Anomaly Detection Homework 7

Vishal Bhalla Matriculation No: 03662226
Nithish Raghunandanan Matriculation No: 03667351

Belief Propagation 2 - Hidden Markov Models (HMM)

January 17, 2016

1. What is the graphical representation of Hidden Markov Model? Draw a corresponding Bayesian Network graph.

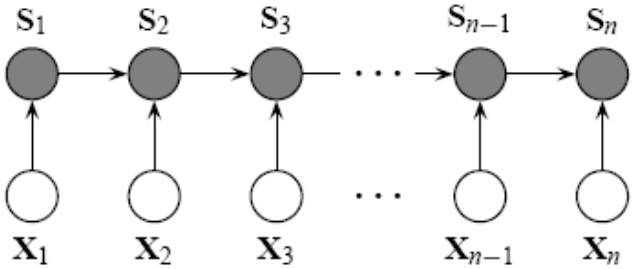

Figure 1: HMM Graphical Model

A representation of a n-state HMM as a graphical model and its corresponding Bayesian Network graph is shown in fig. 1. Each vertical slice represents a time step. The top node represents the s_t variable and the bottom node represents the observable x_t variable. The transition probabilities a_{ij} are the components of the A matrix.

2. How is Hidden Markov Model related to Markov Chains? What advantages does the HMM bring?

A statistical model that has states and known probabilities of the state transitions is called a Markov model. In such a Markov model, the states are visible to the observer. In contrast, a hidden Markov model (HMM) has states that are not directly observable. The. HMM acts as a state machine. Every state is associated with a probability

distribution for observing a set of observation symbols. The transition between the states have fixed probabilities.

3. Describe shortly how we can do Inference and Learning with HMMs (no need to write the exact algorithms).

   Inference and Learning can be performed in an HMM using the well-known forward-backward algorithm.

   The forward-backward algorithm computes the posterior marginals of all hidden state variables given a sequence of observations/emissions $o_{1:t} := o_1, \ldots, o_t$, i.e. it computes, for all hidden state variables $X_k \in \{X_1, \ldots, X_t\}$, the distribution $P(X_k \mid o_{1:t})$. This inference task is usually called smoothing. The algorithm makes use of the principle of dynamic programming to compute efficiently the values that are required to obtain the posterior marginal distributions in two passes. The first pass goes forward in time while the second goes backward in time; hence the name forward-backward algorithm.

   In the forwards pass, we recursively compute the filtered estimate $\alpha_t(i) = P(X_t = i \mid y_{1:t})$, and in the backwards pass, we recursively compute the smoothed estimate $\gamma_t(i) = P(X_t = i \mid y_{1:t})$ and the smoothed two-slice estimate $\xi_{t-1,t|T}(i,j) = P(X_{t-1} = i, X_t = j|y_{1:T})$ which is needed for learning.

4. Name 3 concrete applications where modelling with HMMs is useful.

   (a) Malware and Internet Traffic Classification

   (b) Human identification using Gait

   (c) Gene finding and Prediction of protein secondary structure using HMMs