Probabilistic reasoning in Artificial intelligence

- **Uncertainty:**
- Till now, we have learned knowledge representation using first-order logic and propositional logic with certainty, which means we were sure about the predicates.
- With this knowledge representation, we might write $A \rightarrow B$, which means if A is true then B is true, but consider a situation where we are not sure about whether A is true or not then we cannot express this statement, this situation is **called uncertainty.**
- So to **represent uncertain knowledge**, where we are not sure about the predicates, we **need uncertain reasoning or probabilistic reasoning.**

- **Causes of uncertainty:**
- Following are some leading causes of uncertainty to occur in the **real world.**

1. **Information occurred from unreliable sources.**
2. **Experimental Errors**
3. **Equipment fault**
4. **Temperature variation**
5. **Climate change.**

Probabilistic reasoning:

- Probabilistic reasoning is a way of knowledge representation where we apply the concept of probability to indicate the uncertainty in knowledge.
- In probabilistic reasoning, we combine probability theory with logic to handle the uncertainty.
- **Ex:** In the real world, there are lots of scenarios, where the certainty of something is not confirmed, such as "It will rain today," "behavior of someone for some situations," "A match between two teams or two players."
- These are probable sentences for which **we can assume that it will happen but not sure about it,** so here we use probabilistic reasoning.

- In probabilistic reasoning, there are **two ways to solve problems** with uncertain knowledge:

- **Bayes' rule**
- **Bayesian Statistics**

- **Probability:**
- Probability can be defined as a chance that an uncertain event will occur.
- It is the numerical measure of the likelihood that an event will occur.
- The value of probability always remains between 0 and 1 that represent ideal uncertainties.

- We can find the probability of an uncertain event by using the below formula.

$$\text{Probability of occurrence} = \frac{\text{Number of desired outcomes}}{\text{Total number of outcomes}}$$

- P(¬A) = probability of a not happening event.
- P(¬A) + P(A) = 1.

- **Conditional probability:**
- Conditional probability is a probability of occurring an event when another event has already happened.
- Let's suppose, we want to calculate the event A when event B has already occurred, "the probability of A under the conditions of B", it can be written as:

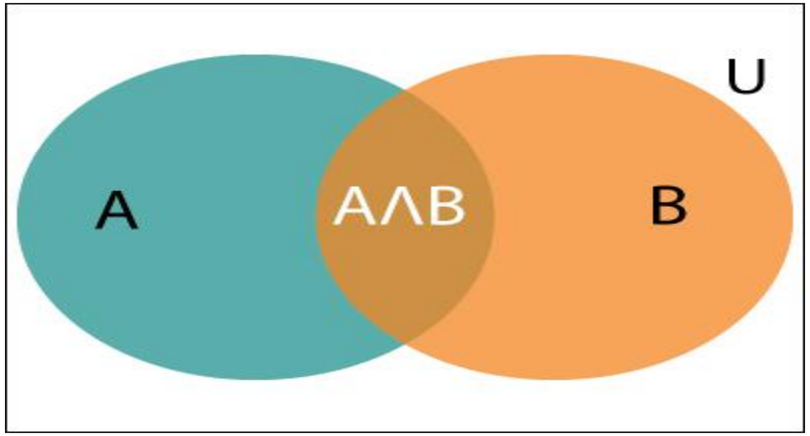
$$P(A|B) = \frac{P(A \wedge B)}{P(B)}$$

- **Where P(A⋀B)= Joint probability of a and B**
- **P(B)= Marginal probability of B.**

- If the probability of A is given and we need to find the probability of B, then it will be given as:

$$P(B|A) = \frac{P(A \land B)}{P(A)}$$

- It can be explained by using the below Venn diagram, where B is occurred event, so sample space will be reduced to set B, and now we can only calculate event A when event B is already occurred by dividing the probability of P(A⋀B) by P(B).



Example:[5 Marks]

- In a class, there are 70% of the students who like English and 40% of the students who likes English and mathematics, and then what is the percent of students those who like English also like mathematics?
- **Solution:**
- Let, A is an event that a student likes Mathematics
- B is an event that a student likes English.

$$P(A|B) = \frac{P(A \wedge B)}{P(B)} = \frac{0.4}{0.7} = 57\%$$

- **Hence, 57% are the students who like English also like Mathematics.**

Bayes' theorem

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)} \quad \text{....(a)}$$

- **Question:** what is the probability that a patient has diseases meningitis with a stiff neck?
- **Given Data:**
- A doctor is aware that disease meningitis causes a patient to have a stiff neck, and it occurs 80% of the time.
- He is also aware of some more facts, which are given as follows:

- The Known probability that a patient has meningitis disease is 1/30,000.
- The Known probability that a patient has a stiff neck is 2%.

- **Let a be the proposition that patient has stiff neck** and
- **b be the proposition that patient has meningitis**.
- so we can calculate the following as:

- **P(a|b) = 0.8**
- **P(b) = 1/30000**
- **P(a)= .02**

$$\mathbf{P(b\,|\,a)} = \frac{P(a|b)P(b)}{P(a)} = \frac{0.8*(\frac{1}{30000})}{0.02} = 0.001333333.$$

Bayesian Belief Network

- Bayesian belief network is key computer technology for dealing with probabilistic events and to solve a problem which has uncertainty.
- We can define a Bayesian network as:

- **"A Bayesian network is a probabilistic graphical model which represents a set of variables and their conditional dependencies using a directed acyclic graph."**

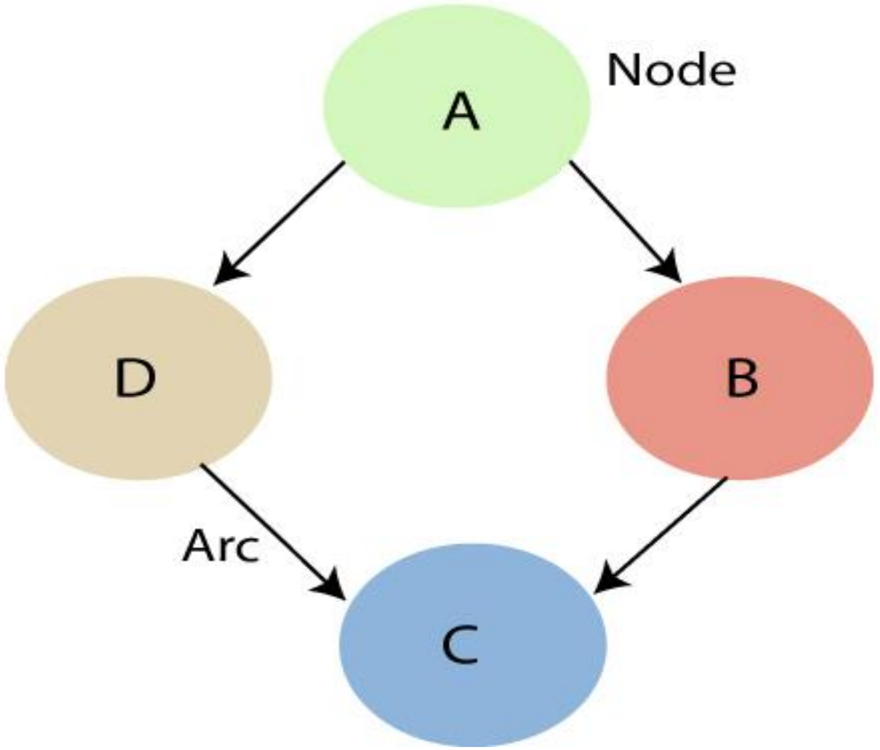
- It is also called a Bayes network, belief network, decision network, or Bayesian model.

- Bayesian networks are probabilistic, because these networks are **built from a probability distribution**, and also use probability theory for prediction and anomaly detection.

- Real world applications are probabilistic in nature, and to **represent the relationship between multiple events, we need a Bayesian network.**

- It can also be used in various tasks including **prediction, anomaly detection, diagnostics, automated insight, reasoning, time series prediction**, and **decision making under uncertainty**.

- Bayesian Network can be used for building models from data and experts opinions, and it consists of two parts:
- **Directed Acyclic Graph**
- **Table of conditional probabilities.**
- **A Bayesian network graph is made up of nodes and Arcs (directed links), where:**



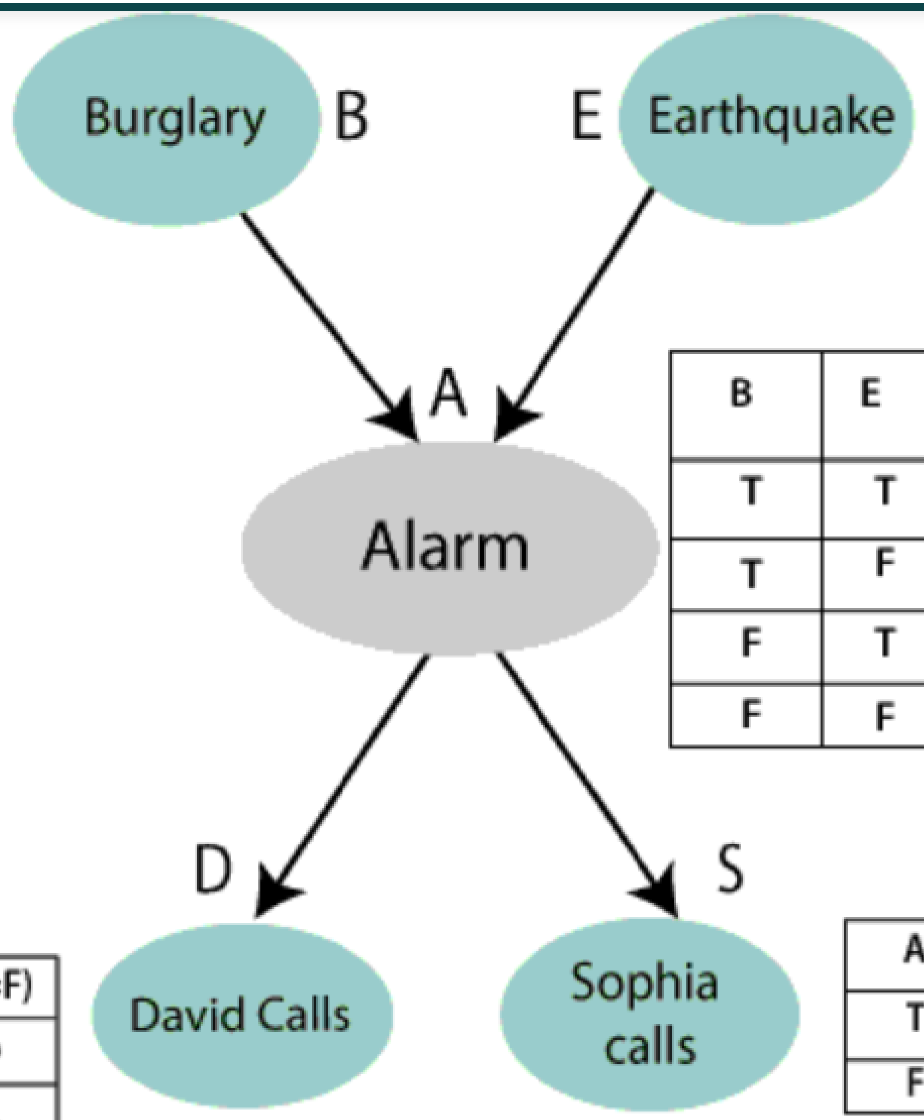
Key Components of BNN:

- A Bayesian belief network (BBN) is a graphical model that represents a set of variables and their probabilistic relationships. The key components include:

1. **Nodes**: Each node represents a random variable, which can be discrete or continuous.
2. **Directed Edges**: Arrows between nodes indicate the direction of influence or causation. An edge from node A to node B suggests that A has a direct effect on B.
3. **Conditional Probability Tables (CPTs)**: Each node has an associated CPT that quantifies the effects of its parent nodes. These tables specify the probability of the node given the values of its parent nodes.
4. **Joint Probability Distribution**: The network provides a compact representation of the joint probability distribution of all variables, allowing for efficient computation of probabilities.
5. **Inference Mechanism**: The ability to update beliefs about certain variables based on evidence observed in others, enabling reasoning under uncertainty.

Example:

T	0.002
F	0.998



T	0.001
F	0.999

B	E	P(A=T)	P(A=F)
T	T	0.94	0.06
T	F	0.95	0.04
F	T	0.69	0.69
F	F	0.999	0.999

A	P (D=T)	P (D=F)
T	0.91	0.09
F	0.05	0.95

A	P (S=T)	P (S=F)
T	0.75	0.25
F	0.02	0.98

P(S, D, A, ¬B, ¬E) = P (S|A) *P (D|A)*P (A|¬B ^ ¬E) *P (¬B) *P (¬E).

= 0.75* 0.91* 0.001* 0.998*0.999

= 0.00068045.

Hence, a Bayesian network can answer any query about the domain by using Joint distribution.