Approximate Plan of the Course

- 21.4. Introduction
- 28.4. ActiveMath Vorstellung /Introduction to ActiveMath
- 12.5. Benutzermodellierung/student modeling
- 19.5. instructional design
- 2.6. XML knowledge representation, adaptive hypermedia
- 9.6. collaborative learning/ Lernen in Gruppen
- 16.6. diagnosis
- 23.6. action analysis
- 30.6. support of meta-cognition
- 7.7 further topics (tutorial dialogues, mobile learning..)
- 14.7. student project reports

Source: Erica Melis
A Generic ITS Architecture

Student

Graphical user interface

Domain KR

Problem Solver

Action Interpreter

Interaction History

Feedback Generator

Student Model

Solution Graph

Solution Evaluator

Problem Selector

Curriculum Planner

Curriculum

Source: Erica Melis
Adaptation dimensions

• Technical environment
• Social context
• Personalization

• Situation

• Our first experience:
  School type, field, language, curriculum, goals, prerequisites, field of interest, mastery level, competencies, competency-level
Шаг 3/3: имя и тип книги

Здесь Вы можете выбрать один из многих различных типов книг, которые ActiveMath способен для Вас создать. Это неважно, хотите ли Вы интенсивно готовиться к контрольной или только получить общее представление - просто выберите из списка внизу тип, который наиболее подходит под Ваши требования. Для того, чтобы позднее эту книгу на Вашей персональной "книжной полке" было проще найти, рекомендуется присвоить имя.

Заголовок Вашей книги: 

Какого типа книгу Вы хотели бы?
- Я хотел бы книгу, которая мне разъяснит все детали выбранной темы.
- Я хотел бы только короткий обзор выбранной темы.
- Я хотел бы книгу, которая мне поможет понять выбранную тему понимать/описывать/называть.
- Я хотел бы книгу, которая мне поможет разъяснить/отождествлять/постигать.
- Я хотел бы книгу, которая мне помогает применять.
- Я хотел бы только им Polya-стиль представленные доказательства.
- Я хотел бы Polya-инспирированную книгу.
- Я хотел бы в выбранных разделах подготовить к контрольной.
- Я хотел бы в выбранных разделах решать упражнения.
- Я хотел бы видеть только те концепции, которые я еще не освоил.
- Я хотел бы выбранные разделы повторить.

далее к следующему шагу
Adapting to Users: Anton

Definition of a morphism of groups
A morphism (of groups) from $G$ to $G'$ is a map $f : G \rightarrow G'$
with the following properties:
- $f(e) = e'$ (the unit element of $G'$);
- for all $(a, b \in G)$, we have $f((a \cdot b)) = f(a) \cdot f(b)$;
- for all $(a \in G)$ : $f((a^{-1})) = f(a)^{-1}$. A bijective morphism is called an isomorphism.

Example
We have to show that the property of associativity holds for the image $\text{fun}(G)$. We prove this by using the properties of the domain via the morphism

Exercise
Which of the following maps is a morphism of groups?

Exercise
Prove for an morphism $\text{fun} : (g, opg) \rightarrow (h, opi)$ between two groups $g$ and $h$ that $\text{fun}(g)$ is closed under $opi$.

Source: Erica Melis
Adapting to Users: Bert

Source: Erica Melis
Systematic approach

input? → User Model → relevant output?

Source: Erica Melis
Output: e.g., Context modeling

• Social context:
  – home/classroom/museum
  – Collaborative/single
  – Country (geographic)
  – Curriculum
  – school type
  – cultural (not only language)

• Technical context
  – Browser (rendering)
  – PC/PDA/.. (rendering, bandwidth..)
  – Availability of tools on client, Handwriting facility
Output: Individual Variables

• Cognitive (actual)
  – capability, incoming knowledge
  – cognitive style
  – problem solving strategies, preferences

• Psychological (mental)
  – interests
  – Preferences, learning style??
  – Meta-cognitive

• Person-in-situation
  – Exploratory behaviour
  – goals

• Affective
  – motivation, impulsivity

• Personal traits
  – Blind, working memory capacity, attention span, reading performance

Source: Erica Melis
Inputs for User Model

- **Self-reports:**
  - Questionnaire
  - on-task-report
  - Open learner model
- **teacher input**
- **behavioral data**
  - performance
  - response to test items (hesitation)
  - time-on-task
  - help or other requests
  - low-level measures
- **Context data**
Online Questionnaires

Please complete this form. It will help ActiveMath to present the content adapted to your needs.

**Login Information:**
- Desired username:
- Full name:
- Email:
- Enter desired password:
- Enter desired password again:

**Information about yourself:**
- What is your field? Mathematics
- What is your educational level? University First Cycle

**Submit!**
## Open Learner Model in **ActiveMath**

### Semi-groups

- **Operations**
  - Definition of a unary operation (assessment details / modification)
  - Definition of a binary operation (assessment details / modification)

- **Structures**
  - Definition of a structure (assessment details / modification)

- **Associativity**
  - Definition of associativity (assessment details / modification)
  - Brackets positioning for an associative operation (assessment details / modification)

### Semi-groups

- Definition of a semi-group (assessment details / modification)
- Definition of a unit of a semi-group (assessment details / modification)
- Unit and semi-group (assessment details / modification)

### Monoids

- **Defining Monoids**
  - Definition of a monoid (assessment details / modification)
  - Definition of commutativity (assessment details / modification)
Student Modeling, techniques

- Stereotypes (deduction)
- Case-based
- Functional heuristic updating
- Bayesian updating
- Bayesian networks
- Dynamic Bayesian Networks
- Fuzzy modeling

Knowledge tracing
model tracing

Source: Erica Melis
Bayesian networks

- Nodes: set of random variables $X_1 X_2 .. X_n$
- Links: probabilistic dependencies among variables
- Conditional probabilities: quantify the dependencies

![Bayesian Network Diagram]

- $P(A) = 0.01$
- $P(B) = 0.02$
- $P(C | A, B) = 0.95$
- $P(C | A, \neg B) = 0.94$
- $P(C | \neg A, B) = 0.29$
- $P(C | \neg A, \neg B) = 0.001$
- $P(D | C) = 0.90$
- $P(D | \neg C) = 0.05$
- $P(E | C) = 0.70$
- $P(E | \neg C) = 0.01$

Source: Erica Melis
Bayesian Net

conditional dependences
Probability distribution
events, causes, evidences
diagnostic/causal update
handle noise and uncertainty

In general evaluation of BN is NP-hard...

Source: Erica Melis
Bayesian Networks in Lumiere

User expertise
Task difficulty
User needs assistance
User distracted
Pause after activity
Recent menu surfing

Source: Erica Melis
BN for predicting student performance

Relevant for ideal solution c,p
Used for selecting problem difficulty in SQL Tutor

Relevant for student solution c,p

Mastered(c)

Performance c,p

<table>
<thead>
<tr>
<th>YY</th>
<th>YN</th>
<th>NY</th>
<th>NN</th>
</tr>
</thead>
<tbody>
<tr>
<td>satisfied</td>
<td>1 - slip</td>
<td>guess</td>
<td>0</td>
</tr>
<tr>
<td>violated</td>
<td>slip</td>
<td>1 - guess</td>
<td>0</td>
</tr>
<tr>
<td>not relev</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Erica Melis
Bayes Net for Motivational Variables:

- autonomy
  - confidence
  - interest
  - Effort
  - Ability

- approval
  - hesitation
  - initiative
  - Granularity of steps
  - achievement
  - correctness

Source: Erica Melis
Correlations between Help-Seeking and Learning

- Confirmatory help attitude
- Help independence attitude
- Don’t care help attitude
- Challenge attitude
- Serious-try-learn attitude
- Get-it-over attitude

Learning factor

- Gender?
- Helpful?
- Like?

Factors:
- Time-on-hint
- Ratio helped problems
- Hints seen per problem
- Used headphone
- Problems per minute
- Time-on-system

Source: Erica Melis
Stereotypes

- Stereotype: body + set of triggers
- may be arranged in hierarchies (inheritance)

Actions and self-ass

Membership in (several) stereotypes

(possible) inheritance

Relevant facts

Source: Erica Melis
Stereotypes, rules

- Trigger rules (**Cond Trigger**)
  - self-assessed ‘expert’ THEN stereo= Expert
  - at least 20 topics K=excellent THEN stereo=Expert

- Rules for evaluation and presentation (**Cond Scoring**)
  - Beginner AND diff(T)=simple THEN ev(T)=10 points
  - knows(T) THEN substract 20 for appropriate(T)
Knowledge Tracing in PACT/cognitive tutors

iterative Bayesian Updating

\[ p(L_n) = p(L_{n-1} | \text{evidence}) + (1 - p(L_{n-1} | \text{evidence})) \times p(T) \]

- \( p(Lo) \) initial learning (a priori) probability of rule
- \( p(T) \) transition prob following an opportunity of applic.

\[ p(\text{correct}) = p(L) \times (1 - p(S)) + (1 - p(L)) \times p(G) \]

- \( p(G) \) guess
- \( p(S) \) slip

Source: Erica Melis
OVERLAY MODEL

- Pre-defined problem solving space includes rules and mal-rules
- Match student’s results with nodes in space
  - Hypothesize next possible step
  - Diagnoses errors
Student Modeling in Andes

- Static Bayes Net on domain knowledge
- with input from dynamic BNs
  - rule nodes + context rule node for each exercise
- complexity of BN is NP-hard. approximate anytime algo based on statistic sampling
- independence assumption

long-term assessment for domain knowledge
Network structure: Static part

- **Rule nodes**
  - $P(R = T)$: probability that the student knows the rule

- **Context rule nodes**
  - $P(CR_i = T)$: probability that the student can use the rule in the corresponding context

\[ P(CR_i = T | R = T) = 1 \]

\[ P(CR_i = T | R = F) \] estimates the level of difficulty of context $i$
Network structure: Dynamic part

Context-Rule1

Fact1

Rule-app1

Rule-app2

Noisy-OR

Noisy-AND

Goal1

Strategy1

Rule-app3

Goal2

Source: Erica Melis
Propagating evidence

Problem 1

Goal 1

Fact 1

Context-Rule 1

Fact 1

Problem 2

Goal 2

Fact 2

Context-Rule 2

Fact 2

Source: Erica Melis
Andes Model Tracing Usage in Excel

- Assess intention -> useful hints
- If error + help request -> best explanation
- Low mastery of important rules -> mini-lesson
Selecting a Hint, algo

- **Step 1: Goal inference**
  - Start with last observed student entry
  - Find closest unsatisfied goal node
  - At decision points, choose highest probability node (most likely goal)

- **Step 2: Prediction**
  - Start from goal found in step 1
  - Find path from goal to “stuck node” (p<0.8)
  - At decision points, choose lowest probability node (most help needed)

Source: Erica Melis
Updating the Student Model

- Student Model should reflect hints
- Hints have a direct influence on the probability of action

<table>
<thead>
<tr>
<th></th>
<th>RA</th>
<th>¬RA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hint</td>
<td>¬Hint</td>
</tr>
<tr>
<td>F7</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>¬F7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

h = strength of hint

Source: Erica Melis
A 2000-kg car in neutral at the top of a 20-degree inclined driveway 20 m long slips its parking brake and rolls down. Assume that the driveway is frictionless.

At what speed will it hit the garage door?

Answer: 

Think about what you need to do in order to have a complete free body diagram for the car.

The driveway exerts a normal force on the car.

Draw all the forces acting on the car as part of your free body diagram.

Do you know of any other forces acting on the car?

Is there a force exerted by the driveway on the car?
Problems with Model Tracing

- Correct domain rules provide *positive* evidence only
- For *negative* evidence buggy rules needed
- Assessors most accurate if
  - student kept along a given solution path
  - student has to provide every step
- Bayes theoretically optimal but some parameter values hard to obtain

Source: Erica Melis
User model in I-Help

- knowledge
- interests
- eagerness
- helpfulness
- cognitive style
- preferences in helper
- preferred people
- banned people
- banned topics
- help-load

Info from:
- user
- peers
- I-Help private
- I-Help Public

For finding and ranking candidate helpers for protecting users

Source: Erica Melis
Test of User Models

• Never fully reliable...
• Empirical test with users
  – protocols, written..teacher assessors
• introspectable and modifiable user models
  – student/teacher revises
  – dialogue about student’s beliefs
• test with artificial users
Which Properties to Adapt to? (WOz)

- course presentation
  - sequencing
  - content, difficulty
  - language
- Feedback
- Feedback strategies
- global suggestions
  - learning plan
  - prompts
- motivation support
- role playing in collaboration

- Mastery level
- learning goals
- user actions
- exercise performance
- learning context
- field
- presentation preferences
- language...
- learner type
- gender
- motivational state
- context

Source: Erica Melis
Wizard of Oz

- Which adaptation targeted?
- Write user‘s and context‘s relevant properties on cards
- Input – Output?
- Observe learner‘s relevant properties, e.g. motivation
- Dependencies of properties?

- add properties and dependencies, if necessary
- are different levels of knowledge needed, which?
- is history needed, if yes, why?
- Is motivational state needed, if yes, which info?
Domain Reasoning (e.g. BEETLE)

- Model tracing
- Dynamic generation of problem solving subspace
- Diagnosis of errors
- Hints for next steps

Source: Erica Melis