Week 8 Video 4

Hidden Markov Models
Markov Model

- There are N states
- The agent or world (example: the learner) is in only one state at a time
- At each change in time, the system can change state
- Based on the current state, there is a different probability for each next state
Markov Model Example

A

B

C

0.3

0.3

0.5

0.7

0.4

0.1

0.2

0.2

0.1
Markov Model Example
Markov Assumption

- For predicting the next state, only the current state matters
- Often a wrong assumption
- But a nice way to simplify the math and reduce overfitting!
Hidden Markov Model (HMM)

- There are $N$ states
- The world (or learner) is in only one state at a time
- We don’t know the state for sure, we can only infer it from behavior(s) and our estimation of the previous state

- At each change in time, the system can change state
- Based on the current state, there is a different probability for each next state
Hidden Markov Model Example
We can estimate the state

- Based on the behaviors we see
- Based on our estimation of the previous state

- What is the probability that the state is $X$, given
  - the probability of the behavior seen
  - the probability of each possible prior state
  - the probability of the transition to $X$ from each possible prior state
A Simple Hidden Markov Model: Bayesian Knowledge Tracing
Hidden Markov Model: BKT

- There are 2 states

- The world (or learner) is in only one state at a time: KNOWN OR UNKNOWN

- We don’t know the state for sure, we can only infer it from CORRECTNESS and our estimation of the previous probability of KNOWN versus UNKNOWN

- At each change in time, the system can LEARN

- Based on the current state, there is a different probability for each next state
  - P(T) of going KNOWN from UNKNOWN
  - KNOWN from KNOWN
Fitting BKT is hard...

- Fitting HMMs is no easier
  - Often local minima

- Several algorithms are used to fit parameters, including EM, Baum-Welch, and segmental k-Means

- Our old friends BiC and AIC are typically used to choose number of nodes
Other examples of HMM in education
Predicting Transitions Between Student Activities (Jeong & Biswas, 2008)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Student Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edit Map (EM)</td>
<td>adding, modifying, or deleting concepts and links</td>
</tr>
<tr>
<td>Ask Query (AQ)</td>
<td>asking Betty queries</td>
</tr>
<tr>
<td>Request Quiz (RQ)</td>
<td>asking Betty to take the quiz</td>
</tr>
<tr>
<td>Resource Access (RA)</td>
<td>accessing the resources</td>
</tr>
<tr>
<td>Request Explanation (RE)</td>
<td>asking Betty for an explanation to her query answer</td>
</tr>
<tr>
<td>Continue Explanation (CE)</td>
<td>asking Betty to provide a more detailed explanation</td>
</tr>
<tr>
<td>Quiz Denied (QD)</td>
<td>asking Betty to take the quiz without adequate preparation</td>
</tr>
<tr>
<td>Quiz Taken (QT)</td>
<td>asking Betty to take the quiz with adequate preparation</td>
</tr>
</tbody>
</table>
Studying patterns in dialogue acts between students and (human) tutors

- (Boyer et al., 2009)

- 5 states
  - 0: Tutor Lecture
  - 4: Tutor Lecture and Probing
  - 3: Tutor Feedback
  - 1: Student Reflection
  - 2: Grounding
A powerful tool

- For studying the transitions between states and/or behaviors

- And for estimating what state a learner (or other agent) is in
Next lecture

- Conclusions and Future Directions