E9 205 – Machine Learning for Signal Processing

Homework # 3
Due date: March. 23, 2022

Analytical in writing and report scanned and submitted.
Source code also need to be included.
Name of file should be "Assignment3_FullName.pdf" submitted to teams channel.
Assignment should be solved individually without consent.

March 15, 2022

1. **Lucky at Casino** - Tejas visits a casino to play the die game which is the following. He bets Rs z and rolls a fair die. The house matches his bet. Megha, who is the casino host, picks another die from a pack of two dice. This pack contains

   - a fair die $P(i) = 1/6$ where $i = 1, .., 6$ and,
   - a loaded die $P(i) = 1/10$ for $i = 1, .., 5$ and $P(i = 6) = 1/2$.

   Each time Megha can keep her current die with a probability of 0.9 or switch to a new die with a probabilty of 0.1. She also has a equal probability of picking the fair or loaded die initially. After Tejas rolls his die, Megha rolls her die. The house wins if Megha's die has the higher value among them or if it is a tie (in which case Tejas loses his money). On the other hand, if Tejas's die has a higher value than Megha's, he wins and gets back Rs $2z$. In his chance, Tejas rolls his die twice and gets values 2 and 3. What is the probability that he bets Rs 100 and wins back Rs 400. (**Points 20**)

2. **Discrete HMM** - Leela is doing a term project on using HMMs as a generative model. She uses a two state discrete HMM. She assumes a simple model with self transition probabilities $a_{11} = 0.8$ and $a_{22} = 0.8$ and initial probability of $\pi_1 = 0.6$. Further, the HMM emits only binary symbols with $b_1(1) = 0$ and $b_2(1) = 1$. Let o_t indicate the symbol emitted at time t. In one of the experiments, she observes $o_3 = 0, o_4 = 0, o_5 = 1$. Find the probability of this observation sequence ? (**Points** 5)

   (**Points 20**)

3. **Implementing HMM** - A set of training and test examples of music and speech are provided.
   $http://www.leap.ee.iisc.ac.in/sriram/teaching/MLSP22/assignments/speechMusicData.tar.gz$

   Using these examples,

   a Generate spectrogram features - Use the log magnitude spectrogram as before with a 64 component magnitude FFT (NFFT). In this case, the spectrogram will have dimension 32 times the number of frames (using 25 ms with a shift of 10 ms).

b Perform a K-means clustering on the spectrogram with $K = 8$ (using both speech and music data) and cluster the spectrogram features into discrete symbols.

c Using a Hidden Markov Model with following definition,

$$\pi = [0.5\ 0.5\ 0.0] \tag{1}$$

$$A = \begin{bmatrix} 0.6 & 0.4 & 0.0 \\ 0.3 & 0.5 & 0.2 \\ 0.0 & 0.1 & 0.9 \end{bmatrix} \tag{2}$$

$$B = \begin{bmatrix} 0.25 & 0.25 & 0.25 & 0.25 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.125 & 0.125 & 0.125 & 0.125 & 0.125 & 0.125 & 0.125 & 0.125 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.5 & 0.5 & 0.0 \end{bmatrix} \tag{3}$$

a Write a code to implement the likelihood computation using the forward variable. Take any speech file and any music file (at random), find the likelihood under the model. Which file is more likely under this model ?

b Write a code to implement the likelihood computation using the backward variable. For the same speech and music files chosen in [a], find the likelihood under the model. Does the forward and backward approach give the same likelihood ?

c For the files chose, write a code to implement the Viterbi algorithm to decode the best state sequence using the given HMM definition.

c Using the above HMM model as initialization, perform the Baum-Welch reestimation method to train HMMs with all the HMM training examples for speech and for music (two different HMMs). Show the plot of the likelihood at each training iteration. Does the EM algorithm improve the likelihood at each iteration ?

d Classify the test examples and report the performance.

(**Points** 10 + 10 + 25 + 15 = 60 marks)