Probabilistic Reasoning

Unit # 1

Course Outline

- Knowledge Representation
- Modeling and Reasoning with Bayesian Networks
- Handling Knowledge Acquisition Issues
- Belief Updating in Singly and Multiply Connected Networks
- Dynamic Bayesian Networks and their Variants
- Parameter and Structure Learning
- Papers Reading (a lot of them!)

Useful Information

- Course Wiki
  - http://cse655fall2012.wikispaces.com
- Software Tools
  - **GeNIe** (http://genie.sis.pitt.edu/)
  - Netica (http://www.norsys.com/netica.html)
  - Hugin (http://www.hugin.com/)
  - Bayesian PowerConstructor (http://webdocs.cs.ualberta.ca/~jcheng/bnpc.htm)
  - **IBAYes** (http://ailab.iba.edu.pk/ibayes.html)

Reference Books

- K.B. Korb and A.E. Nicholson, Bayesian Artificial Intelligence, Chapman & Hall/CRC, 2003.
- R.E. Neapolitan, Learning Bayesian Networks, Prentice Hall, 2003.
- U.B. Kjaerulff and A.L. Madsen, Bayesian Networks and Influence Diagrams: A Guide to Construction and Analysis, Springer, 2007.
- A. Mittal, Bayesian Network Technologies: Applications and Graphical Models, IGI Publishing, 2007.
- F.V. Jensen and T.D. Nielsen, Bayesian Networks and Decision Graphs, Springer, 2007.
- O. Pourret, P. Naïm, and B. Marcot, Bayesian Networks: A Practical Guide to Applications, Wiley, 2008.
- R.E. Neapolitan and X. Jiang, Probabilistic Methods for Bioinformatics: With an Introduction to Bayesian Networks, Morgan Kaufmann Publishers, 2009.

Marks Distribution (Tentative)

• 2 Midterms (15 marks each)	30
• Final	40
• Term Paper	20
• Assignment/Presentation	10

Previous Offering

- Papers published by Students
  - Asma Larik and Sajjad Haider, Efforts to Blend Ontology with Bayesian Networks: An Overview, In Proceedings of 3rd International Conference on Advanced Computer Theory and Engineering, Chendgu, China, 2010.
  - Quratulain Rajput and Sajjad Haider, A Comparison of Two Ontology based Semantic Annotation Frameworks, Advances in Information and Communication Technologies, 33, 2010, pp. 187 – 194.
  - Raza H. Abedi, Sayeed Ghani and Sajjad Haider, Selection of Cluster Heads in Wireless Sensor Networks using Bayesian Network, In Proceedings of International Conference on Computer, Electrical, Systems, Science and Engineering , Amsterdam, Netherlands, 2010
  - Saleha Raza and Sajjad Haider, Modeling First-Order Bayesian Networks (FOBN) - A Comparative Study of BLOG, BLP and MEBN, In Proceedings of 3rd International Conference on Advanced Computer Theory and Engineering, Chendgu, China, 2010.
- IBAYes
  - A probabilistic reasoning tool was developed and launched by two students (Asma and Saleha) of Fall 2009 class.

Conditional Independence

- Two events A and B are independent if knowing that A has happened does not say anything about B happening.

$$P(A\ B) = P(A)\ P(B)$$
$$P(A \mid B) = P(A)$$

- Two events A and B are conditionally independent given a third event C precisely if the occurrence or non-occurrence of A and B are independent events in their conditional probability distribution given C.

$$P(A\ B \mid C) = P(A \mid C)\ P(B \mid C)$$
$$P(A \mid B\ C) = P(A \mid C)$$

Bayes Theorem

- $P(A \mid B) = \dfrac{P(B \mid A)\ P(A)}{P(B)}$

$$= \frac{P(B \mid A)\ P(A)}{P(B|A)P(A)+P(B|\neg A)P(\neg A)}$$

- P(A) is the prior probability and P(A | B) is the posterior probability.

- Suppose events $A_1, A_2, \ldots\ldots, A_k$ are mutually exclusive and exhaustive; i.e., exactly one of the events must occur. Then for any event B:

$$P(A_i \mid B) = \frac{P(B \mid A_i)\ P(A_i)}{\sum P(B \mid A_i)\ P(A_i)}$$

Example I

- According to American Lung Association, 7% of the population has lung cancer. Of these people having lung disease, 90% are smokers; and of those not having lung disease, 25.3% are smokers.
- Determine the probability that a randomly selected smoker has lung cancer.

Example I Solution

- Let L = Lung Cancer, S = Smoker
- Given that
  - P(L) = 0.07
  - P(S | L) = 0.90 P(~S | L) = 0.10
  - P(S | ~L) = 0.253 P(~S | ~L) = 0.747
- Find probability, P(L | S)

$$P(L|S) = \frac{P(S \cap L)}{P(S)} = \frac{P(S|L)P(L)}{P(S|L)P(L) + P(S|\sim L)P(\sim L)}$$

$$P(L|S) = \frac{0.9 \times 0.07}{0.9 \times 0.07 + 0.253 \times 0.93}$$

Example II

- Assume that about 1 in 1000 individuals in a given organization have committed a security violation.
- Assume that the **sensitivity** of a routine screening polygraph is about 85%. That is, the probability that the polygraph report will indicate a concern is about 85% if the individual has committed a security violation.
- Assume the **specificity** of the polygraph is about 80%. That is, if the individual has not committed a security violation, there is about an 80% chance that the polygraph report will not indicate a concern.
- What is the posterior probability that an individual whose polygraph report indicates a concern has committed a security violation?

Example II Solution

- Let
  - S = Security Violation Committed,
  - T = Test Positive
- Given that
  - P(S) = 0.001
  - P(T | S) = 0.85 P(~T | S) = 0.15
  - P(T | ~S) = 0.20 P(~T | ~S) = 0.80
- Find probability, P(S | T)

$$P(S|T) = \frac{P(T|S)P(S)}{P(T|S)P(S) + P(T|{\sim}S)P({\sim}S)}$$

$$P(T|S) = \frac{0.85\ x\ 0.001}{0.85\ x\ 0.001 + 0.20\ x\ 0.999}$$

Example III

- Suppose that Bob can decide to go to work by one of three modes of transportation, car, bus, or commuter train. Because of high traffic, if he decides to go by car, there is a 50% chance he will be late. If he goes by bus, which has special reserved lanes but is sometimes overcrowded, the probability of being late is only 20%. The commuter train is almost never late, with a probability of only 1%, but is more expensive than the bus.
- Suppose that Bob is late one day, and his boss wishes to estimate the probability that he drove to work that day by car. Since he does not know which mode of transportation Bob usually uses, he gives a prior probability of 1/3 to each of the three possibilities. What is the boss' estimate of the probability that Bob drove to work?