Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 6.017

IJCSMC, Vol. 6, Issue. 5, May 2017, pg.344 – 346

The Bayesian Belief Network for Inference

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Abstract— The Bayesian Belief Network is a probabilistic model based on probabilistic dependencies. It is used for reasoning and finding the inference in uncertain situations. That is, Bayesian Belief Networks can be used to make future predications and explaining the observations. It is used to represent the probabilistic relationship between among multiple events. It is represented by directed acyclic graph(DAG). Each node has conditional probability table. The probability for the chain of variables can be found using conditional probability table. It is based on Bayes theorem.

Keywords— Bayesian Belief Network, Bayes theorem, Conditional probability, Event, Inference.

I. INTRODUCTION

A Bayesian network (or a belief network) is a probabilistic graphical model. This model represents a set of variables and their probabilistic dependencies. Bayesian Belief Networks provide the modelling and reasoning about the uncertainty. Bayesian Belief Networks cover both subjective probabilities and probabilities based on objective data. For example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms. Given symptoms, the network can be used to compute the probabilities of the presence of various diseases. A belief network, also called a Bayesian network, is an acyclic directed graph (DAG), where the nodes are random variables. If there is an arc from node A to another node B, A is called a parent of B, and B is a child of A. The set of parent nodes of a node Xi is denoted by its parents (Xi). Thus, a belief network consists of

I. a DAG, where each node is labelled by a random variable;
II. a domain for each random variable; and
III. a set of conditional probability distributions giving P(Xi|parents(Xi)).

Full joint distribution is defined in terms of local conditional distributions as

$$P(X_1, X_2, \ldots\ldots, Xn) = \prod_{i=1}^{n} (P(Xi \mid Parents(Xi))$$

If node Xi has no parents, its local probability distribution is said to be unconditional, otherwise it is conditional. If the value of a node is observed, then the node is said to be an evidence node. Each variable is associated with a conditional probability table which gives the probability of this variable for different values of its parent nodes.

The value of

$P(X_1, ..., Xn)$

for a particular set of values for the variables can be easily computed from the conditional probability table.

II. MODELING BAYESIAN BELIEF NETWORK

Consider the five events M, N, X, Y, and Z. Each event has a conditional probability table. The events M and N are independent events i. e. they are not influenced by any other events. The conditional probability table for X shows the probability of X, given the conditions of the events M and N i. e. true or false. The event X occurs if event M is true. The event X also occurs if event N does not occur. The events Y and Z occur if the event X does not occur. The following figure shows the belief network for the given situation.

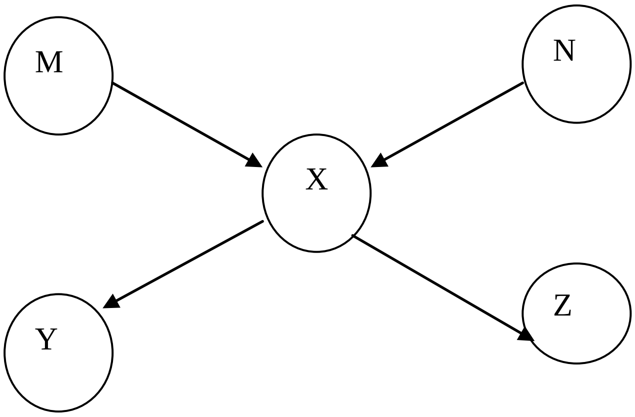

Figure 1: Bayesian Belief Network

The conditional probabilities for various events are given below in tables.

TABLE I

Conditional probability for event M

P(M)	0.5

TABLE II

Conditional probability for event N

P(N)	0.4

TABLE III

Conditional probability for event X

P(X|M and N)	M	N
0.2	T	T
0.8	T	F
0.0	F	T
0.2	F	F

TABLE IV

Conditional probability for event Y

P(Y|X)	X
0.0	T
0.7	F

TABLE V

Conditional probability for event Z

P(Z|X)	X
0.0	T
0.8	F

III. REASONING AND INFERENCE

Suppose we want to know the probability that event M does not occur , event N occurs, event Y occurs and event Z does not occur, the we want the probability P(¬M, ¬N, Y, ¬Z). This can be given by P (¬M) × P (¬N) × P (X | ¬M and ¬N) × P (¬Z | X)

So using conditional probability table, we have

P(¬M, ¬N, Y, ¬Z) = 0.7 × 0.4 × 0.1 × 1.0 = 0.028

In general, the probability of any combination of variables like P (A_1, A_2, A_3, ...) can be obtained from the belief network using the conditional probability tables.
In modelling uncertainty with probabilities, we have to deal with mainly two types of complexities.

1) Space Complexity

To store full joint distribution requires to remember $o(d^n)$ numbers where n is the number of random variables and d is the number of values.

2) Inference complexity.

To compute some queries requires $o(d^n)$ steps.

IV. CONCLUSIONS

The Bayesian belief network is used to find the inference from probability distribution table. The probability of various variables depends of other conditionally dependent or independent variables. Independent variables probability does not depend on other variables in Bayesian belief network.

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