Introduction to Student Modeling and Bayesian Knowledge Tracing

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Intelligent Tutoring Systems

Student modeling and its context
• **Intelligent Tutoring Systems**

Image from the Statistics and Probability Course from the Open Learning Initiative

**Student modeling and its context**
• Intelligent Tutoring Systems

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Student modeling and its context
Algebra Cognitive Tutor

Analyze real world problem scenarios

Supporting Self Regulated Learning with Intelligent Tutoring Systems

Track knowledge tracing

Use tables, spreadsheet

Use equations, symbolic calculator

Model tracing to provide context-sensitive Instruction

Image from V. Aleven, 2015 Supporting Self Regulated Learning with Intelligent Tutoring Systems
ITS detect and fit to individual differences in:

- student knowledge,
- engagement, and
- motivation,

Student modeling and its context
The area of study covering the set of tools and techniques to achieve this assessment is student modeling.

Student modeling and its context
Student modeling and its context
… while student performance is observable, student knowledge remains latent.

Student modeling and its context
Knowledge Component

A skill or knowledge component is a description of a mental structure or process that a learner uses, alone or in combination with other knowledge components, to accomplish steps in a task or a problem.

(Koedinger et al, 2012)
• Student Models
  – Bayesian Knowledge Tracing (BKT)
    Corbett, Anderson, 1995
  – Performance Factors Analysis (PFA)
    Pavlik, Cen, Koedinger, 2009
  – ELO Rating System
    Pelánek, 2014
  – Item Response Theory

Student modeling and its context
Bayesian Knowledge Tracing (BKT)

- BKT is a model used to infer student’s knowledge given their history of responses to problems and can be used to predict future performance.

- BKT is a two state Hidden Markov Model, these states being the one in which the student knows a given skill, and the one where the student does not. Once the student knows a skill, it will not be forgotten.

- Usually, a separate BKT model is fit for each skill and only the first attempt at each question is taken for each student.
Not Learned \( \xrightarrow{T} \) Learned \( L_t \)

Incorrect Answer \( \xleftarrow{G} \) Correct Answer

Knowledge World
Not observable

Performance World
Observable
• ... So in general ...

Image from Millan, Loboda, Perez-de-la-Cruz, 2010
Where,

- $L_0$, the probability a student knows the skill before attempting the first problem,
- $T$, is the transition probability at each practice opportunity,
- $G$, the probability of Guessing
- $S$, the probability of Slipping
- $L_t$ is the probability of knowing a skill at the “time-attempt” point $t$
- $C_{t+1}$ is the probability of answering correctly the next question
### Skill: Calculate the median

$L_0 = 0.25 \quad T = 0.2 \quad S = 0.15 \quad G = 0.1$

| Student | Right | $L_t$ | $P(L_{t-1} | \text{Action}_t)$ | $C_{t+1}$ |
|---------|-------|------|-------------------------------|----------|
| Student 1 | 0 | 0.230 | 0.038 | 0.323 |
| Student 1 | 1 | 0.714 | 0.642 | 0.685 |
| Student 1 | 1 | 0.950 | 0.937 | 0.862 |
| Student 1 | 0 | 0.752 | 0.690 | 0.714 |
| Student 1 | 1 | 0.958 | 0.948 | 0.869 |
• **ASSISTments**: (https://www.assistments.org/) This intelligent tutor developed by the Worcester Polytechnic Institute is used by more than 600 teachers from 42 American states and 14 countries and their students solved $10^6$ problems in 2015.

Where is Student modeling being used?
Cognitive tutors from Carnegie Learning Inc: Spin-off from Carnegie Mellon University

Over 500,000 students per year

The Algebra Tutor is being used by more than 17,000 students in 147 schools

Where is Student modeling being used?
Outline maps from Masaryk University Brno
Thanks for your attention
Questions?

Thanks for your support