Core Lecture 2: Adaptive Learning Support

TECHNOLOGIES FOR LEARNING

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Overview

• Motivation

• History

• Intelligent Tutoring Systems
  ◦ Instructional Feedback
  ◦ Scaffolding
  ◦ Sequencing and Generation
  ◦ Tutorial Dialog
  ◦ ...

• Adaptive Educational Hypermedia
  ◦ Adaptive Presentation
  ◦ Adaptive Navigation
  ◦ Adaptive Recommendation
The power of individual tutoring
Edward Thorndike (1912)


“If, by a miracle of mechanical ingenuity, a book could be so arranged that only to him who had done what was directed on page one would page two become visible, and so on, much that now requires personal instruction could be managed by print.”
Sidney Pressey (1926)

- First teaching machine
  - Mode 1: automatic, MCQ-based assessment
  - Mode 2: “adaptive self-assessment” – answer until correct
  - Studies confirmed learning

A simple apparatus which gives tests and scores – and teaches. School and Society, 23 (586), 373–376.
B. F. Skinner (1950s)

- **Behaviorism**
  - Our brain is a black box
  - Behavior is detectable, measurable and influenced by environmental conditions
  - Behavior is a consequence of reinforcements
  - Unobservable cognitive activities such as thinking, perception, emotions are secondary
  - Learning should be directed with positive reinforcement

- **Linear programmed instruction**
  - Carefully crafted sequence of small steps
  - Learner receives automatic, immediate and regular reinforcement
  - Teaching happens through a response/reward mechanism

The behavior of organisms.
Norman Crowder (1959)

- **Branching programmed instruction**
  - Individual paths of programmed instruction
  - The material starts with a rather hard question (unlike Skinner’s)
  - Branching helps to differentiate between able and not-able students and guide them through different paths
  - Incorrect answers trigger dedicated remedial explanations

Richard Smallwood (1962)

A decision structure for teaching machines. Cambridge: MIT Press.

From Programmed Instruction to Computer-Assisted Instruction

1. “The decomposition of the subject matter into a set of concepts that the educator would like to teach to the student.” (Part of the domain model.)

2. “A set of test questions, for each concept, that adequately tests the student’s understanding of the concept.” (Part of the domain model.)

3. “An array of information blocks, for each concept that can be presented to the student in some order (to be decided by the teaching machine) - and thus provide a course of instruction to the student on the concept.” (Part of the domain model.)

4. “A model that can be used to estimate the probability that a given student with a particular past history will respond to a given block or test question with a particular answer.” (The student model.)

5. “A decision criterion upon which to base the decisions mentioned in 3.” (The pedagogical model.)

From Behaviorism to Cognitivism/Constructivism
Cognitivism/Constructivism

- Perception and memory research
- Facilitation of understanding and remembering
- Consequences:
  - "advance organizers"
  - concept maps
  - complex feedback
  - learner can choose and switch topics
  - adaptive tutoring
- Learning from experience
- Learner builds a representation of the material by practicing
- Consequences:
  - learner should be self-guided
  - tutor gives only support and advice (scaffolding)
  - tutor offers cognitive tools for exploring the material from different perspectives
Jaime Carbonell (1970)


- First Intelligent Tutoring System - SCHOLAR
  - Domain model is a semantic net
  - Overlay student model
Benjamin Bloom (1984)

The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. Educational Researcher 13:4-16.

- Meta-study of pedagogical methods and factors
  - None of instructional techniques...
  - None of classroom factors...
  - None of household/personal factors...

- ... come close to the effect of one-on-one TUTORING
Intelligent Tutoring Systems

- Domain Model
- Pedagogical / Adaptation Model
- Student Model

- Interface Model
Kinds of Adaptation

• Inner loop adaptation – problem solving support
  ◦ Feedback
  ◦ Scaffolding

• Outer loop adaptation:
  ◦ Intelligent sequencing of problems (mastery learning)
  ◦ Adaptive course generation (pedagogical planning)

• Adaptation of advanced interface model
  ◦ Adaptive educational game
  ◦ Adaptive training VR
  ◦ Adaptive tutorial dialog
Feedback

• Research on feedback effectiveness started within the programmed instruction field. Behaviorist view:
  ◦ Feedback reinforces successful behavior and “punishes” unsuccessful

• Cognitivist view:
  ◦ Feedback can reduce uncertainty about the own performance.
  ◦ Feedback can reduce the *cognitive load*.
  ◦ Feedback can correct inappropriate task strategies, procedural errors and misconceptions.
  ◦ Feedback can hint towards successful strategies, etc...
Feedback - the diversity of factors and parameters

**Conditions of the feedback receiver**
- Prior level of the relevant competencies
- Representation of standards and competencies
- Self-assessment skills
- Skills and strategies in information processing
- Will and skills in overcoming errors and obstacles

**Conditions of the feedback giver**
- Instructional objectives, beliefs, approach
- Level of the relevant competencies
- Representation of standards and competencies
- Diagnostic expertise / accuracy
- Level of instructional design expertise
- Will and skills in tutoring – human feedback source
- Technical characteristics – technical feedback source

**Conditions of the instructional context**
- Instructional domain, topic, curriculum
- Instructional goals, methods, material, resources, etc.
- Learning task requirements – competencies
- Errors and obstacles, and sources of these errors
- Potential feedback sources – e.g., student, teacher, peer, technical device of a digital learning environment

**Feedback functions**
- Cognitive level
- Meta-cognitive level
- Motivational level

**Feedback contents**
- Evaluative component
- Tutoring component
  - hints, cues
  - analogies
  - explanations
  - worked examples
  - guiding questions
  - etc.

**Interactive Tutoring Feedback Model by S. Narciss**
Feedback – level of details

- Minimal Feedback:
  - Knowledge of a result
  - Flag feedback
  - Knowledge of a correct response
  - Summative feedback

- Formative feedback
  - Hints
    - Pointing hint: “Check your trigonometry.”
    - Reminder hint: “The formula you need includes…"
    - Bottom-out hint: “Replace cos(20 deg) with sin(20 deg).”
  - Explanations

<table>
<thead>
<tr>
<th>Feedback</th>
<th>Equation</th>
<th>Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine, that’s right</td>
<td>3x + 7 = 25</td>
<td>-7</td>
</tr>
<tr>
<td>3x = 18</td>
<td>3x = 18</td>
<td></td>
</tr>
<tr>
<td>You cannot subtract 3 here, because 3 and the variable x are linked by multiplication!</td>
<td>3x = 18</td>
<td>-3</td>
</tr>
<tr>
<td>x = 15</td>
<td>x = 15</td>
<td></td>
</tr>
</tbody>
</table>
Immediate feedback:
At every step;
prevent errors from being encoded in memory

Delayed feedback:
After the solution is submitted;
allows correct information to be encoded with no interference

Feedforward: before the task. E.g., “What is the sum of supplementary angles?”
Scaffolding

Zone of proximal development (Learner can do with guidance)

Learner can do unaided

Learner cannot do

Skill Level

Content Difficulty

Bored

(goal)

Confused

ZPD
Scaffolding

• Offering help and advice to support learning → this support is gradually reduced (fading the scaffolding)

• Characteristics:
  ◦ Step-by-step guidance
  ◦ Constraining students reasoning
  ◦ Increasing interest related to the task
  ◦ Further questions or explanations for deeper understanding
  ◦ Adapted instructions → avoid focusing on wrong solution paths
  ◦ Indicating the differences between the learner’s work and the desired solution
ITS: known effects

• Intelligent Tutoring Systems are known to increase:
  ◦ speed of learning
  ◦ knowledge gain (immediate post-test)
  ◦ knowledge retention (delayed post-test)
  ◦ knowledge transfer (deeper learning facilitates successful application of learnt skills in new context)
Adaptive Hypermedia
Why Adaptive Hypermedia?

- 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
What Can Be Adapted?

- Web-based systems = Pages + Links
- Adaptive presentation
  - content adaptation
- Adaptive navigation support
  - link adaptation
Classification of Adaptive Hypermedia techniques

Adaptive hypermedia techniques

Adaptive presentation

Adaptive multimedia presentation

Adaptive text presentation

Adaptation of modality

Natural language adaptation

Inserting/removing fragments

Direct guidance

Canned text adaptation

Altering fragments

Adaptive link sorting

Stretchtext

Adaptive link hiding

Sorting fragments

Adaptive link annotation

Dimming fragments

Adaptive link generation

Hiding

Removal

Map adaptation

Classification of Adaptive Hypermedia techniques
Adaptive Stretchtext (PUSH)

**task**

**summary**

In this case, we perform and document an object-oriented analysis

The model should include the abstractions (represented as object types)

necessary to understand how the subsystem described by the functional

requirements is expressed in an object-oriented world. This analysis

will render us a high-level view of the subsystem without any

consideration (or at least as little consideration as possible) taken to

distribution, persistence aspects or other design and implementation

considerations. The goal is a model that clearly describes and gives an

understanding of a subsystem without the gory details of design and

implementation.

The ideal object model resulting from the ideal object modelling

process, is functionally complete in the sense that it covers all areas of

the functional specification of a subsystem.

**basic introduction**

**purpose**

The ideal object model resulting from the ideal object modelling

process, is functionally complete in the sense that it covers all areas.
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)
QuizGuide: Dual Adaptive Annotations

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

What is the final value of i

i = 

Submit
```
AH: known effects

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