Learning Goals

- Understand how knowledge tracing can be used to support learning
- Understand and create a scenario where the assumptions of knowledge tracing are met
- Recognize the parameters and formula of BKT
- Apply knowledge tracing to find the weights of the parameters
- Recognize enhancements and variations of knowledge tracing
How can we assess learning besides at tests?

- Pretest/Posttest data
- Process Data
  - Eye tracking
  - Collaborative dialogues
  - Student actions while learning
What is knowledge tracing?

- Modeling student learning as the student engages in the learning process
- Tracks the learning of individual skills that the student is working to acquire
- Focus on Bayesian Knowledge Tracing (BKT)
  - Introduced in 1995 (Corbett & Anderson)
  - Uses Bayesian calculations to update a set of parameters every time new information is received
Predicting Future Performance
Predicting Future Performance
Predicting Future Performance

0 0 1 0 0 1 \cdots 1 ?
Predicting Future Performance

Next problem in the sequence
Posttest performance
Knowledge Versus Performance
Knowledge Versus Performance
When would you want to use knowledge tracing?
Assumptions of BKT

1. The observable action can be marked as correct or incorrect (Binary)
2. Each unit (e.g., step, problem) is associated with one skill
What is a skill?

\[
\frac{2}{5} + \frac{3}{9} = \frac{?}{?}
\]
What is a skill?

\[
\frac{2}{5} + \frac{3}{9} = ?
\]

- Adding fractions?
What is a skill?

\[
\frac{2}{5} + \frac{3}{9} = ?
\]

- Adding fractions?
- Having the correct numerator, having the correct denominator?
What is a skill?

\[
\frac{2}{5} + \frac{3}{9} = ?
\]

- Adding fractions?
- Having the correct numerator, having the correct denominator?
- Having the correct numerator, having the correct denominator, converting the denominators to a common term, recognizing when a conversion needs to be done?
Questions?
Exercise 1: Skill Decomposition

- Materials:
  - Problem examples
  - Transaction File
BKT Concept

- Infer the student’s knowledge based upon performance
- Assumptions
  - The skill is either learned or unlearned
  - A student cannot forget a skill
  - Each step is an opportunity for the student to learn the skill
  - Each action/exercise is labelled with just one skill
BKT Model Parameters

- Initial knowledge ($L_0$)
- Transfer (T)
- Slip (S)
- Guess (G)
Computing the likelihood of a sequence of observations

Evaluating the probability of observing correct answers

\[ P(\text{correct}_n) = P(L_n)(1 - P(S)) + (1 - P(L_n))P(G) \]
Computing the likelihood of a sequence of observations

Using bayesian updates given the observation at each step

\[ P(L_n|\text{correct}_n) = \frac{P(L_n)(1 - P(S))}{P(\text{correct}_n)} \]

\[ P(L_n|\text{incorrect}_n) = \frac{P(L_n)P(S)}{P(\text{incorrect}_n)} \]
Computing the likelihood of a sequence of observations

Using probability of transition

\[ P(L_{n+1}) = P(L_n) + (1 - P(L_n))P(T) \]
Exercise 2.1: Computing the likelihood of a sequence of observations

Exercise available from moodle
Knowledge Versus Performance

\[ p_L = 0.2 \]
\[ p_T = 0.1 \]
\[ p_G = 0.5 \]
\[ p_S = 0.05 \]
Knowledge Versus Performance

\[ p_L = 0.2 \]
\[ p_T = 0.1 \]
\[ p_G = 0.5 \]
\[ p_S = 0.05 \]
Exercise 2.2: Computing the most likely sequence of knowledge states

Exercise available from moodle
BKT Model Parameters

- Initial knowledge ($L_0$)
- Transfer (T)
- Slip (S)
- Guess (G)
Methods of Fitting Parameters

● Grid Search
  ○ Brute force: testing all possible set of parameters and computing the likelihood
  ○ Gives the optimal parameters

● Expectation Maximization
  ○ Iterative: Alternates between computing the most likely hidden state sequence and estimating the parameters
  ○ Can give suboptimal sets of parameters
Exercise 2.3: Computing the model parameters from observations of multiple students

Exercise available from moodle
Questions?
Tools

- Bayes Net Toolkit – Student Modeling
  - Expectation Maximization

- Java Code
  - Grid Search/Brute Force
  - [http://users.wpi.edu/~rsbaker/edmtools.html](http://users.wpi.edu/~rsbaker/edmtools.html)
Extensions/Variations

- Individual differences
- Difficulty
- Partial credit
- Dependencies between skills
- Forgetting
Questions?
Learning Goals - Check Understanding

- Understand how knowledge tracing can be used to support learning
- Understand and create a scenario where the assumptions of knowledge tracing are met
- Recognize the parameters and formula of BKT
- Apply knowledge tracing to find the weights of the parameters
- Recognize enhancements and variations of knowledge tracing
Exercise 3: How would you apply BKT to your project?

- **With your group:**
  - Consider the activities that you are having students engage in, are any appropriate for knowledge tracing?
  - If yes, what would be the step level that you would want to trace? What are the knowledge components that are involved?
  - If no, how could you adapt one of your activities allow for knowledge tracing? What would be the step level that you would want to trace? What are the knowledge components that are involved?

- **You do not need to use this method in your projects.**