# Bayesian Belief Network

# Bayesian Belief Network:

A BBN (Bayesian Belief Network) is a computational model which is based on graph probability theory. The structure of BBN is represented by Direct Acyclic Graph (DAG). Formally, a DAG is a pair *(N, A)* where *N* is the node set and *A* is the arc set. If there are two nodes *u* and *v* belonging to *N* and there is an arc going from *u* to *v* then *u* is termed as parent of *v* and *v* is called child of *u*. In terms of cause-effect relationship u is cause and v is effect. A node can be a parent for another node whereas the same node can be child for a different node. For example:

b

v

u

a

a and b are parents of u and u is child for a and b whereas u is a single parent for v and with respect to cause- effect relationship a and b are direct causes of u and u is directly causing v whereas a and b are indirectly responsible for occurrence of v.

## Bayes Theorem:

For two random variables X and Y the following equation holds true.

Where P(X, Y) is called joint probability of X and Y. P(Y|X) and P(X|Y) are conditional probabilities and are read as probability of Y given X and probability of X given Y respectively. P(X) and P(Y) are marginal probabilities of X and Y. If X and Y are independent from each other then:

## Belief Propagation:

Evidence

**Posterior Belief**

Prior Belief

P(Y|D): A posterior, P(D|Y): Likelihood, P(Y): A Priori/ Belief, P(D): Evidence

## Joint Probability:

Given X1, X2,………,Xn are features (nodes) in a BBN. Then Joint probability is defined as:

## Marginal Probability:

Given the joint probability, marginal probability of Xi = x0 is calculated as:

# Constructing Discrete Bayesian Belief Network:

BBN can be constructed using only continuous variables, only categorical variables or mix of variables. We will discuss discrete BBN which is constructed using categorical variables only. There are two major components of constructing a Bayesian belief network. Structure Learning and Parameter Learning.

## Structure Learning:

Structure leaning is the basis of Bayesian Belief Network analysis. Effectiveness of the solution depends on the optimality of the learnt structure. We can use the following approaches:

1. One can use expert view and cerate the structure based on the domain knowledge.
2. Using machine learning algorithm, we can learn local optimal structure. Please note global optimal structure is NP -hard problem. There are many algorithms to learn the structure like, K2, hill climbing and tabu etc. Please refer to “bnlearn” package in R and the following link for Python packages. <http://pgmpy.chrisittner.de/>
3. Combination of both. Use machine learning technique to build the model and with the reduced set of explanatory variables use expert view or machine learning technique to create the structure. This is could be a quick and effective way.

## Parameter Learning:

Another major component of BBN is CPT (Conditional Probability Table). Since each node in the structure is a random variable it can take multiple values/ states. Each state will have some probability of occurrence. We call these probabilities as Beliefs. Also, each node is connected to other nodes in the network. As per the structure we learn the conditional probability of each state of a node. Tabular form of all such probabilities are called CPT.