Assignment 4 - AI

Anushka Ajay Ahire
19111011
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Hidden Markov model

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1 Introduction

Hidden Markov Model (HMM) is a statistical Markov model in which the system being modeled is assumed to be a Markov process – call it **X** – with unobservable ("hidden") states. HMM assumes that there is another process **Y** whose behavior "depends" on **X**.
Let Xn and Yn be discrete-time stochastic processes and $n >= 1$ The pair (Xn, Yn) is a hidden Markov model if:

- Xn is a Markov process whose behavior is not directly observable ("hidden")
- P(Y_n ϵ A—$X_1 = x_1$ ......$X_n = x_n$) = P(Y_n ϵ A, $X_n = x_n$)

2 Examples:

- Drawing balls from hidden urns In its discrete form, a hidden Markov process are often visualized as a generalization of the urn problem with replacement where each item from the urn is returned to the first urn before subsequent step. The Markov process itself can't be observed, only the sequence of labelled balls, thus this arrangement is named a hidden Markov process.
- Weather Guessing Game Consider two friends, Alice and Bob, who live far aside from one another and who talk together daily over the

phonephone about what they did that day. Bob is merely curious about three activities: walking within the park, shopping, and cleaning his apartment. the selection of what to try to to is decided exclusively by the weather on a given day. Alice has no definite information about the weather, but she knows general trends. supported what Bob tells her he did every day , Alice tries to guess what the weather must are like. Alice believes that the weather operates as a discrete Markov chain . There are two states, "Rainy¨and "Sunny", but she cannot observe them directly, that is, they're hidden from her. On every day , there's a particular chance that Bob will perform one among the subsequent activities, counting on the weather: "walk", "shop", or "clean". Since Bob tells Alice about his activities, those are the observations. the whole system is that of a hidden Markov model (HMM).

3 Structural architecture

In the standard type of hidden Markov model considered here, the state space of the hidden variables is discrete, while the observations themselves can either be discrete or continuous. The parameters of a hidden Markov model are of two types, transition probabilities and emission probabilities (also known as output probabilities). The transition probabilities control the way the hidden state at time t is chosen given the hidden state at time $t-1$

The hidden state space is assumed to consist of one of N possible values, modelled as a categorical distribution. This means that for each of the N possible states that a hidden variable at time t can be in, there is a transition probability from this state to each of the N possible states of the hidden variable at time $t+1$ for a total of N^2 transition probabilities. Note that the set of transition probabilities for transitions from any given state must sum to 1. Thus, the NxN matrix of transition probabilities is a Markov matrix. Because any one transition probability can be determined once the others are known, there are a total of $N(N-1)$ transition parameters.

In addition, for each of the N possible states, there is a set of emission probabilities governing the distribution of the observed variable at a particular time given the state of the hidden variable at that time. The size of this set depends on the nature of the observed variable. For example, if the observed variable is discrete with M possible values, governed by a categorical distribution, there will be $(M-1)$ separate parameters, for a total of $N(M-1)$ emission parameters over all hidden states. On the other hand, if the observed variable is an M-dimensional vector distributed according to

an arbitrary multivariate Gaussian distribution, there will be M parameters controlling the means and $M(M+1)/2$ parameters controlling the covariance matrix, for a total of
$N\left(M+\frac{M(M+1)}{+}2\right)=\frac{NM(M+3)}{2}=O(NM2) emission parameters.$

4 Applications:

Hidden Markov Model can be applied in many fields where the goal is to recover a data sequence that is not immediately observable. Applications include: Computational finance, Single-molecule kinetic analysis, Cryptanalysis Speech recognition, including Siri, Speech synthesis, Part-of-speech tagging, Document separation in scanning solutions Machine translation, Partial discharge, Gene prediction, Handwriting recognition, Alignment of bio-sequences, Time series analysis, Activity recognition, Protein folding, Sequence classification, Metamorphic virus detection, DNA motif discovery, DNA hybridization, kinetics, Chromatin state discovery,Transportation forecasting Solar irradiance variability