INFSCI 2480: Adaptive Information Systems

Adaptive E-Learning Systems

Peter Brusilovsky
School of Information Sciences
University of Pittsburgh, USA
Find out more about any of these Grand Challenges:

- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery
Overview

• The Context

• Technologies

• Adaptive E-Learning Systems vs. Learning Management Systems (LMS)
Major Aspects of AIS

• What is adaptive?
  – Adaptive sequencing of educational tasks
  – Adaptive content presentation
  – Adaptive ordering of search results

• What kinds of information about user?
  – User knowledge
  – User interests
  – User individual traits
Why Adaptive E-Learning?

• Adaptation was always an issue in education - what is special about the Web?
• greater diversity of users
  – “user centered” systems may not work
• new “unprepared” users
  – traditional systems are too complicated
• users are “alone”
  – limited help from a peer or a teacher
Technologies

- Origins of AEL technologies
- ITS Technologies
- AH Technologies
- “Native” Web Technologies
Origins of AEL Technologies

Intelligent Tutoring Systems

Adaptive Hypermedia Systems

Adaptive Web-based Educational Systems
Origins of AEL Technologies (1)

Adaptive Hypermedia Systems

Intelligent Tutoring Systems

Adaptive Presentation

Curriculum Sequencing

Adaptive Navigation Support

Intelligent Solution Analysis

Problem Solving Support
Technology inheritance examples

• Intelligent Tutoring Systems (since 1970)
  – CALAT (CAIRNE, NTT)
  – PAT-ONLINE (PAT, Carnegie Mellon)

• Adaptive Hypermedia Systems (since 1990)
  – AHA (Adaptive Hypertext Course, Eindhoven)
  – KBS-HyperBook (KB Hypertext, Hannover)

• ITS and AHS
  – ELM-ART (ELM-PE, Trier, ISIS-Tutor, MSU)
Origins of AEL Technologies (2)
Inherited Technologies

• Intelligent Tutoring Systems
  – course sequencing
  – intelligent analysis of problem solutions
  – interactive problem solving support
  – example-based problem solving

• Adaptive Hypermedia Systems
  – adaptive presentation
  – adaptive navigation support
How to Model User Knowledge

- **Domain model**
  - The whole body of domain knowledge is decomposed into set of smaller knowledge units
  - A set of concepts, topics, etc

- **Student model**
  - Overlay model
  - Student knowledge is measured independently for each knowledge unit
Simple overlay model
Weighted overlay model
Course Sequencing

- Oldest ITS technology
  - SCHOLAR, BIP, GCAI...
- Goal: individualized “best” sequence of educational activities
  - information to read
  - examples to explore
  - problems to solve ...
- Curriculum sequencing, instructional planning, ...
Course Sequencing

• What is modeled?
  – User knowledge of the subject
  – User individual traits

• What is adapted?
  – Order of educational activities
  – Presentation of hypertext links
  – Presented content
  – Problem solving feedback
Active vs. Passive Sequencing

• Active sequencing
  – goal-driven expansion of knowledge/skills
  – achieve an educational goal
    • predefined (whole course)
    • flexible (set by a teacher or a student)

• Passive sequencing (remediation)
  – sequence of actions to repair misunderstanding or lack of knowledge
Levels of sequencing

• High level and low level sequencing
Sequencing options

- On each level sequencing decisions can be made differently
  - Which item to choose?
  - When to stop?
- Options
  - predefined
  - random
  - adaptive
  - student decides
Simple cases of sequencing

- No topics
- One task type
  - Problem sequencing and mastery learning
  - Question sequencing
  - Page sequencing
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
Sequencing for AES

- Simplest technology to implement with CGI
- Important for WBE
  - “no perfect order”
  - lack of guidance
- No student modeling capability!
  - Requires external sources of knowledge about student
  - Problem/question sequencing is self-sufficient
ELM-ART: question sequencing
SIETTE: Adaptive Quizzes

Combination of CAT and concept Based adaptation
Models in SIETTE
Beyond Sequencing: Generation
Adaptive Problem Solving Support

• The “main duty” of ITS
• From diagnosis to problem solving support
• Highly-interactive support
  – interactive problem solving support
• Low-interactive support
  – intelligent analysis of problem solutions
Adaptive Problem Solving Support

• What is modeled?
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  – Problem solving feedback
Intelligent analysis of problem solutions

- Intelligent analysis of problem solutions
- Classic system: PROUST
- Support: Identifying misconceptions (bug model) and broken constraints (CM)
- Provides feedback adapted to the user model: remediation, positive help
- Low interactivity: Works after the (partial) solution is completed
Example: ELM-ART

RECTANGLE-AREA

Define a function RECTANGLE-AREA, that takes as input the side lengths of a rectangle and calculates its area.

Examples:

(EXAMPLE-AREA 3 5)
15
(EXAMPLE-AREA 4 2)
8
(EXAMPLE-AREA 0 10)
0

Type in your solution here:

; ;
; (defun rectangular-area (a b) (\times a b))

[Code editor interface]
Example: SQL-Tutor
Interactive Problem Solving Support

- Classic System: Lisp-Tutor
- The “ultimate goal” of many ITS developers
- Several kinds of adaptive feedback on every step of problem solving
  - Coach-style intervention
  - Highlight wrong step
  - What is wrong
  - What is the correct step
  - Several levels of help by request
Example: PAT-Online

You have just been promoted at PAT-E-OH Furniture Inc. and have received a raise to $5.50 per hour.

1. How much would you get paid if you worked 5 hours?
2. How much would you get paid if you worked 25 hours?
3. How much would you get paid if you worked 10 1/2 hours?
4. How much would you get paid if you worked 100 hours?
5. How much would you get paid if you worked 200 hours?
6. If you plan on working 10 hours a week during a forty week school year, what would be your total earnings be for the entire year?

For the formula, define a variable for the time worked and use this variable to write a rule for your total pay.

<table>
<thead>
<tr>
<th>Heading</th>
<th>Time worked</th>
<th>Earnings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Hours</td>
<td></td>
</tr>
<tr>
<td>Formula</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example: WADEIn

http://adapt2.sis.pitt.edu/cbum/
Problem-solving support

• Important for WBE
  – problem solving is a key to understanding
  – lack of problem solving help
• Hardest technology to implement
  – research issue
  – implementation issue
• Excellent student modeling capability!
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
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
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
Adaptive hypermedia

- Hypermedia systems = Pages + Links
- Adaptive presentation
  - content adaptation
- Adaptive navigation support
  - link adaptation
- Could be considered as “soft” sequencing
  - Helping the user to get to the right content
Adaptive Navigation Support

• What is modeled?
  – User knowledge of the subject
  – User individual traits

• What is adapted?
  – Order of educational activities
  – Presentation of hypertext links
  – Presented content
  – Problem solving feedback
Adaptive Annotation: Icons

1. Concept role
2. Current concept state
3. Current section state
4. Linked sections state

InterBook system

1. Concept role
2. Current concept state
3. Current section state
4. Linked sections state
Adaptive Presentation

• What is modeled?
  – User knowledge of the subject
  – User individual traits

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  – Presented content
  – Problem solving feedback
Example: SASY

Scrubtable adaptive presentation

Adapting to User Knowledge: Other Ideas

• Adaptive interface
  – Presence of menus and widgets in an educational applet can be adapted to user knowledge

• Educational animation and simulation
  – Adaptive explanations
  – Adaptive visualization
Demo: WADEIn

Monitor your progress with operations that are your current goals

The length of the bar indicates the amount of exploration (Exploration Mode), and the color saturation indicates the confirmed knowledge (Knowledge Evaluation Mode).

Use the progress indicators to identify operations that need your attention.

Navigate the evaluation of the current expression

Go slowly on a step-by-step basis attending all the changes on the screen.
Go quicker skipping operators.
Quickly jump to the beginning or the end of the evaluation.

Check your current context

Set everything and START the evaluation

Select one of the predefined expressions OR type in your own
Select the mode
Set the values of variables
START the evaluation

Learn by watching animations and reading explanations

At any time consult the original expression AND the order of execution (precedence of operators).
Monitor values of variables appearing in the current expression.
Watch all visualizations, observe how the current expression changes as it is being evaluated.
Read the explanations of the visual actions happening above.
Watch for controls indicating that more complicated concepts are involved in the context of the current operation.
Adapting to Individual Traits

• Source of knowledge
  – educational psychology research on individual differences

• Known as cognitive or learning styles
  – Field dependence, wholist/serialist (Pask)
  – Kolb, VARK, Felder-Silverman classifiers
Style-Adaptive Hypermedia

• What is modeled?
  – User knowledge of the subject
  – User individual traits

• What is adapted?
  – Order of educational activities
  – Presentation of hypertext links
  – Presented content
  – Problem solving feedback
Style-Adaptive Hypermedia

• Different content for different style
  – Recommended/ordered links
  – Generated on a page
  – Mixed evidences in favor

• Different navigation tools for different styles
  – Adding/removing maps, advanced organizers, etc.

• Good review:
Example: AES-CS

Interface for field-independent learners
Example: AES-CS

Interface for field-dependent learners
Style-Adaptive Feedback

• What is modeled?
  – User knowledge of the subject
  – User individual traits

• What is adapted?
  – Order of educational activities
  – Presentation of hypertext links
  – Presented content
  – Problem solving feedback
## Overview: Classic Technologies

<table>
<thead>
<tr>
<th>What?</th>
<th>Knowledge</th>
<th>Styles</th>
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<tr>
<td>Order of activities</td>
<td>Sequencing</td>
<td>?</td>
</tr>
<tr>
<td>Feedback</td>
<td>Adaptive diagnosis</td>
<td>Style-adaptive feedback</td>
</tr>
<tr>
<td>Content</td>
<td>Adaptive presentation</td>
<td>Adaptive presentation</td>
</tr>
<tr>
<td>Links</td>
<td>Adaptive navigation support</td>
<td>Adaptive navigation support</td>
</tr>
</tbody>
</table>
Origins of AEL Technologies (2)

- Information Retrieval
- CSCL
- Adaptive Hypermedia Systems
- Adaptive Information Filtering
- Intelligent Monitoring
- Intelligent Collaborative Learning
- Intelligent Tutoring Systems
- Machine Learning, Data Mining
- Adaptive Hypermedia
- Intelligent Tutoring
Native Web Technologies

• Availability of logs
  – Log-mining
  – Intelligent class monitoring
  – Class progress visualization

• One system, many users - group adaptation!
  – Adaptive collaboration support

• Web is a large information resource - helping to find relevant open corpus information
  – Adaptive content recommendation
Modern Fusion Technologies

• Collaborative Content Recommendation
  – Logs, CF, sequencing
  – Challenge – changing context

• Social navigation
  – Collaboration, logs, ANS

• Learning Analytics
  – Helping the teacher and the process
  – Logs, visualization, data mining
What You Can Get from Logs?

• Log processing and presentation
  – Presenting student progress on topic and concept level: making sense of class

• Course/site improvements

• Grouping users by learning styles

• Intelligent class monitoring
  – Comparing progress, identifying students way ahead and behind
Adaptive Collaboration Support

- Peer help
- Collaborative group formation
- Group collaboration support
  - Collaborative work support
  - Forum discussion support
- Mutual awareness support
Personalized Access to Educational Resources

- A lot of resources are available on the Web and in educational DL/Repositories.
- A new direction of adaptation - provide personalized access to these resources
  - Content based recommender
- Adding advantage of community wisdom
  - Collaborative recommender systems
  - Social navigation systems
Modeling User Interests

• Concept-level modeling
  – Same domain models as in knowledge modeling, but the overlay models level of interests, not level of knowledge

• Keyword-level modeling
  – Uses a long list of keywords (terms) in place of domain model
  – User interests are modeled as weighted vector or terms
  – Originated from adaptive filtering/search area
Use of Profiles in AES: ML Tutor
Social Computing for WBE

• Web 2.0 for education
• Collaborative resource discovery systems
  – CoFIND
  – UMtella (Demo)
• Presence-based collaboration (Educo)
• Social navigation support for open corpus resources (Knowledge Sea II)
• Social guidance (Progressor)
Example: UMtella

<table>
<thead>
<tr>
<th>Resource</th>
<th>Shared by</th>
<th>Earned Ratings</th>
<th>View Times</th>
<th>Reviews</th>
<th>Favorite?</th>
<th>Info</th>
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<tbody>
<tr>
<td>PhD Comics: Facebook</td>
<td>Hoyt</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>+</td>
<td>Detail Remark</td>
</tr>
<tr>
<td>Web 2.0 ... The Machine is Using Us</td>
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<td>6</td>
<td>1</td>
<td>+</td>
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<td>Chris Anderson discusses the long tail</td>
<td>Sevinell</td>
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<td>2</td>
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<td>Detail Remark</td>
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<td>+</td>
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</tr>
<tr>
<td>Social Networking in Plain English</td>
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<td>3</td>
<td>1</td>
<td>+</td>
<td>Detail Remark</td>
</tr>
<tr>
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<td>3</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>1</td>
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<td>5</td>
<td></td>
<td></td>
<td>Detail Remark</td>
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<td>Flock: A Social Web Browser</td>
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<td>5</td>
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<td>Detail Remark</td>
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<td>Page Rank Checker</td>
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<td>Ending A Site Google Page Rank</td>
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<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td>Detail Remark</td>
</tr>
</tbody>
</table>
Course Sequencing for Static Courses? Applying ITS Techniques in Large-Scale Web-based Education

Peter Brusilovsky
Carnegie Technology Education and HCI Institute, Carnegie Mellon University
4415 Forbes Avenue, Pittsburgh, Pa 15213, USA
pbl@cs.cmu.edu

Abstract. We argue that traditional sequencing technology developed in the field of intelligent tutoring systems could find an immediate place in large-scale Web-based education as a core technology for concept-based course maintenance. This paper describes a concept-based course maintenance system that we have developed for Carnegie Technology Education. The system can check the consistency and quality of a course at any moment of its life and also assist course developers in some routine operations. The core of this system is a refined approach to inheriting the course material and a set of "scripts" for performing different operations.

1 Introduction

Course sequencing is one of the oldest technology in the field of intelligent tutoring systems (ITS). The idea of course sequencing is to generate an individualized course for each student by dynamically selecting the most optimal teaching operation (presentation, example, question, or problem) at any moment of education. An ITS with course sequencing represents knowledge about the subject as a network of concepts where each concept represents a small piece of subject knowledge. The learning material is stored in a database of teaching operations. Each teaching operation is indexed by concepts it deals with. The driving force behind any sequencing mechanism is a student model that is a weighted overlay of the domain model. For every domain model concept it reflects the current level of student knowledge about it. Using this model and some teaching strategy a sequencing engine can decide which one of the many teaching operations stored in the database is the best for the student given his or her level of knowledge and educational goal.

Various approaches to sequencing were explored in numerous ITS projects. The majority of existing ITS can sequence only one kind of teaching operations. For example, a number of sequencing systems including the oldest sequencing systems [2, 14] and some others [8, 12, 15] can only manipulate the
Demo: Knowledge Sea II
Demo: Progressor+
What LMS Can Do

• For students
  – Course information and content delivery
  – Assessment and grades
  – Communication and collaboration

• For teachers
  – Authoring
  – Learning control
  – Student monitoring
  – Communication
What AES Can Do for Students

• Presentation
  – Adaptive presentation, adaptive navigation support, adaptive sequencing

• Assessment
  – Adaptive testing

• Communication and collaboration
  – Peer help and collaborative group formation
  – Collaboration coach

• Learning by doing
  – Problem solving support
What AES Can Do for Teachers

- Student monitoring
  - Identifying students in trouble
- Control
  - Sequencing
  - Adaptive navigation support
- Authoring
  - Concept-based authoring and courseware engineering
AES vs. LMS

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

• Why LMS are not really adaptive?
  – Except simple control and learning design
Challenges

• How to make it working in practice?
  – AES systems use advanced techniques - hard to develop
  – AWBES content is based on knowledge - hard to create
  – AES require login and user modeling - hard to integrate

• Possible solutions - (watch, PhD students!)
  – Component-based architectures for AWBES
  – Authoring support
  – Open Corpus adaptive systems
Component-based Architectures

• Research systems can provide a better support of almost each function of E-Learning process
• Adaptive systems show how to implement nearly each component adaptively
• We need the ability to assemble from components
  – Course authors can choose best components and best content for their needs
  – Components providers and content providers have a chance to compete in developing better products
Current State

• Several component-based frameworks
  – ADAPT², ActiveMath, MEDEA,…
• Attempts to develop systems with internal components
• Reusable user/student model servers
• Some matching work in the standardization movement
Re-use/Standards Movement

• Learning Object Re-use supported by coming standards is another major research direction in E-Learning
• The re-use movement joins many existing streams of work driven by similar ideas
  – Create content once, use many times
  – Content independent from the “host” system
  – Content and interfaces with the host system are based on standards (metadata, CMI, etc)
• Let content providers be players in E-Learning
• The future is components and re-use
What is the Future?

• How to use good component/content if you have a Blackboard, Moodle or other major CMS?
• Is the future model a Blackboard-style giant system where all components are advanced and adaptive?
  – Wait for the CMS giants to integrate better tools?
  – Create our own “adaptive Blackboards”
• Is there any other choice?
ADAPT² Architecture

Portal
Activity Server
Value-added Service
Student Modeling Server
Knowledge Tree II Portal

<table>
<thead>
<tr>
<th>Database Course [Yudelson, Michael]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refer to Instructions document below for help on working with the course material</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Folders/Documents</th>
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<tbody>
<tr>
<td>Instructions</td>
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<tr>
<td>Table Creation</td>
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<td>Table Deletion and Alteration</td>
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<td>Key Constraints</td>
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<td>Tuple Insertion</td>
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<td>SELECT-FROM</td>
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<td>Arithmetic Expressions</td>
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<td>SELECT-FROM-WHERE</td>
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<tr>
<td>Pattern Matching</td>
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<tr>
<td>Multiple Table Queries</td>
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<td>ORDER BY</td>
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<table>
<thead>
<tr>
<th>SELECT FROM [Yudelson, Michael]</th>
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</table>

<table>
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<th>Folders/Documents</th>
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<tbody>
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<td>Q SELECT-FROM question1</td>
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<tr>
<td>Q SELECT-FROM question2</td>
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<td>Q SELECT-FROM question3</td>
</tr>
<tr>
<td>Q SELECT-FROM question4</td>
</tr>
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<td>Q SELECT-FROM question5</td>
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<tr>
<td>D Selecting One Attribute</td>
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<tr>
<td>D Selecting Multiple Attributes</td>
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<td>D Selecting All Attributes</td>
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<tr>
<td>DSkipping Duplicates</td>
</tr>
<tr>
<td>D Selecting Multiple Attributes (Projection)</td>
</tr>
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</table>

- My rating: ★★★★★ N/A
- Group rating: ★★★★★ N/A