CSCE 624 Sketch Recognition
Fall 2019
Assignment 3

Due: 10/15/2019 2pm CT

Overview

In this third homework assignment, we'll consider a powerful and versatile machine learning algorithm, the **HIdden Markov Model**. HMMs are based on Markov chains, which are sequences of states governed by transition probabilities, but HMMs rely on external observations to determine the most likely sequence of states.

A detailed tutorial on HMMs is available here.

Assignment Instructions

1. HMM Implementation
    a. You will need to implement an HMM in code using NodeJS. Starter code to help with reading input data is provided on eCampus.
        i. Specifically, you should write functions to perform both forward and backward chaining using the Viterbi algorithm.
        ii. Pruning, while not directly evaluated, could be applied to optimize your algorithm.
    b. You will implement the hmm function in hmm.js.
        i. The function takes as input the states, emissions, and associated probabilities as well as the direction and a list of observations.
        ii. Remember that backward chaining will require using the reverse observation order.
    c. Your program will need to return a nested array where each entry contains the most likely sequence of states *after* ***each*** *observation*. The first element in the array will be an array of just 1 state. The second element in the array will be an array of 2 states, etc.
2. Report

    Your report should be written in LaTeX (see www.overleaf.com for an easy to use, online LaTeX editor) and contain the following sections

a. Discuss the intuition of HMMs and how they can be applied to sketch recognition, plus one or two other domains.
b. What are some pros and cons of HMMs?
c. When might using a HMM be a good idea? When might it be a bad idea?

3. Submission

You should submit a zip file of the following files. The zip should be named lastName_firstName_UIN_HW3.zip where you use your info. For example, John Smith with a UIN 123001234 would name their zip Smith_John_123001234_HW3.zip

a. hmm.js
b. lastName_firstName_UIN_report.pdf

Your submission should be made to eCampus by the due date at the top of these instructions.

Example Input and Output

Input

```
{
  "states": ["Rainy", "Sunny"],
  "emissions": ["Walk", "Shop", "Clean"],
  "start_probabilities": {"Rainy": 0.6, "Sunny": 0.4},

  "transition_probabilities": {"Rainy": {"Rainy": 0.7, "Sunny": 0.3},
"Sunny": {"Rainy": 0.4, "Sunny": 0.6}},

  "emission_probabilities": {"Rainy": {"Walk": 0.1, "Shop": 0.4,
"Clean": 0.5}, "Sunny": {"Walk": 0.6, "Shop": 0.3, "Clean": 0.1}},

  "direction": "forward",
  "observations": ["Walk", "Shop", "Clean"]
}
```

Output

```
[
  ["Sunny"],
  ["Sunny", "Sunny"],
  ["Sunny", "Rainy", "Rainy"]
]
```

input

```
{
  "states": ["A", "E", "I", "O", "U"],
  "emissions": ["Flat", "Open", "Circle"],
  "start_probabilities": {"A": 0.6, "E": 0.1, "I": 0.1, "O": 0.1,
"U": 0.1},

  "transition_probabilities": {"A": {"A": 0.4, "E": 0.3, "I": 0.1,
"O": 0.1, "U": 0.1}, "E": {"A": 0.2, "E": 0.2, "I": 0.4, "O": 0.1,
"U": 0.1}, "I": {"A": 0.2, "E": 0.1, "I": 0.2, "O": 0.2, "U": 0.3},
"O": {"A": 0.2, "E": 0.1, "I": 0.1, "O": 0.2, "U": 0.4}, "U": {"A":
0.5, "E": 0.1, "I": 0.1, "O": 0.1, "U": 0.2}},

  "emission_probabilities": {"A": {"Flat": 0.6, "Open": 0.1,
"Circle": 0.3}, "E": {"Flat": 0.6, "Open": 0.1, "Circle": 0.3}, "I":
{"Flat": 0.2, "Open": 0.7, "Circle": 0.1}, "O": {"Flat": 0.1, "Open":
0.2, "Circle": 0.7}, "U": {"Flat": 0.1, "Open": 0.2, "Circle": 0.7}},

  "direction": "forward",
  "observations": ["Flat", "Open", "Open", "Closed"]
}
```

output

```
[
  ["A"]
  ["A", "I"]
  ["A", "I", "I"]
  ["A", "I", "I", "U"]
]
```

input

```
{
  "states": ["A", "E", "I", "O", "U"],
  "emissions": ["Flat", "Open", "Circle"],
  "start_probabilities": {"A": 0.6, "E": 0.1, "I": 0.1, "O": 0.1,
"U": 0.1},

  "transition_probabilities": {"A": {"A": 0.4, "E": 0.3, "I": 0.1,
"O": 0.1, "U": 0.1}, "E": {"A": 0.2, "E": 0.2, "I": 0.4, "O": 0.1,
"U": 0.1}, "I": {"A": 0.2, "E": 0.1, "I": 0.2, "O": 0.2, "U": 0.3},
"O": {"A": 0.2, "E": 0.1, "I": 0.1, "O": 0.2, "U": 0.4}, "U": {"A":
0.5, "E": 0.1, "I": 0.1, "O": 0.1, "U": 0.2}},

  "emission_probabilities": {"A": {"Flat": 0.6, "Open": 0.1,
"Circle": 0.3}, "E": {"Flat": 0.6, "Open": 0.1, "Circle": 0.3}, "I":
{"Flat": 0.2, "Open": 0.7, "Circle": 0.1}, "O": {"Flat": 0.1, "Open":
0.2, "Circle": 0.7}, "U": {"Flat": 0.1, "Open": 0.2, "Circle": 0.7}},

  "direction": "backward",
  "observations": ["Flat", "Open", "Closed", "Closed"]
}
```

output

```
[
  ["O"]
  ["O", "U"]
  ["I", "O", "U"]
  ["E", "I", "O", "U"]
]
```