Adaptive Educational Hypermedia: From Generation to Generation
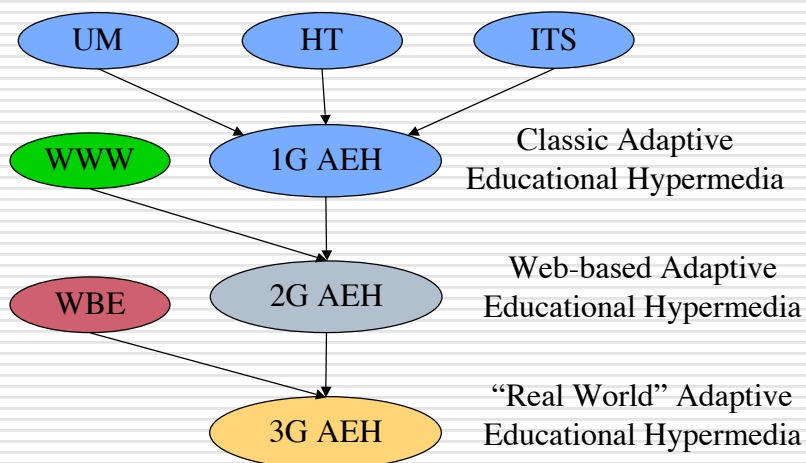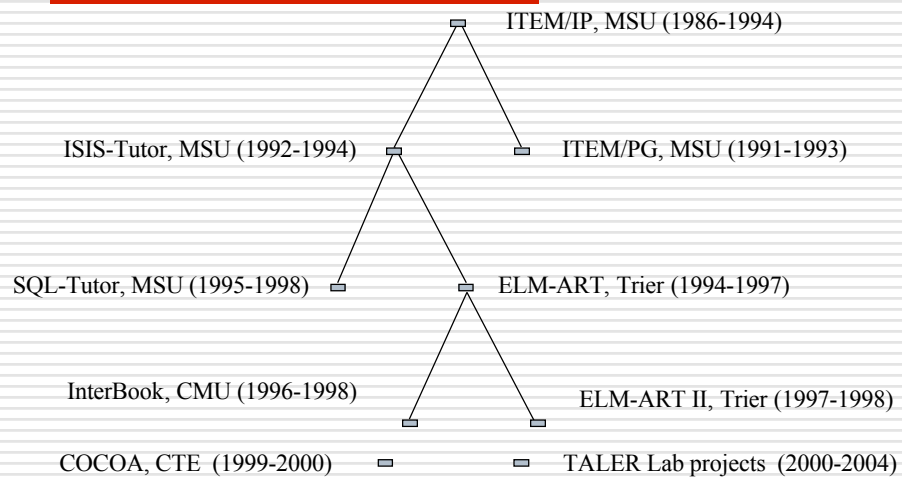
Peter Brusilovsky

School of Information Sciences

University of Pittsburgh, USA

From Generation to Generation

UM   HT   ITS

WWW   1G AEH   Classic Adaptive Educational Hypermedia

WBE   2G AEH   Web-based Adaptive Educational Hypermedia

3G AEH   "Real World" Adaptive Educational Hypermedia

Personal View

ITEM/IP, MSU (1986-1994)

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

SQL-Tutor, MSU (1995-1998) ELM-ART, Trier (1994-1997)

InterBook, CMU (1996-1998) ELM-ART II, Trier (1997-1998)

COCOA, CTE (1999-2000) 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
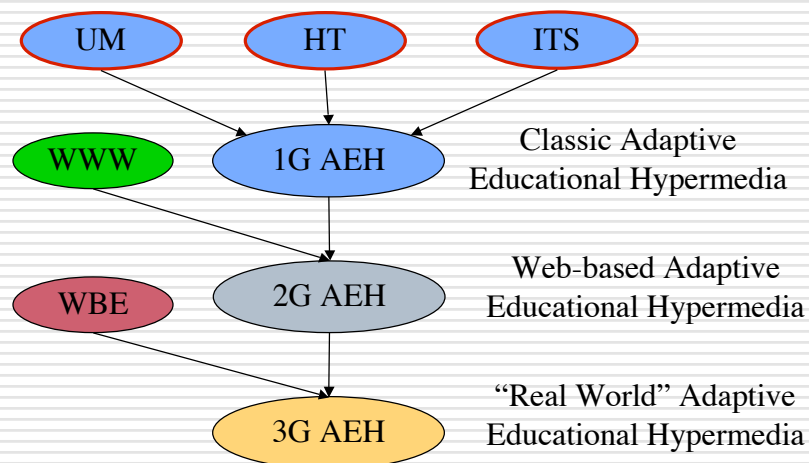- ⇨ The hyperspace is relatively large

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
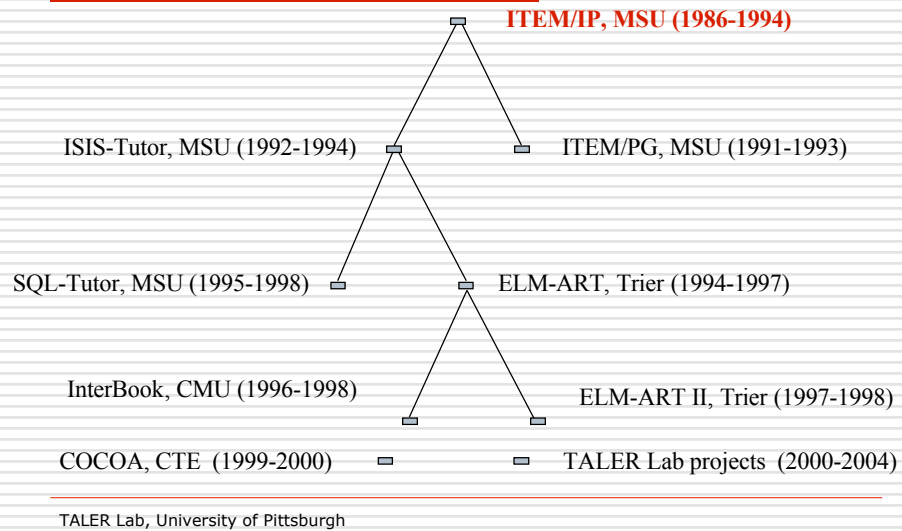 - EPIAIM, HyPLAN, LISP-Critic, ORIMUHS

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

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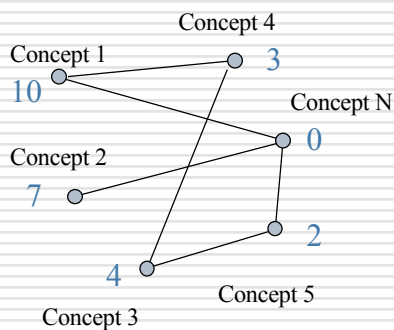COCOA, CTE (1999-2000)   TALER Lab projects (2000-2004)

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)

Knowledge and learning material

Concepts   Examples

Example 1

Concept 4

Concept 1

Example 2   Example M

Concept N

Problems

Concept 2

Problem 1

Concept 5

Problem 2   Problem K

Concept 3
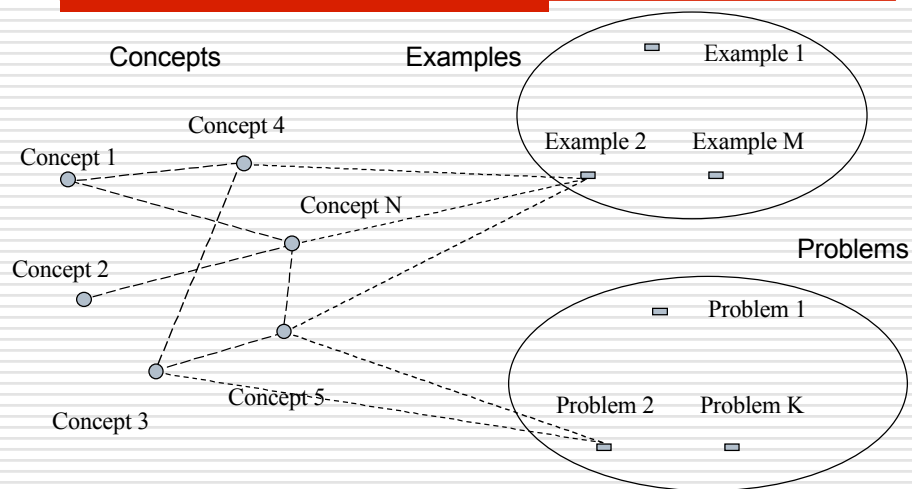
Weighted overlay model

Concept 4

Concept 1
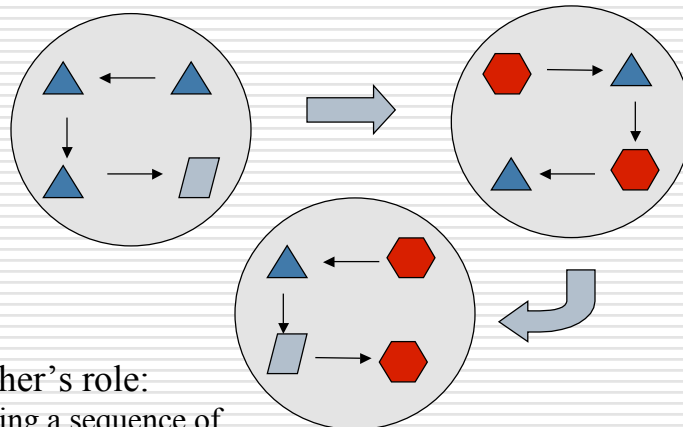
3

10

Concept N

0

Concept 2

7

2

4

Concept 5

Concept 3

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 ...
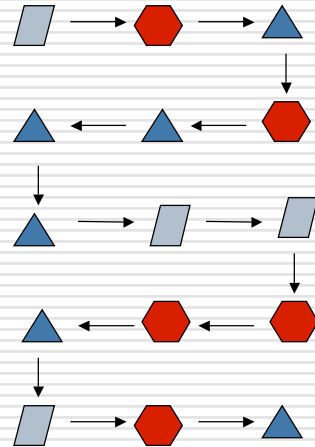
Sequencing in ITEM/IP

- • 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

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Conditional text filtering

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

If switch is known and user_motivation is high

Fragment 1

Fragment 2

Fragment K

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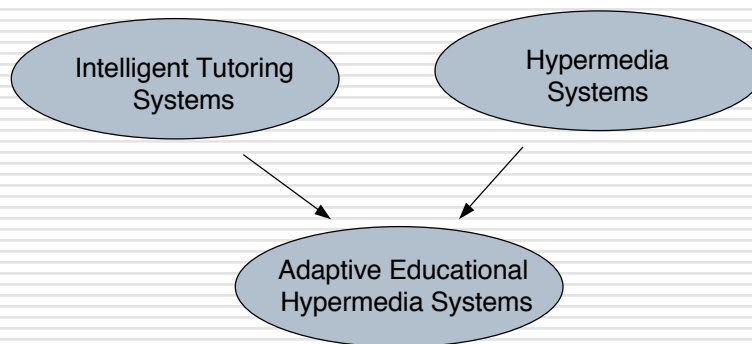
Early Adaptive Hypermedia
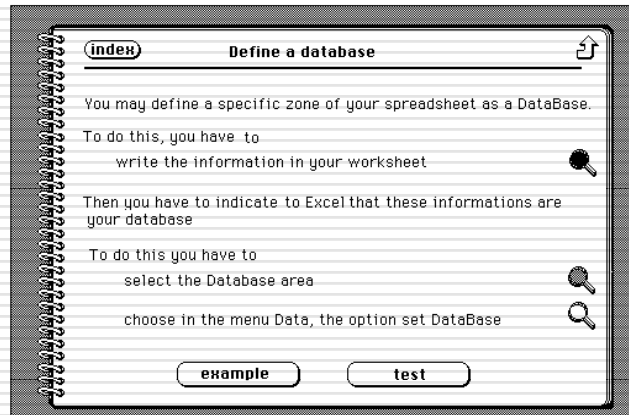
Annotations for topic states in *Manuel Excell*: not seen (white lens) ;
partially seen (grey lens) ; and completed (black lens)

Generation 1

Adaptive systems

Collects information about individual user

User Modeling side

Adaptive System

User Model

Adaptation side

Provides adaptation effect

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…

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

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Adaptive Stretchtext (PUSH)

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Example: Stretchtext (ADAPTS)
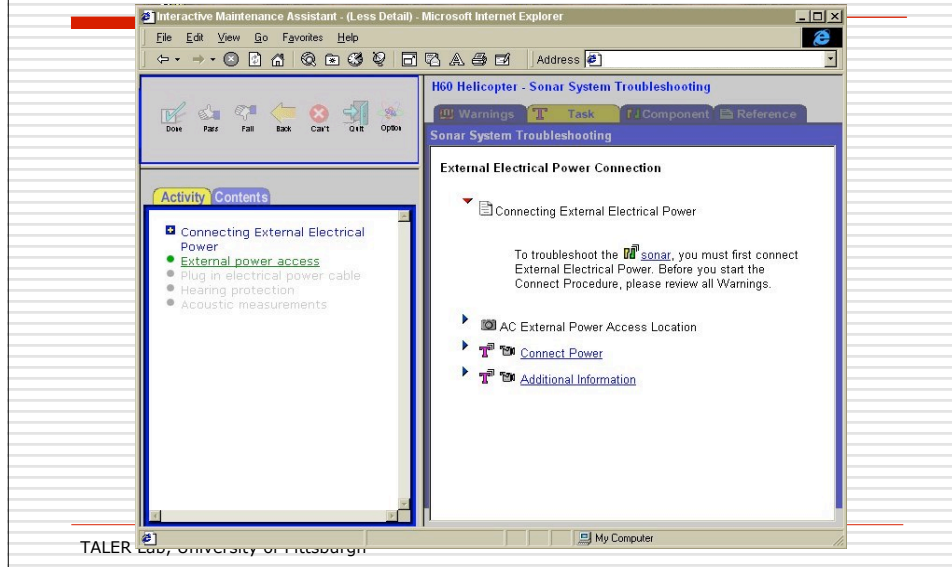
Adaptive Presentation: Evaluation

☐ 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)
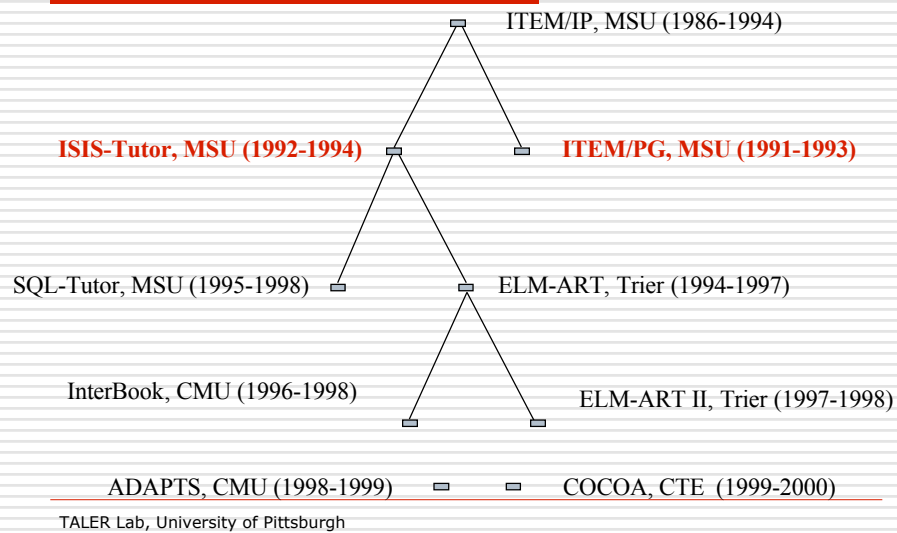- Global orientation support (whole hyperspace)

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

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

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InterBook, CMU (1996-1998)   ELM-ART II, Trier (1997-1998)

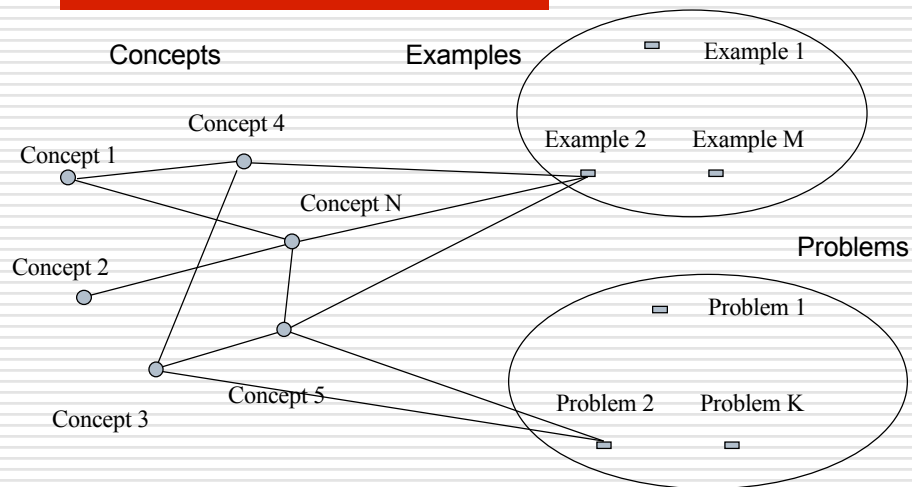ADAPTS, CMU (1998-1999)   COCOA, CTE (1999-2000)

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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

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Knowledge and learning material

Concepts   Examples   Example 1

Concept 4

Concept 1   Example 2   Example M

Concept N

Concept 2   Problems

Concept 5   Problem 1

Concept 3   Problem 2   Problem K

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 '+')

Sample index page (annotation)

Sample index page (annotation and hiding)

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
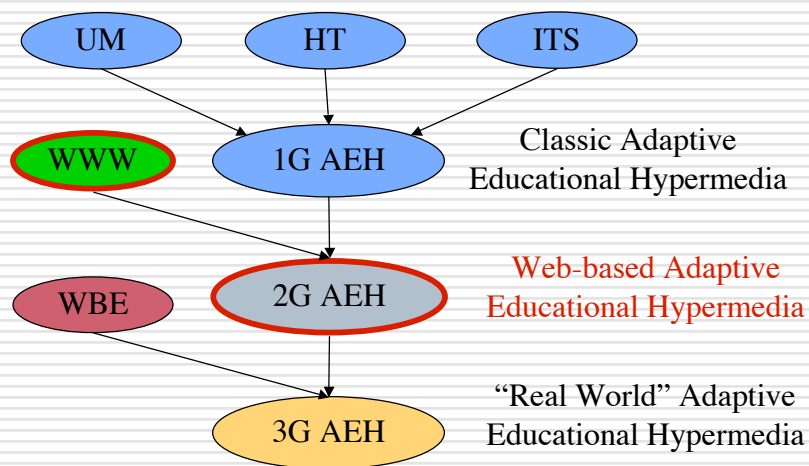- ☐ Adaptive hypermedia: human intelligence and AI collaborate in making a decision

Similar works 1991-1994

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

Generation 2

UM   HT   ITS

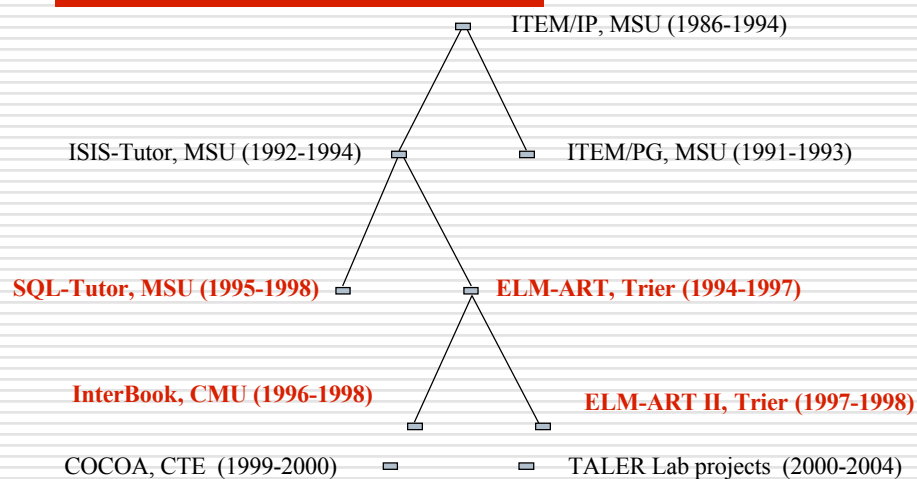WWW   1G AEH   Classic Adaptive Educational Hypermedia

WBE   2G AEH   Web-based Adaptive Educational Hypermedia

3G AEH   "Real World" Adaptive Educational Hypermedia

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

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SQL-Tutor, MSU (1995-1998)   **ELM-ART, Trier (1994-1997)**

InterBook, CMU (1996-1998)   **ELM-ART II, Trier (1997-1998)**

COCOA, CTE (1999-2000)   TALER 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

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Similarity-Based Navigation

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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

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ELM-ART: Evaluation Results

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

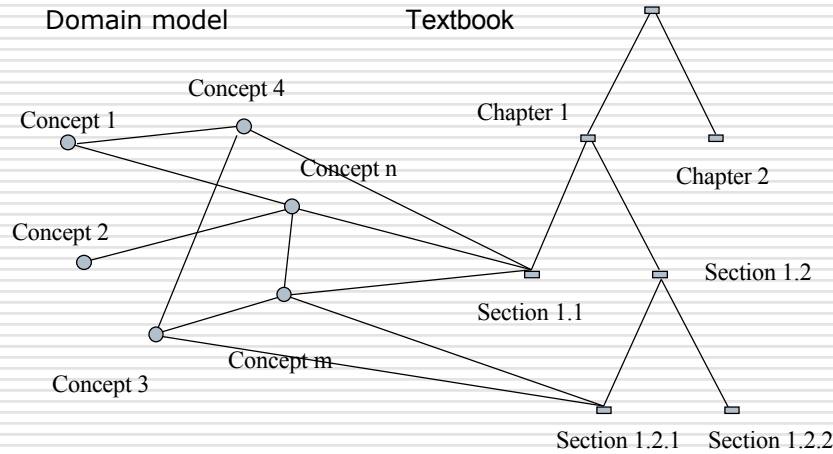- ☐ Users with starting programming and Web experience worked twice as longer if adaptive annotation was provided. No effect of adaptive guidance.

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 4

Concept 1

Chapter 1

Concept n

Chapter 2

Concept 2

Section 1.2

Section 1.1

Concept m

Concept 3

Section 1.2.1   Section 1.2.2

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Netscape: InterBook User and Author Manual

Back | Forward | Home | Reload | Images | Open | Print | Find | Stop

InterBook User and Author Manual
- 3. Interbooks: InterBook-served electronic textbooks
  - 3.1 Content structuring
    - 3.1.3 The annotated textbook

Content | Glossary | Help | Search | Hint

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.

Continue | Teach me

Background:

concept
domain model
glossary
section

Outcome:

background concept
outcome concept
spectrum

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Glossary view
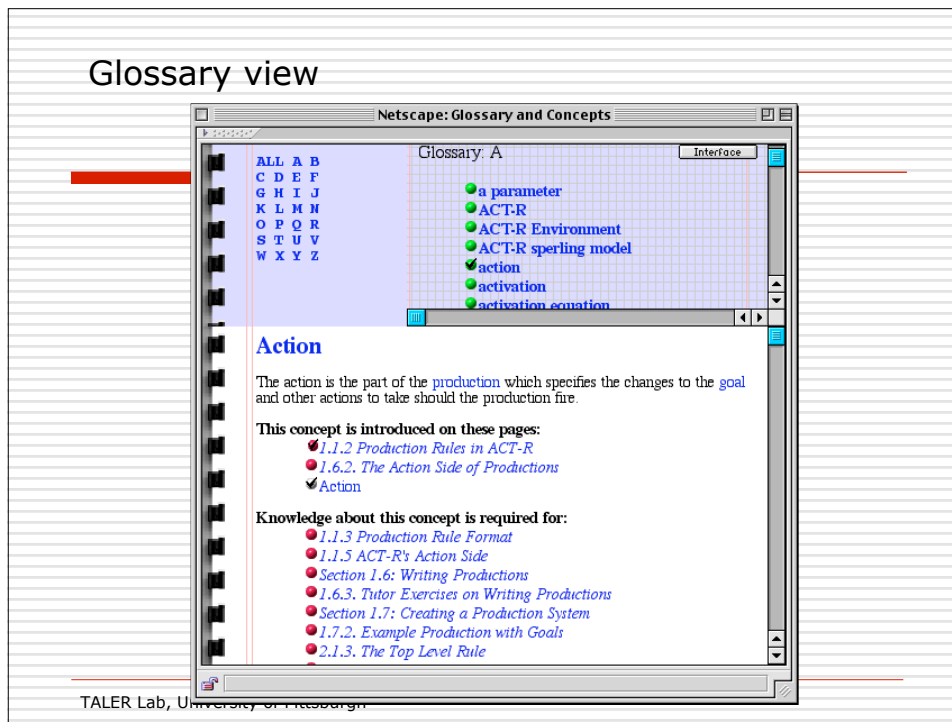
Adaptive annotation in InterBook
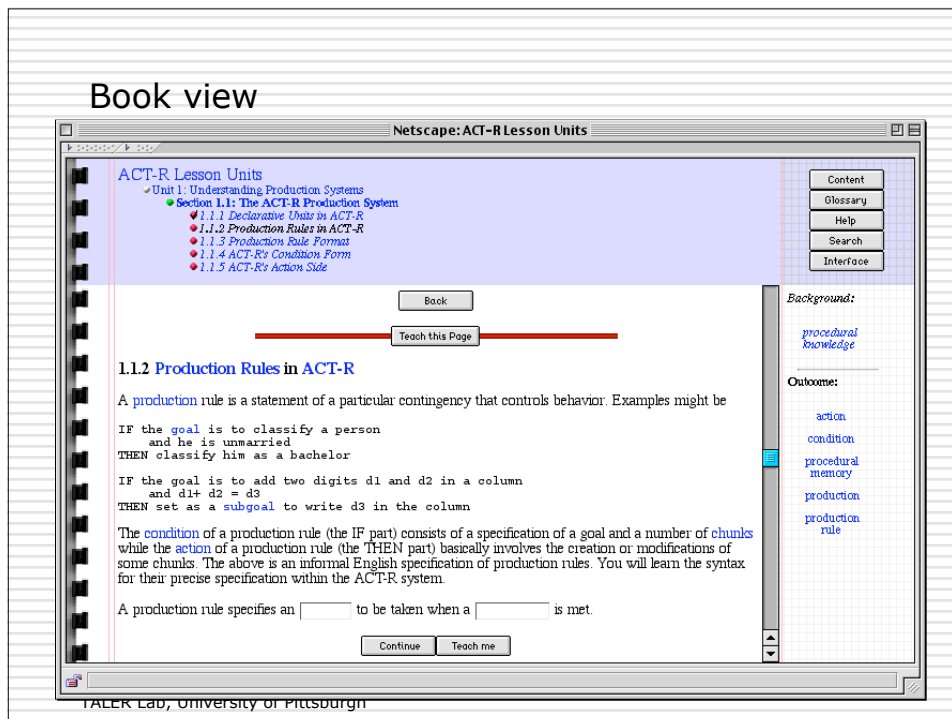

1. State of concepts (unknown, known, ..., learned)
2. State of current section (ready, not ready, nothing new)
3. States of sections behind the links (as above + visited)

Bookshelves and books

Interface

Books on this site:
ACT-R Shelf
- ACT-R Lesson Units
- ACT-R 4.0A Users Manual
- ACT-R Environment

InterBook Shelf
- InterBook User and Author Manual
- How to publish your Electronic Book on the Web with InterBook
- World-Wide Intelligent Textbooks

Claris Works Shelf
- The Database

ACT-R Lesson Units
- Unit 1: Understanding Production Systems
  - **Section 1.1: The ACT-R Production System**
    - *1.1.1 Declarative Units in ACT-R*
    - *1.1.2 Production Rules in ACT-R*
    - *1.1.3 Production Rule Format*
    - *1.1.4 ACT-R's Condition Form*
    - *1.1.5 ACT-R's Action Side*
  - **Section 1.2: The Count Example**
  - *Section 1.3: The Addition Example*
  - **Section 1.4: The Semantic Example**
  - **Section 1.5: Creating Declarative Structure**
  - *Section 1.6: Writing Productions*
  - *Section 1.7: Creating a Production System*
- Unit 2: Knowledge Representation in ACT-R
- Unit 3: Parameters and Conflict Resolution
- **Unit 4: Activation and Latency**
- *Unit 5: Partial Matching and Accuracy*

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Book view

ACT-R Lesson Units

- Unit 1: Understanding Production Systems
  - **Section 1.1: The ACT-R Production System**
    - *1.1.1 Declarative Units in ACT-R*
    - *1.1.2 Production Rules in ACT-R*
    - *1.1.3 Production Rule Format*
    - *1.1.4 ACT-R's Condition Form*
    - *1.1.5 ACT-R's Action Side*

Content
Glossary
Help
Search
Interface

Back

Teach this Page

1.1.2 Production Rules in ACT-R

A production rule is a statement of a particular contingency that controls behavior. Examples might be

```
IF the goal is to classify a person
   and he is unmarried
THEN classify him as a bachelor

IF the goal is to add two digits d1 and d2 in a column
   and d1+ d2 = d3
THEN set as a subgoal to write d3 in the column
```

The condition of a production rule (the IF part) consists of a specification of a goal and a number of chunks while the action of a production rule (the THEN part) basically involves the creation or modifications of some chunks. The above is an informal English specification of production rules. You will learn the syntax for their precise specification within the ACT-R system.

A production rule specifies an [____] to be taken when a [____] is met.

Continue   Teach me

Background:

procedural knowledge

Outcome:

action
condition
procedural memory
production
production rule

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Goal-directed learning: "help" and "teach this"

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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

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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

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...

Explain more

Next

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AHA! (De Bra)

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AHA!

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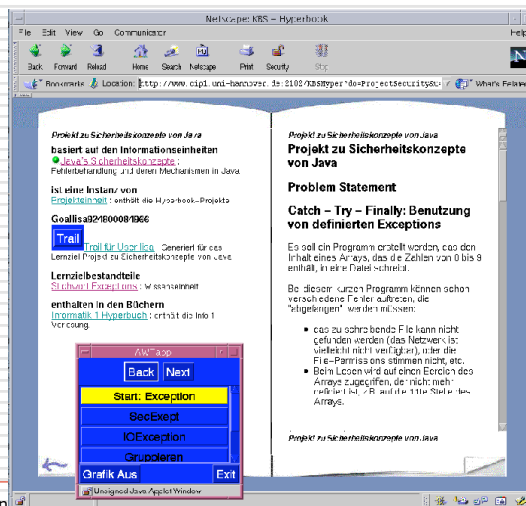
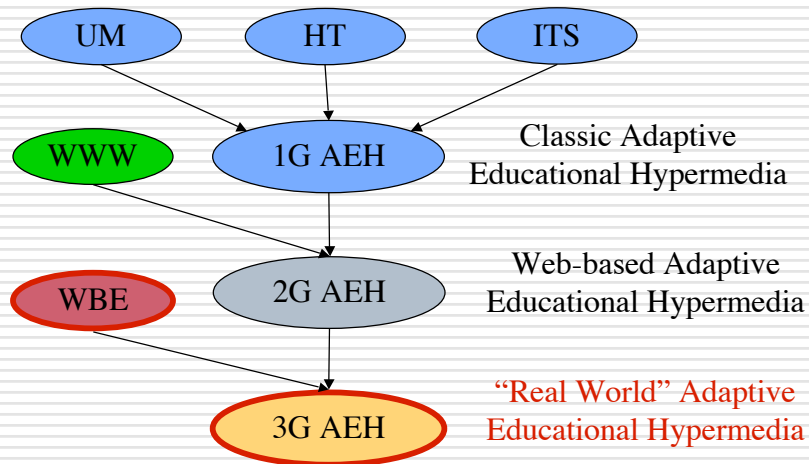# INSPIRE (Grigoriadou, Papanikolaou, Kornilakis, Magoulas)

NetCoach (Weber)

Generation 3

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Educational Hypermedia

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Educational Hypermedia
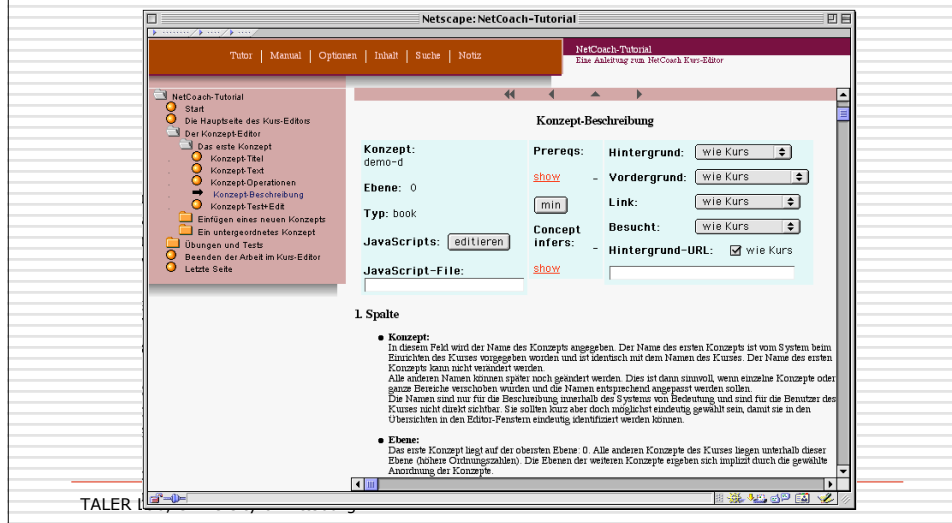
Practical E-Learning

☐ 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
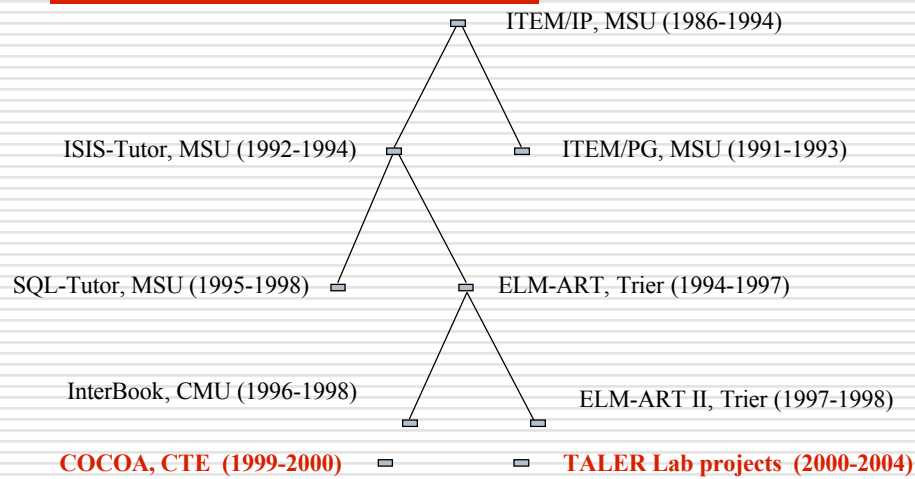- ☐ Distributed learning content
- ☐ Semantic Web

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

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SQL-Tutor, MSU (1995-1998)   ELM-ART, Trier (1994-1997)

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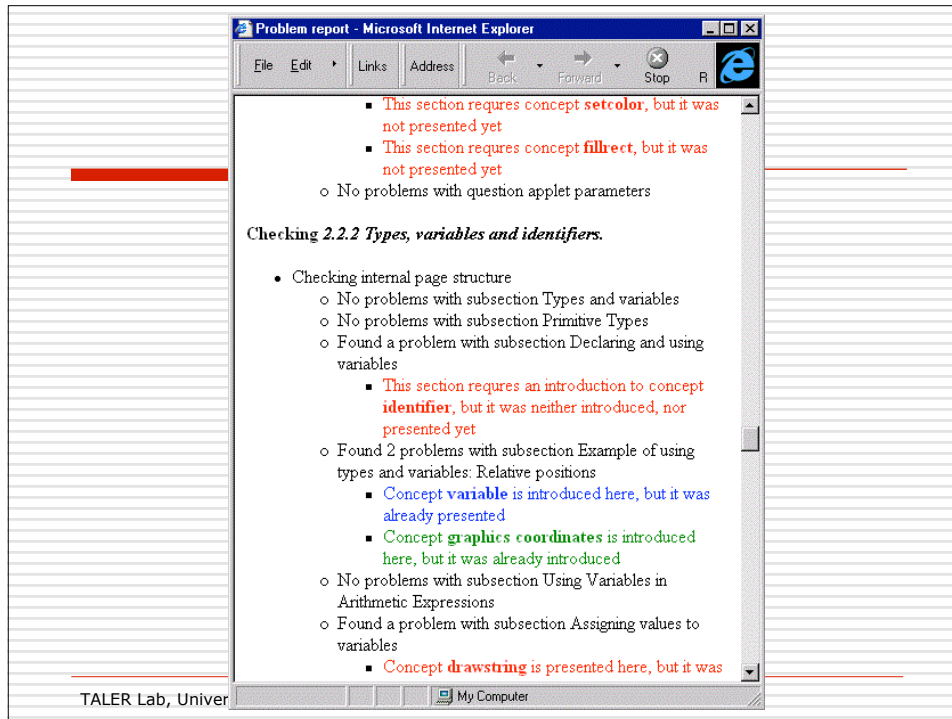
COCOA, CTE (1999-2000)   **TALER Lab projects (2000-2004)**

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
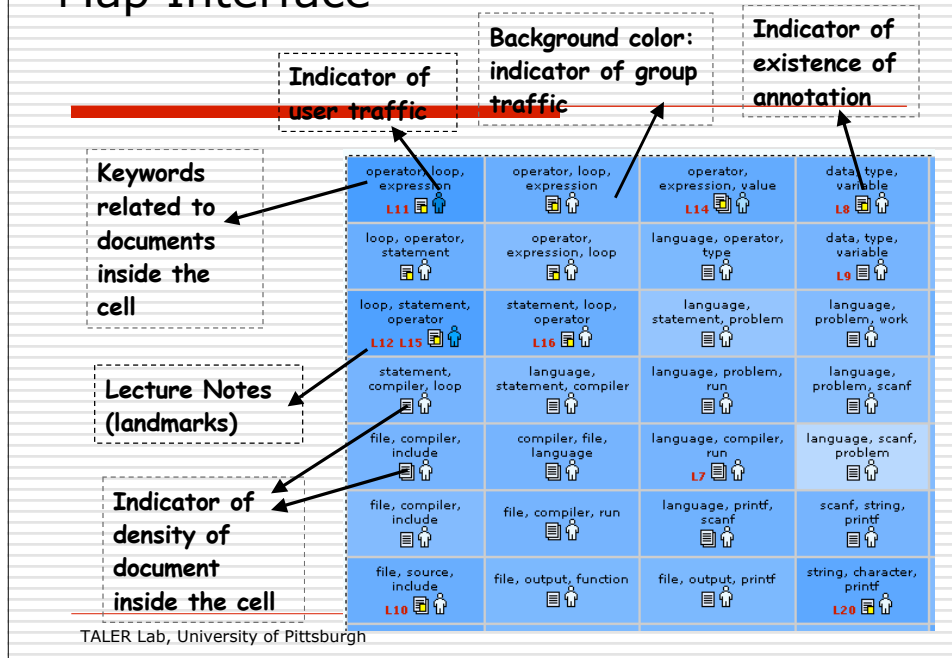- ☐ Processing open corpus content without manual idexing
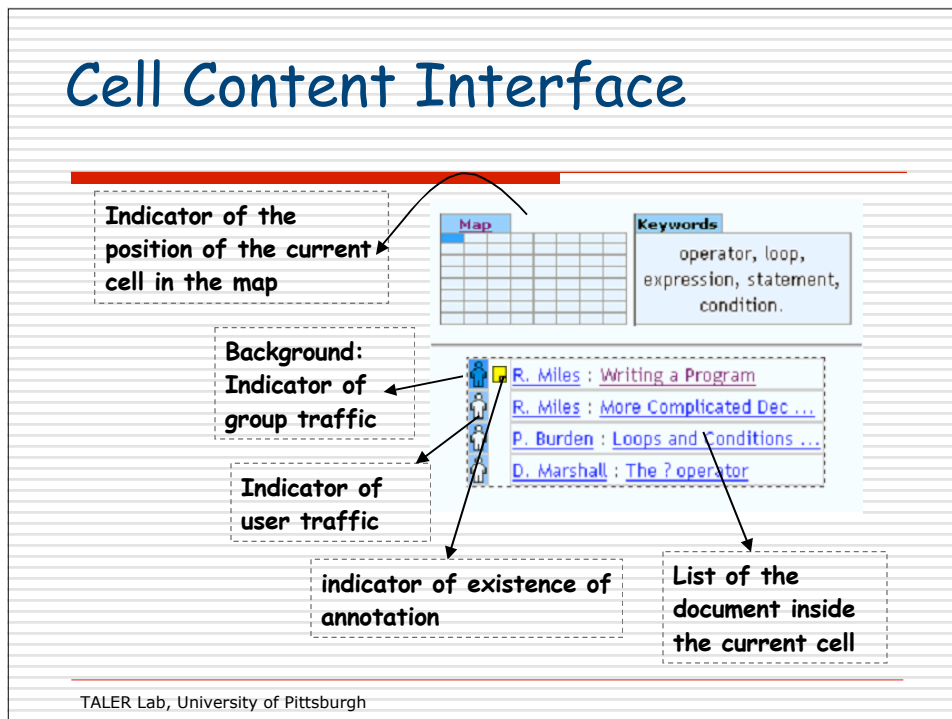 - ■ Knowledge Sea

Knowledge Sea Map

Hypertext 1

Hypertext 3

Hypertext 2
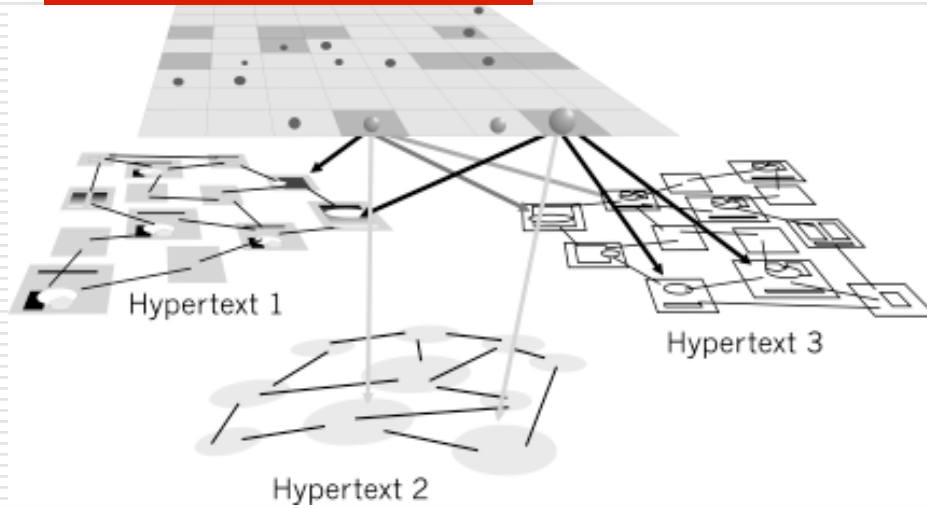
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Map Interface

Indicator of user traffic

Background color: indicator of group traffic

Indicator of existence of annotation

Keywords related to documents inside the cell

Lecture Notes (landmarks)

Indicator of density of document inside the cell

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Cell Content Interface

Indicator of the position of the current cell in the map

Background: Indicator of group traffic

Indicator of user traffic

indicator of existence of annotation

List of the document inside the current cell

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SANS within a book

Knowledge Tee Architecture

Portal

Activity Server

Value-added Service

Student Modeling Server

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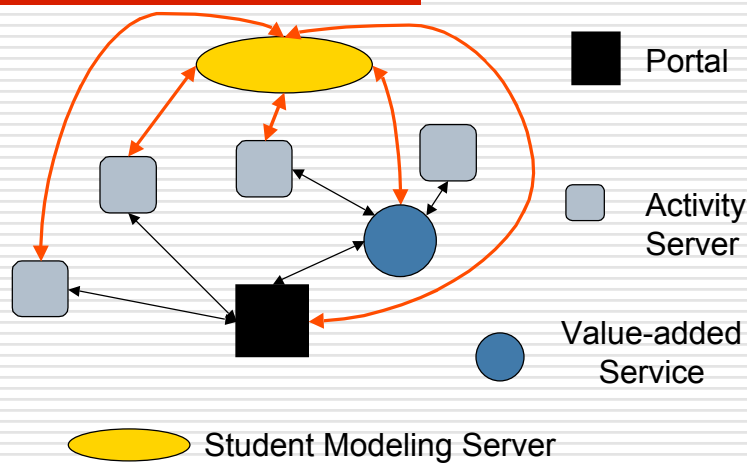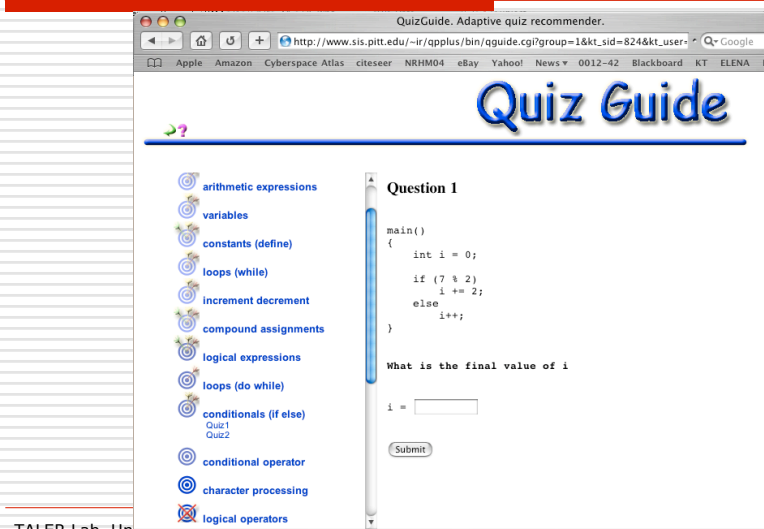
KnowledgeTree Portal
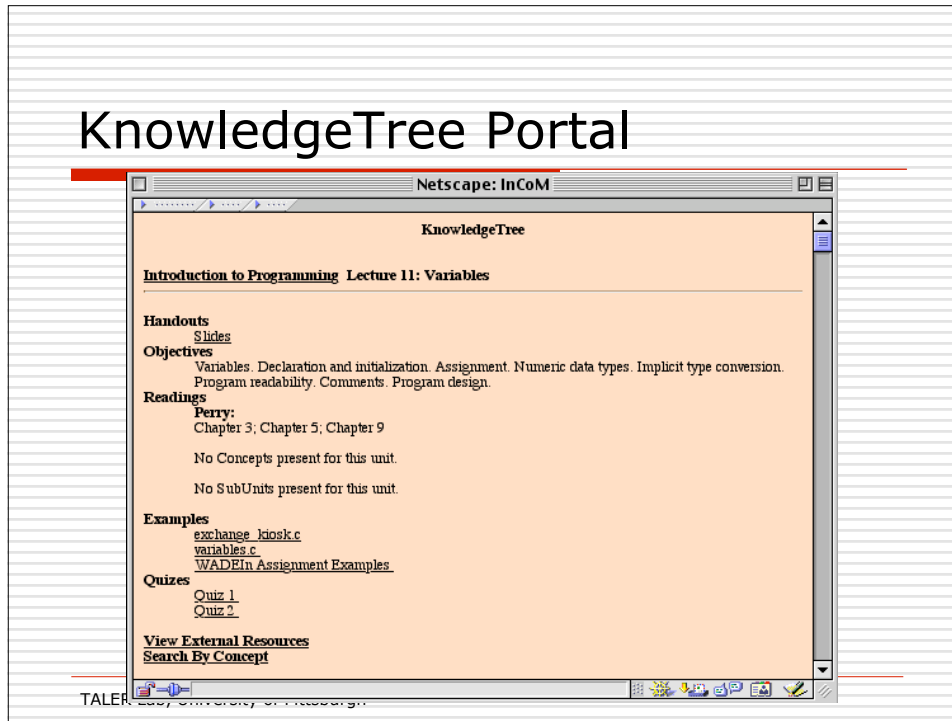
AnnotatED Service
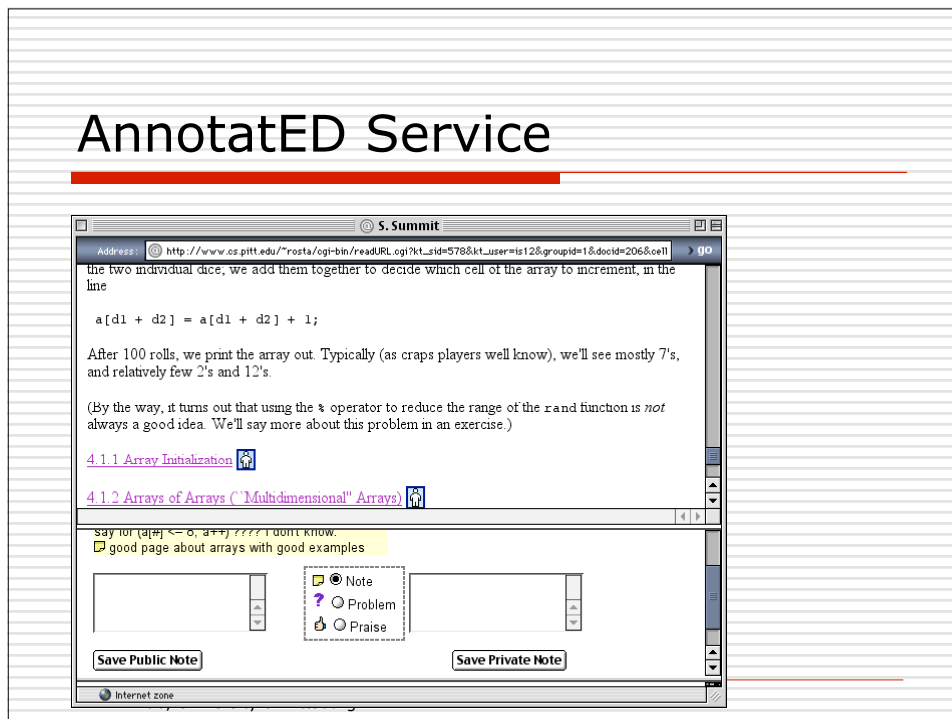
QuizGuide value-added service
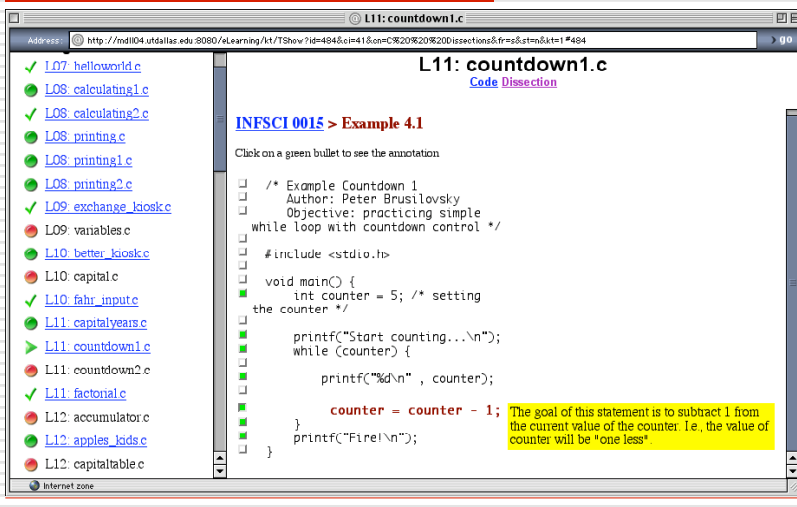
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NavEx Value-added Service

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More information...

- *Adaptive Hypertext and Hypermedia Home Page:* http://wwwis.win.tue.nl/ah/
- Brusilovsky, P. (1996) Methods and techniques of adaptive hypermedia. *User Modeling and User-Adapted Interaction* 6 (2-3), 87-129.
- Brusilovsky, P., Kobsa, A., and Vassileva, J. (eds.) (1998), *Adaptive Hypertext and Hypermedia*. Dordrecht: Kluwer Academic Publishers.