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Learner Modeling

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Learning Objectives

At the end of this session you should be able to:

- Describe some aspects of a learner model
- Analyze a classroom scenario to identify adaptivity actions based on learner models
- Explain incorporation of learner models in some adaptive tutoring systems

Activity – You as a teacher

- Consider a class that you are teaching
- What aspects of student related information do you consider?
  - Think about your decisions regarding topic, level of depth, way of teaching, exams
  - List down as many points as you can
- For each point above, how do you use the information?
- Do Think-Pair-Share:
  - Think individually for a few minutes; Pair discussion with your neighbour
  - Share your ideas with the class

Some sample answers

- Student goals – Decide the topics to be covered
- Prior knowledge – Decide the depth of each topic

- Body language – Determine level of engagement, modify treatment
- Class participation – Estimate level of learning, modify activities

- Time taken to complete a test – Decide number of questions and level of difficulty for the next test
- Performance in a test – Determine difficult topics, misconceptions

- Explicit feedback – Adapt course accordingly
- ...

Learner Model: Definitions

– “The learner model is a model of the knowledge, difficulties and misconceptions of the individual. As a student learns the target material, the data in the learner model about their understanding is updated to reflect their current beliefs” [Bull, 2004]

– “The student model in an intelligent tutor observes student behavior and creates a qualitative representation of her cognitive and affective knowledge. This model partially accounts for student performance (time on task, errors) and reasons about adjusting feedback” [Woolf, 2009]

Activity – Definition of learner model

- Which items from your list (created earlier) should be included in a learner model?

- Should there be any additional items?
  - Discuss with your neighbour and expand your list!
  - Some possibilities:
    - Record scores achieved by a student over a period of time
    - Record time taken by a student to answer a question versus their performance in the question

- Group the items in your list into 3-4 categories

Aspects in a learner model

From [Woolf 2009]

- **Topic related**
  - Knowledge of concepts, facts, procedures
- **Misconceptions**
  - Common well-understood errors
- **Affect**
  - Engagement, boredom, frustration
- **Experience**
  - Attitude, plans, goals, history
- **Stereotypes**
  - Default characteristics assigned to groups of students

Why learner models?

- Every learner has different characteristics, and needs
- An adaptive system should consider individual differences and provide personalized learning experience

- Some characteristics where learners may differ:
  - Prior knowledge
  - Motivation
  - Learning goals / interests
  - Cognitive abilities
  - Learning styles
  - Affective states

Example 1: Learning Styles

- Several models and research over 30 years!
- Two definitions:
  - "a description of the attitudes and behaviours which determine an individual's preferred way of learning" [Honey & Mumford, 1982]
  - "characteristic strengths and preferences in the ways they [learners] take in and process information" [Felder, 1996]

- Some examples:
  - Active experimentation; Reflecting
  - Learning by listening; Learning from examples
  - Collaborative learning
  - ...

Felder-Silverman Learning Style Model

- Each learner has a preference on each of the dimensions:
- **Active – Reflective**
  - learning by doing – learning by thinking things through
  - group work – work alone
- **Sensing – Intuitive**
  - concrete material – abstract material
  - more practical – more innovative and creative
  - patient / not patient with details
  - standard procedures – challenges
- **Visual – Verbal**
  - learning from pictures – learning from words
- **Sequential – Global**
  - learn in linear steps – learn in large leaps
  - good in using partial knowledge – need “big picture”

Activity:

What is your LS?

FSLSM: Identifying learning styles

- "Index of Learning Styles" (ILS) questionnaire:
  - 44 questions (11 for each dimension)
  - Available online
  - For each dimension:
    - [+11 to +9] indicates strong preference for one (ex. Active)
    - [-11 to -9] indicates strong preference for other (ex. Reflective)
    - [+3 to -3] indicates well-balanced
- Salient features:
  - Combines major learning style models (Kolb, Pask, MBTI)
  - Describes learning style in more detail (Types <-> Scale)
  - Describes tendencies

Example use of Learning Styles: Adaptation for active/reflective

- Active learners
  - Self-assessments before and after content
  - High number of exercises
  - Low number of examples
  - Outline only at the beginning of content
  - Conclusion at the end of the chapter
- Reflective learners
  - Outlines between content
  - Conclusion after content
  - Avoid self-assessments before content
  - Examples after content
  - Exercises after content
  - Low number of exercises

From [Graf & Kinshuk 2008]

Identifying learning styles automatically

- [Graf & Kinshuk 2008] mapped learner behaviour described by FSLSM to online learning
  - Used indications from LMS data and a rule-based approach to identify learning styles

- Data recorded:
  - No of Visits and Time spent on different features of a course - Content objects, Outlines, Examples, Exercises, Self-assessment tests, Discussion Forum
  - Also recorded: time spent on results of a test/exercise, retakes, Performance on questions about facts or concepts, details or overview, graphics or text, interpreting or developing solutions, postings to forum, Skipping learning objects

- Experiments (75 students) to compare rule-based vs data-driven approaches with ILS; Found that rule-based is closer to ILS results

Example 2: Cognitive abilities

- Abilities to perform any of the functions involved in cognition whereby cognition can be defined as the mental process of knowing, including aspects such as awareness, perception, reasoning, and judgment [Colman, 2006]

- Cognitive abilities are more or less stable over time, unlike learning styles

- Activity: Come up with some examples of abilities that could be considered as cognitive abilities.

Cognitive abilities for learning

Some important cognitive abilities: [Graf & Kinshuk 2008]

- **Working Memory Capacity**:
  - allows us to keep active a limited amount of info (7+/-2 items) for short time (Miller, 1956)

- **Inductive Reasoning Ability:**
  - is the ability to construct concepts from examples

- **Information Processing Speed:**
  - determines how fast the learners acquire the information correctly

- **Associative Learning Skill:**
  - is the skill to link new knowledge to existing knowledge

Example 3: Affective states

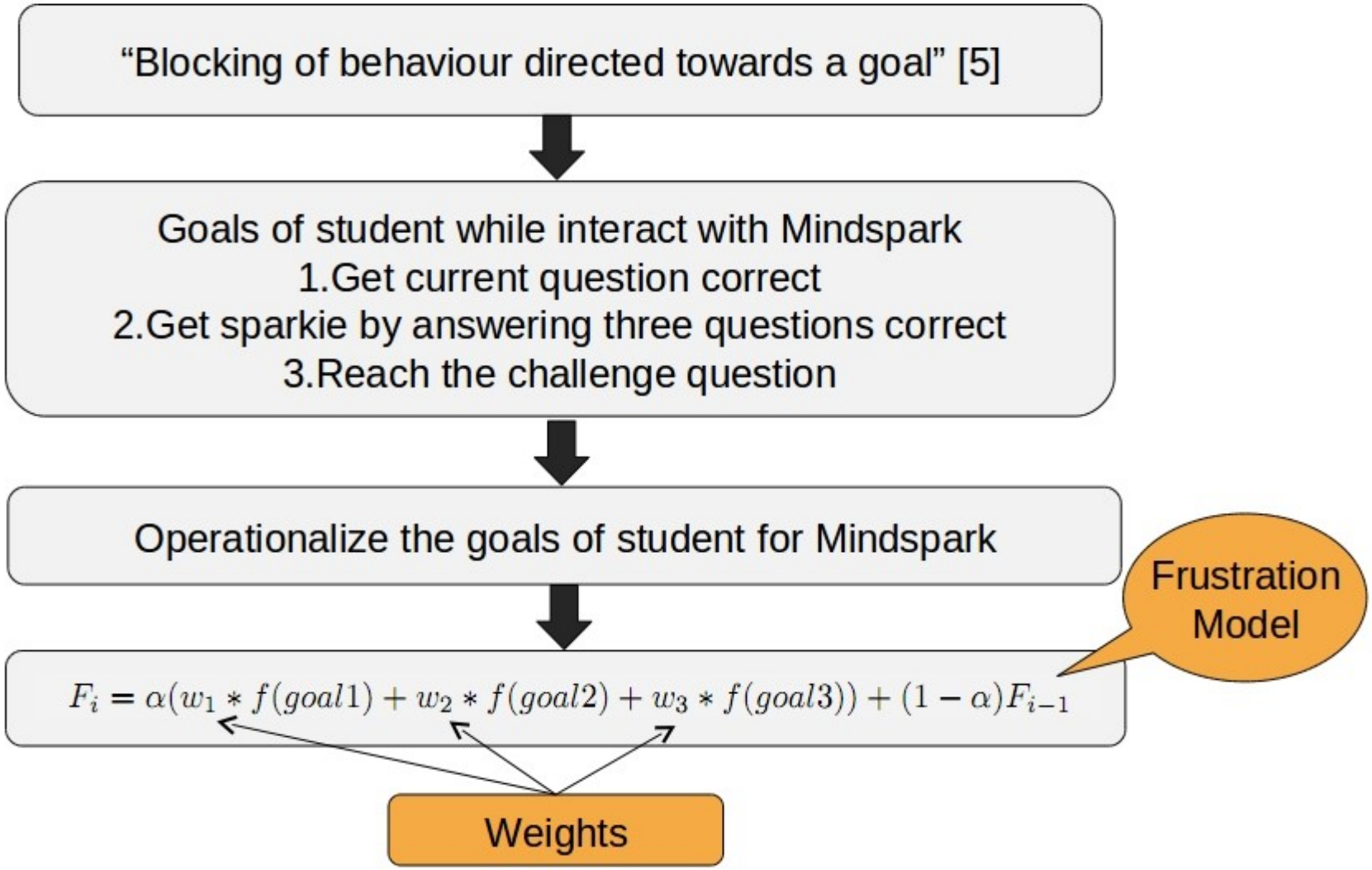
- Cognitive affective states: boredom, frustration, confusion, delight, engaged concentration and surprise [Baker et. al. 2010].

- For effective tutoring, student motivation and affective components should also be identified and considered while tailoring the learning content

Identifying affective states

- Human observation
  - Facial expression
  - Head movement
  - Gestures
  - Speech
- Sensor data
  - Facial analysis
  - Voice analysis
  - Physiological signals
  - Text inputs
- From log data
  - Correlation, classification
  - Machine learning techniques

Modeling frustration



Example Systems: Mindspark

- Mindspark is a commercially deployed system for Math tutoring in schools (for standards III to VIII)
  - Models and adapts on learner achievement
  - Content organized hierarchically into
    - Topic (Math) -> Teacher Topic (Alegbra) -> Cluster (Linear eq)
    - Cluster has 30-50 questions, divided into Sub difficulty levels
  - Performance less 75% in a cluster => Remedial (hints)
  - Second failure => Previous cluster or lower level
  - Developed by Educational Initiatives, India
  - http://www.mindspark.in

Example Systems: PAT

- PAT (Pump Algebra Tutor)
  - Models and reasons about student's skills
  - Uses pre-defined if-then production rules, such as
    1. Correct: IF the goal is to solve a(bx + c) = d, THEN rewrite the equation as bx + c = d/a
    2. Correct: IF the goal is to solve a(bx + c) = d, THEN rewrite the equation as abx +a c = d
    3. Incorrect: IF the goal is to solve a(bx + c) = d, THEN rewrite the equation as abx + c = d
  - Dynamically updates estimates of how well the student knows each production rule and selects future activities
  - http://act.psy.cmu.edu/awpt/awpt-home.html

Example Systems: Cardiac Tutor

- Cardiac Tutor
  - Models procedures used by student and simulates heart-condition of a patient in real-time
  - Expert procedures are represented as protocols (steps) and student actions are compared with these
  - Simulation supports various state-transition events, having different probabilities, based on learning needs
  - http://centerforknowledgecommunication.com/

Example Systems: Wayang Outpost

- Wayang Outpost helps students prepare for standardized Math tests such as SAT
  - Models affective states such as interest in a topic through student surveys and correlation with log data (such as time spent on problem, use of hints)
  - Students address environmental issues of saving orangutans while solving geometry problems
  - Provides customized hints based on student model (Visual hints for students with high spatial skills, Computational hints for others)
  - http://wayangoutpost.com/

More Example Systems

- Andes - Physics tutor for students to create equations and graphics; feedback and hints
  - http://www.andestutor.org/
- AutoTutor – Animated agent that acts as a dialog partner with the student
  - http://www.autotutor.org/
- Anurup – Framework to help instructors create adaptive tutoring systems
  - http://www.cdacmumbai.in/fai

Activity – Automating learner modeling

- Consider your list of student-related information and your adaptations (created in an earlier activity)
- Suppose the same adaptations have to be now incorporated into an automated system

- For each item in your list:
  - Identify relevant data that has to be recorded to enable the adaptation
  - Identify resources that are required to capture the above data
  - Suggest an algorithm that could be used to perform the adaptation automatically

- Do Think-Pair-Share

Concepts of student models

Foundational concepts from [Woolf 2009]

- **Domain model**
  - Capture the domain knowledge of the student as an annotated version of expert knowledge (of facts, procedures, methods) in that area
- **Overlay model**
  - Subset of domain model that shows the difference between novice and expert reasoning
- **Bug libraries**
  - Capture common misconceptions
- **Bandwidth**
  - Amount and quality of information recorded during each interaction of the student with the system
- **Open student model**
  - Student may inspect her model created in the system and reflect on their knowledge

Tools for automated learner modeling

- Model-tracing
  - Encode and follow student solution steps through the problem space and apply pre-defined rules at each step
- Formal logic
  - Pre-defined set of premises (Ex:- students who make mistake M dont understand topic T), observe student actions and infer conclusions
- Machine learning
  - Bayesian Belief Networks
  - Hidden Markov Models

- Details are beyond the scope of this session!

Revisit Learning Objectives

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References

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