

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