic Adaptive Educational Hypermedia
Web-based Adaptive Educational Hypermedia
“Real World” Adaptive Educational Hypermedia

TALER Lab, University of Pittsburgh
**Personal View**

- InterBook, CMU (1996-1998)
- COCOA, CTE (1999-2000)
- COCOA, CTE (1999-2000)
- InterBook, CMU (1996-1998)
- ITEM/IP, MSU (1986-1994)
- TALER Lab projects (2000-2004)

---

**Why Adaptive Hypermedia?**

Hypermedia systems are flexible but ...

✓ Different people are different
✓ Individuals are different at different times
✓ "Lost in hyperspace"

We may need to make hypermedia adaptive where ..

⇒ There us a large variety of users
⇒ Same user may need a different treatment
⇒ The hyperspace is relatively large
So, where we may need AH?

- Educational Hypermedia
  - Hypadapter, Anatom-Tutor, ISIS-Tutor, Manuel Excell, ELM-ART, InterBook, AHA

- On-line Information systems
  - MetaDoc, KN-AHS, PUSH, HYPERFLEX

- On-line Help Systems
  - EPIAIM, HyPLAN, LISP-Critic, ORIMUHS

---

Generation 0

- UM
- HT
- ITS
- WWW
- 1G AEH, Classic Adaptive Educational Hypermedia
- WBE
- 2G AEH, Web-based Adaptive Educational Hypermedia
- 3G AEH, “Real World” Adaptive Educational Hypermedia
Personal View: Generation 0

ITEM/IP, MSU (1986-1994)

ISIS-Tutor, MSU (1992-1994)


ITEM/IP

ITEM/IP

ILE for Introductory Programming

Integrated system

Tutorial (presentation of optimal sequence of explanations, examples and problems)

Environment (playing with examples, design and debug problem solutions)

Manual (a manual for reference-style access to studied information, examples, solved problems)

TALE Lab, University of Pittsburgh
Knowledge and learning material

Concepts
- Concept 1
- Concept 2
- Concept 3
- Concept 4
- Concept N

Examples
- Example 1
- Example 2
- Example M

Problems
- Problem 1
- Problem 2
- Problem K

Weighted overlay model

- Concept 1
- Concept 2
- Concept 3
- Concept 4
- Concept N

- Weighted scores: 10, 7, 4, 3, 2
Course Sequencing

- Oldest ITS technology
  - SCHOLAR, BIP, GCAI...
- Goal: individualized
  - “best” sequence of educational activities
- ITEM/IP: multi-type
  - information to read
  - examples to explore
  - problems to solve ...

Sequencing in ITEM/IP

- Teacher’s role:
  - Defining a sequence of learning goals
Adaptive presentation

- Goal: make the same “page” suitable for students with different knowledge
  - beginners (in tutorial mode)
  - advanced (in manual mode)
  - smooth transition
- Methods to achieve the goals
  - comparisons of several concepts
  - extra explanations for beginners
  - more complete information for advanced

---

Conditional text filtering

- Similar to UNIX cpp
- Universal technology
  - Altering fragments
  - Extra explanation
  - Extra details
  - Comparisons
- Low level technology
  - Text programming

<table>
<thead>
<tr>
<th>Condition</th>
<th>Fragment</th>
</tr>
</thead>
<tbody>
<tr>
<td>If switch is known and user_motivation is high</td>
<td>Fragment 1</td>
</tr>
<tr>
<td></td>
<td>Fragment 2</td>
</tr>
<tr>
<td></td>
<td>Fragment K</td>
</tr>
</tbody>
</table>
Problems

- A category of students wanted to make the choice of next thing to do themselves
- Combining guidance and freedom?
- Added menu-based access to new material
- Two information spaces with separate access...
  - Explored material (past)
  - New material (future)
- And in 1991 we have found hypertext...

Origins of Adaptive Educational Hypermedia

- Intelligent Tutoring Systems
- Hypermedia Systems
- Adaptive Educational Hypermedia Systems
Early Adaptive Hypermedia

Annotations for topic states in Manuel Excell: not seen (white lens); partially seen (grey lens); and completed (black lens)

TALER Lab, University of Pittsburgh

Generation 1

UM  HT  ITS

WWW  1G AEH

WBE  2G AEH

3G AEH

Classic Adaptive Educational Hypermedia

Web-based Adaptive Educational Hypermedia

“Real World” Adaptive Educational Hypermedia

TALER Lab, University of Pittsburgh
Adaptive systems

Classic loop “user modeling - adaptation” in adaptive systems

What can be taken into account?

- Knowledge about the content and the system
- Short-term and long-term goals
- Interests
- Navigation / action history
- User category, background, profession, language, capabilities
- Platform, bandwidth, context...

TALER Lab, University of Pittsburgh
What Can Be Adapted?

- Hypermedia = Pages + Links
- Adaptive presentation
  - content adaptation
- Adaptive navigation support
  - link adaptation

Adaptive Presentation: Goals

- Provide the different content for users with different knowledge, goals, background
- Provide additional material for some categories of users
  - comparisons
  - extra explanations
  - details
- Remove irrelevant piece of content
- Sort fragments - most relevant first
Adaptive Presentation Techniques

- Conditional text filtering
  - ITEM/IP
- Adaptive stretchtext
  - MetaDoc, KN-AHS
- Frame-based adaptation
  - Hypadapter, EPIAIM
- Natural language generation
  - PEBA-II, ILEX

Adaptive Stretchtext (PUSH)
Example: Stretchtext (ADAPTS)

Adaptive Presentation: Evaluation

- MetaDoc: On-line documentation system, adapting to user knowledge on the subject
- Reading comprehension time decreased
- Understanding increased for novices
- No effect for navigation time, number of nodes visited, number of operations
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: Techniques

- Direct guidance
- Restricting access
  - Removing, disabling, hiding
- Sorting
- Annotation
- Generation
  - Similarity-based, interest-based
- Map adaptation techniques
Personal View: Generation 1


ISIS-Tutor: ILE + hypertext

- An adaptive tutorial for CDS/ISIS/M users
- Domain knowledge: concepts and constructs
- Hypertext - a way to access learning material:
  - Description of concepts and constructs
  - Examples and problems indexed with concepts (could be used in an exploratory environment)
- Educational status of explanations, examples and problems is shown with link annotation

TALER Lab, University of Pittsburgh
Knowledge and learning material

Student modeling and adaptation

- States for concepts:
  - not ready (may be hidden)
  - ready (red)
  - known (green)
  - learned (green and ‘+’)

- State for problems/examples:
  - not ready (may be hidden)
  - ready (red)
  - solved (green and ‘+’)

TALER Lab, University of Pittsburgh
### Sample index page (annotation)

<table>
<thead>
<tr>
<th>Page Title</th>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Общий вид формулы</td>
<td>2. Арифметические выражения</td>
</tr>
<tr>
<td></td>
<td>3. Удаление пустых строк</td>
<td>4. Безусловный переход на новую строк</td>
</tr>
<tr>
<td></td>
<td>5. Переход на новую строк</td>
<td>6. Выбор позиции в строке</td>
</tr>
<tr>
<td></td>
<td>7. Печать позиций</td>
<td>8. Вывод поля</td>
</tr>
<tr>
<td></td>
<td>9. Начало MFL</td>
<td>10. Вычисление интервала</td>
</tr>
<tr>
<td></td>
<td>11. Арифметическая функция L</td>
<td>12. Арифметическая функция MFu</td>
</tr>
<tr>
<td></td>
<td>13. Арифметическая функция Val</td>
<td>14. Арифметическая функция Яв</td>
</tr>
<tr>
<td></td>
<td>15. Арифметическая функция Мах</td>
<td>16. Арифметическая функция Мах</td>
</tr>
<tr>
<td></td>
<td>17. Арифметическая функция Ян</td>
<td>18. Сложение X и Y</td>
</tr>
<tr>
<td></td>
<td>19. Бинарное / и T</td>
<td>20. Сложение интервала</td>
</tr>
<tr>
<td></td>
<td>21. Повторяющийся интервал</td>
<td>22. Выход MFL</td>
</tr>
<tr>
<td></td>
<td>23. Сложение выражения</td>
<td>24. Пустые значения интервала</td>
</tr>
<tr>
<td></td>
<td>25. Сложение интервал</td>
<td>26. Начало интервала</td>
</tr>
<tr>
<td></td>
<td>27. Сложение интервал с +</td>
<td>28. Установка режима вывода</td>
</tr>
<tr>
<td></td>
<td>29. Установка режима вывода</td>
<td>30. Сложение значений интервалов с +</td>
</tr>
<tr>
<td></td>
<td>31. Сложение значений интервалов с X</td>
<td>32. Сложение значений интервалов с X</td>
</tr>
<tr>
<td></td>
<td>33. Сложение значений интервалов с C</td>
<td>34. Сложение значений интервалов с C</td>
</tr>
<tr>
<td></td>
<td>35. Сложение значений интервалов с M</td>
<td>36. Режим L,U в команде M</td>
</tr>
<tr>
<td></td>
<td>37. Режим L в команде M</td>
<td>38. Режим U в команде M</td>
</tr>
<tr>
<td></td>
<td>39. Режим U в команде M</td>
<td>40. Строковая функция F</td>
</tr>
<tr>
<td></td>
<td>41. Строковая Функция N</td>
<td>42. Строковая Функция S</td>
</tr>
<tr>
<td></td>
<td>43. Программа пользователя формат</td>
<td>44. Выражение отношения</td>
</tr>
<tr>
<td></td>
<td>45. Установка режима вывода</td>
<td></td>
</tr>
</tbody>
</table>

### Sample index page (annotation and hiding)

<table>
<thead>
<tr>
<th>Page Title</th>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Общий вид формулы</td>
<td>2. Арифметические выражения</td>
</tr>
<tr>
<td></td>
<td>3. Удаление пустых строк</td>
<td>4. Безусловный переход на новую строк</td>
</tr>
<tr>
<td></td>
<td>5. Переход на новую строк</td>
<td>6. Выбор позиции в строке</td>
</tr>
<tr>
<td></td>
<td>7. Печать позиций</td>
<td>8. Вывод поля</td>
</tr>
<tr>
<td></td>
<td>9. Начало MFL</td>
<td>10. Вычисление интервала</td>
</tr>
<tr>
<td></td>
<td>11. Арифметическая функция L</td>
<td>12. Арифметическая функция MFu</td>
</tr>
<tr>
<td></td>
<td>13. Арифметическая функция Val</td>
<td>14. Арифметическая функция Яв</td>
</tr>
<tr>
<td></td>
<td>15. Арифметическая функция Мах</td>
<td>16. Арифметическая функция Мах</td>
</tr>
<tr>
<td></td>
<td>17. Арифметическая функция Ян</td>
<td>18. Сложение X и Y</td>
</tr>
<tr>
<td></td>
<td>19. Бинарное / и T</td>
<td>20. Сложение интервала</td>
</tr>
<tr>
<td></td>
<td>21. Повторяющийся интервал</td>
<td>22. Выход MFL</td>
</tr>
<tr>
<td></td>
<td>23. Сложение выражения</td>
<td>24. Пустые значения интервала</td>
</tr>
<tr>
<td></td>
<td>25. Сложение интервал</td>
<td>26. Начало интервала</td>
</tr>
<tr>
<td></td>
<td>27. Сложение интервал с +</td>
<td>28. Установка режима вывода</td>
</tr>
<tr>
<td></td>
<td>29. Установка режима вывода</td>
<td>30. Сложение значений интервалов с +</td>
</tr>
<tr>
<td></td>
<td>31. Сложение значений интервалов с X</td>
<td>32. Сложение значений интервалов с X</td>
</tr>
<tr>
<td></td>
<td>33. Сложение значений интервалов с C</td>
<td>34. Сложение значений интервалов с C</td>
</tr>
<tr>
<td></td>
<td>35. Сложение значений интервалов с M</td>
<td>36. Режим L,U в команде M</td>
</tr>
<tr>
<td></td>
<td>37. Режим L в команде M</td>
<td>38. Режим U в команде M</td>
</tr>
<tr>
<td></td>
<td>39. Режим U в команде M</td>
<td>40. Строковая функция F</td>
</tr>
<tr>
<td></td>
<td>41. Строковая Функция N</td>
<td>42. Строковая Функция S</td>
</tr>
<tr>
<td></td>
<td>43. Программа пользователя формат</td>
<td>44. Выражение отношения</td>
</tr>
<tr>
<td></td>
<td>45. Установка режима вывода</td>
<td></td>
</tr>
</tbody>
</table>

**TALER Lab, University of Pittsburgh**
ISIS-Tutor: Evaluation

- 26 first year CS students of MSU
- 3 groups:
  - control (no adaptation)
  - adaptive annotation
  - adaptive annotation + hiding
- Goal: 10 concepts (of 64), 10 problems, all examples

ISIS-Tutor: Evaluation Results

- The students are able to achieve the same educational goal almost twice as faster
- The number of node visits (navigation overhead) decreased twice
- The number of attempts per problem to be solved decreased almost 4 times (from 7.7 to 1.4-1.8)
THM1: It works!

- Adaptive presentation makes user to understand the content faster and better
- Adaptive navigation support reduces navigation efforts and allows the users to get to the right place at the right time
- Altogether AH techniques can significantly improve the effectiveness of hypertext and hypermedia systems

THM2: AH as “best of both worlds”

- The Artificial Intelligent approach: machine intelligence makes a decision for a human
  - Adaptive NL generation, sequencing
- The HCI approach: human intelligence is empowered to make a decision
  - Classic stretchtext and hypertext
- Adaptive hypermedia: human intelligence and AI collaborate in making a decision
Similar works 1991-1994

- γπAdaptρ (Hohl, Böker, Gunzenhäuser, 1991)
  - Sorting page fragments and links by relevance
- Manuel Excel (de La Passardiére, Dufresne, 1992)
  - Adaptive link annotation with icons
- ANATOM-Tutor (Beaumont, 1994)
  - Adaptive presentation, hypertext + ITS
- MetaDoc (Boyle, Encarnacion, 1994)
  - Adaptive stretchtext

Generation 2

[Diagram showing a tree structure with nodes labeled UM, HT, ITS, WWW, WBE, 1G AEH, 2G AEH, 3G AEH, Classic Adaptive Educational Hypermedia, Web-based Adaptive Educational Hypermedia, “Real World” Adaptive Educational Hypermedia]
Generation 2 vs Generation 1

- Generation 1 systems:
  - Research oriented
  - Traditional hypertext/hypermedia
  - Developed independently

- Generation 2 systems
  - Practically oriented
  - Web-based hypermedia
  - Influenced by earlier research
  - Less value on evaluation

Personal View: Generation 2

ITEM/IP, MSU (1986-1994)

ISIS-Tutor, MSU (1992-1994)
ITEM/IPG, MSU (1991-1993)


ELM-ART, Trier (1994-1997)

InterBook, CMU (1996-1998)


COCOA, CTE (1999-2000)

TALE Lab projects (2000-2004)
ELM-ART: Lisp ITS on WWW

- ELM-ART:
  - ELM-PE (ILE with problem solving support)
  - Adaptive Hypermedia (all educational material)
- Model: adaptive electronic textbook
  - tests
  - examples
  - problems

Knowledge representation

- Domain knowledge
  - conceptual network for Lisp
  - problem solving plans
  - debugging knowledge
- Student model
  - Overlay model for Lisp concepts
  - Episodic model for problem-solving knowledge
ELM-ART: Adaptive Textbook

- Electronic Textbook
  - Intelligent, adaptive, interactive
- Adaptive navigation support
- Adaptive sequencing (pages and questions)
- Adaptive similarity-based navigation
- Adaptive selection of relevant examples
- Intelligent program diagnosis
- Open student modeling

Adaptive navigation support
Adaptive Diagnostics

Similarity-Based Navigation
ELM-ART: Evaluation

- No formal classroom study
- Users provided their experience
- Drop-out evaluation technology
- 33 subjects
  - visited more than 5 pages
  - have no experience with Lisp
  - did not finish lesson 3
  - 14/19 with/without programming experience
ELM-ART: Evaluation Results

- Users with no previous programming and Web experience worked twice as long if adaptive guidance was provided. No effect of adaptive annotation.
- Users with starting programming and Web experience worked twice as long if adaptive annotation was provided. No effect of adaptive guidance.

InterBook: a Shell for AET

- “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
Knowledge and hyperspace

Domain model

Textbook

Concept 1

Concept 4

Concept n

Chapter 1

Chapter 2

Section 1.1

Section 1.2

Section 1.2.1

Section 1.2.2

Concept 2

Concept m

Concept 3

Concept n

3.1.3 The annotated textbook

To make the textbook "more intelligent" and to connect it to the
processes, we have to let the system know what 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 the
unit is provided (we call this list "concept - 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 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
- 

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: Test Exercises on Writing Productions
- Section 1.7: Creating a Production System
- 1.7.3: Example Production with Goal
- 2.1.3: The Top Level Rule

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)
Goal-directed learning: “help” and “teach this”

InterBook: Evaluation

- Goal: to find a value of adaptive annotation
- Electronic textbook about ClarisWorks
- 25 undergraduate teacher education students
- 2 groups: with/without adaptive annotation
- Format: exploring + testing knowledge
- Full action protocol
InterBook Evaluation Results

- No performance difference between groups
- About 90% of clicks were made with sequential navigation buttons
- Adaptive annotation encourages non-sequential navigation
- Adaptive annotation benefits those who use it as expected

Adaptive annotation can:

- Reduce navigation efforts
- Reduce repetitive visits to learning items
- Encourage non-sequential navigation
- Make system more attractive for students
- But we still need to understand better
  - When it is helpful
  - How to match functionality to students
THM3: AH is not a Silver Bullet

- Myth: AH is an alternative to user-centered design. No need to study the user - we will adapt to everyone.
- The truth:
  - AH is a powerful HCI tool - as mouse, visualization, VR.
  - We need to study our users and apply all usual range of usability techniques - we just have one more tool to use in our repository.

---

THM3: AH is not a Silver Bullet

- Myth: Just plug AH in and it will work.
- The truth:
  - Most AH techniques are “non-prescriptive” - the user retains freedom.
  - To benefit from AH the users should understand how AH works and collaborate with the system towards achieving her goal.

---

TALER Lab, University of Pittsburgh
Other Generation 2 AEHS

- ELM-ART stream: Exploring new approaches and techniques
  - AHA!, INSPIRE, MetaLinks, MANIC
- InterBook stream: Creating authoring frameworks and tools
  - Frameworks:
    - KBS-HyperBook, Multibook
  - Authoring Tools:
    - AHA!, NetCoach, MetaLinks

MetaLinks (Murray)
Metalinks

- Related links
- Custom depth control
- Narrative smoothing
- No effect of smoothing!
- Good narration...

AHA! (De Bra)

---

TALER Lab, University of Pittsburgh
AHA!

Hypermedia structures and systems
author: Prof. Dr. P.M.E. De Bruijne

Welcome to the hypermedia course at the Eindhoven University of Technology. This course combines the following, just necessarily:
- Introduction to hypermedia
- Basics of hypermedia
- The evolution of hypermedia

You are advised to read the material in this textbook. You can set your preferences to study the course material before described in the sections below:
- Introduction to hypermedia
- Basics of hypermedia
- The evolution of hypermedia

KBS-HyperBook (Nejdl, Henze)
INSPIRE (Grigoriadou, Papanikolaou, Kornilakis, Magoulas)

NetCoach (Weber)
Generation 3

- UM
- HT
- ITS
- WWW
- 1G AEH
- 2G AEH
- 3G AEH

Classic Adaptive Educational Hypermedia
Web-based Adaptive Educational Hypermedia
“Real World” Adaptive Educational Hypermedia

Practical E-Learning

- Integrated Course Management Systems
  - Blackboard, WebCT, ...
- Support almost all aspects of E-Learning
  - Course material presentation
  - Assessment with quizzes
  - Threaded discussions
  - Student management and grading
- “MS Word”-style all-in-one tool for WBE
Adaptive E-Learning?

- Adaptive E-Learning systems can provide a more advanced support for most functions
  - Course material presentation - InterBook, AHA
  - Assessment with quizzes - SIETTE
  - Threaded discussions - help agents
  - Student management - intelligent monitoring

- Why they are rarely used in practical E-Learning?

Practical Adaptive E-Learning

- Model 1: Adapting to current E-Learning Paradigm - CMS
- More versatile adaptive systems
- An ability to integrate open corpus content
- Improving CMS content
- Giving more power to the teacher
  - Customize the system to specific course and material
Emerging E-Learning

- Interoperability and standards
  - IEEE CMI, SCORM
- Semantics and metadata
  - LOM
- Component-based architectures
  - OKI, uPortal
- Resource reusability
- Distributed learning content
- Semantic Web

Practical Adaptive E-Learning

- Model 2: Embedding adaptivity into emerging E-Learning
- Use of current interoperability standards (SCORM, LOM)
- Developing new interoperability architectures
- Resource discovery
- The use of Semantic Web
Personal View: Generation 3

- InterBook, CMU (1996-1998)
- COCOA, CTE (1999-2000)
- TALER Lab projects (2000-2004)

CoCoA - Static Sequencing

- Many contributors for a single course
- Almost impossible to keep the course consistent without special tool
- Courseware engineering: From course authoring in small to course authoring in large
- CoCoA - Static sequencing
  - Prerequisite checking
  - Goal focusing
  - Learning activity balance
Open Corpus Adaptive Hypermedia

- Classic AH - Closed Corpus of pre-processed content
- Integrate Open Corpus content
- Bringing open corpus content in by indexing
  - KBS-HyperBook, SIGUE
- Processing open corpus content without manual indexing
  - Knowledge Sea
Knowledge Sea Map
Map Interface

Keywords related to documents inside the cell

Lecture Notes (landmarks)

Cell Content Interface

Indicator of the position of the current cell in the map
SANS within a book

Knowledge Tee Architecture

Portal
Activity Server
Value-added Service
Student Modeling Server

TALER Lab, University of Pittsburgh
KnowledgeTree Portal

AnnotatED Service
QuizGuide value-added service

NavEx Value-added Service
More information...

- Adaptive Hypertext and Hypermedia Home Page: http://wwwis.win.tue.nl/ah/