Introduction to Bayesian Networks

Understanding the Basics of Probabilistic Models

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What is a Bayesian Network?

- A Bayesian Network is a probabilistic graphical model that represents a set of variables and their conditional dependencies via a Directed Acyclic Graph (DAG).

- Analogy: A family tree but for probabilities.
- Also known as Bayesian Belief Networks or Bayes Nets.

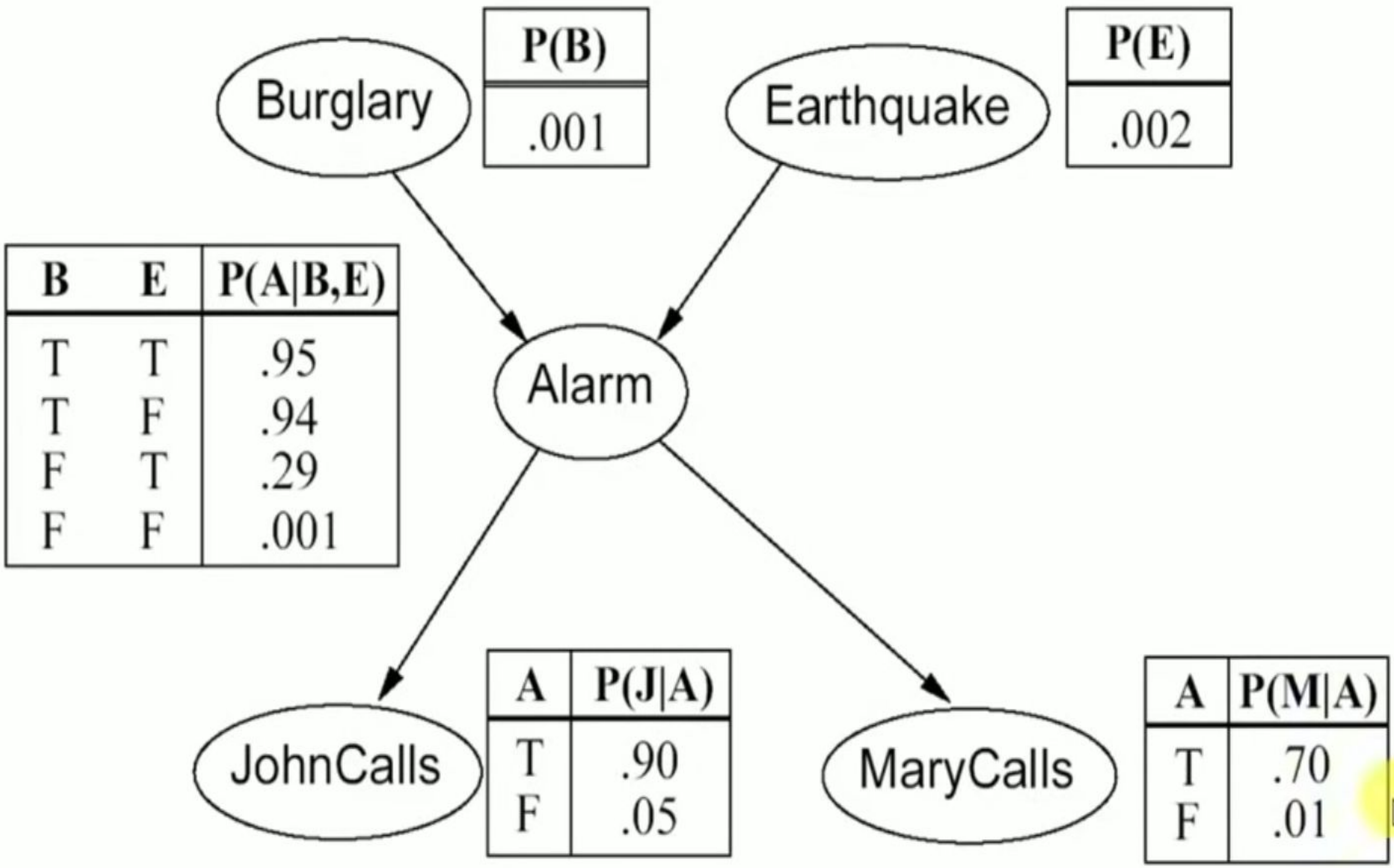
Key Terms

1. Node: Represents a random variable (e.g., Rain, Traffic).
2. Edge: Represents a dependency between variables.
3. Conditional Probability Table (CPT): Quantifies the relationship between a node and its parent nodes.

Why Use Bayesian Networks?

1. Handle uncertainty.
2. Provide a structured way to model problems.
3. Applications: Predictive modeling, diagnostics, decision-making.

Example: Burglary Alarm



P(B)
.001

P(E)
.002

B	E	P(A|B,E)
T	T	.95
T	F	.94
F	T	.29
F	F	.001

A	P(J|A)
T	.90
F	.05

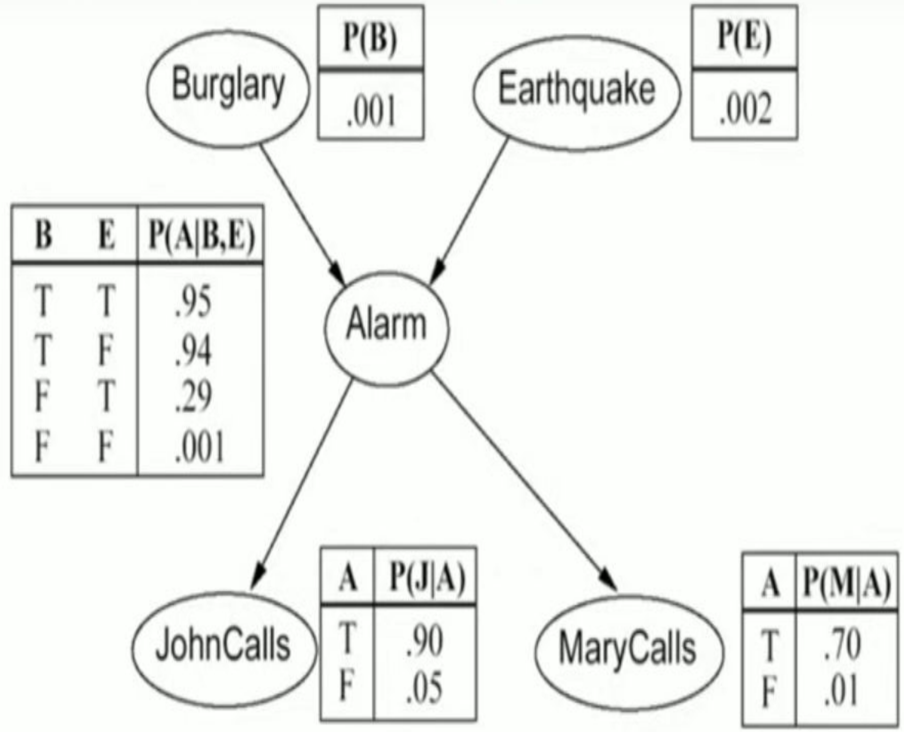
A	P(M|A)
T	.70
F	.01

Alarm-Burglary-Earthquake Example Scenario

BAYESIAN BELIEF NETWORKS – EXAMPLE – 1

- You have a new burglar alarm installed at home.
- It is fairly reliable at detecting burglary, but also sometimes responds to minor earthquakes.
- You have two neighbors, John and Merry , who promised to call you at work when they hear the alarm.
- John always calls when he hears the alarm, but sometimes confuses telephone ringing with the alarm and calls too.
- Merry likes loud music and sometimes misses the alarm.
- Given the evidence of who has or has not called, we would like to estimate the probability of a burglary.

1. What is the probability that the alarm has sounded but neither a burglary nor an earthquake has occurred, and both John and Merry call?



Solution:

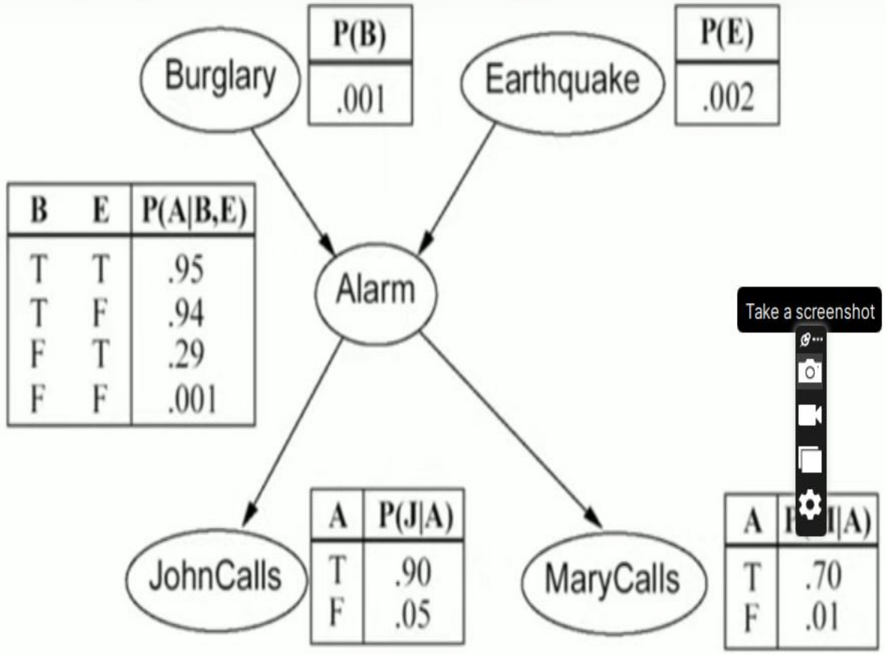
$$P(j \wedge m \wedge a \wedge \neg b \wedge \neg e) = P(j \mid a)\, P(m \mid a)\, P(a \mid \neg b, \neg e)\, P(\neg b)\, P(\neg e)$$

$$= 0.90 \times 0.70 \times 0.001 \times 0.999 \times 0.998$$

$$= 0.00062$$

BAYESIAN BELIEF NETWORKS – EXAMPLE – 1

2. What is the probability that John call?



Solution:

$$P(j) = P(j \mid a)\, P(a) + P(j \mid \neg a)\, P(\neg a)$$

$$= P(j|a)\{P(a|b,e)*P(b,e)+P(a|\neg b,e)*P(\neg b,e)+P(a|b,\neg e)*P(b,\neg e)+P(a|\neg b,\neg e)*P(\neg b,\neg e)\}$$

$$+ P(j|\neg a)\{P(\neg a|b,e)*P(b,e)+P(\neg a|\neg b,e)*P(\neg b,e)+P(\neg a|b,\neg e)*P(b,\neg e)+P(\neg a|\neg b,\neg e)*P(\neg b,\neg e)\}$$

$$= 0.90 * 0.00252 + 0.05 * 0.9974 = 0.0521$$

Conditional Probability

- Probabilities for the Alarm Example:
  - P(Alarm | Burglary, Earthquake).
  - P(JohnCalls | Alarm).

Full Bayesian Network

- The complete network includes all nodes, edges, and Conditional Probability Tables(CPTs) for the example.

- Study more examples including Rain-Sprinkle-Wet Grass example from different sources.

Advantages and Limitations

- Advantages:

  Intuitive and flexible.

  Efficient for inference.

- Limitations:

  Computationally intensive for large networks.

  Requires accurate probability values.

Introduction to Fuzzy Logic

Understanding the Basics with Examples

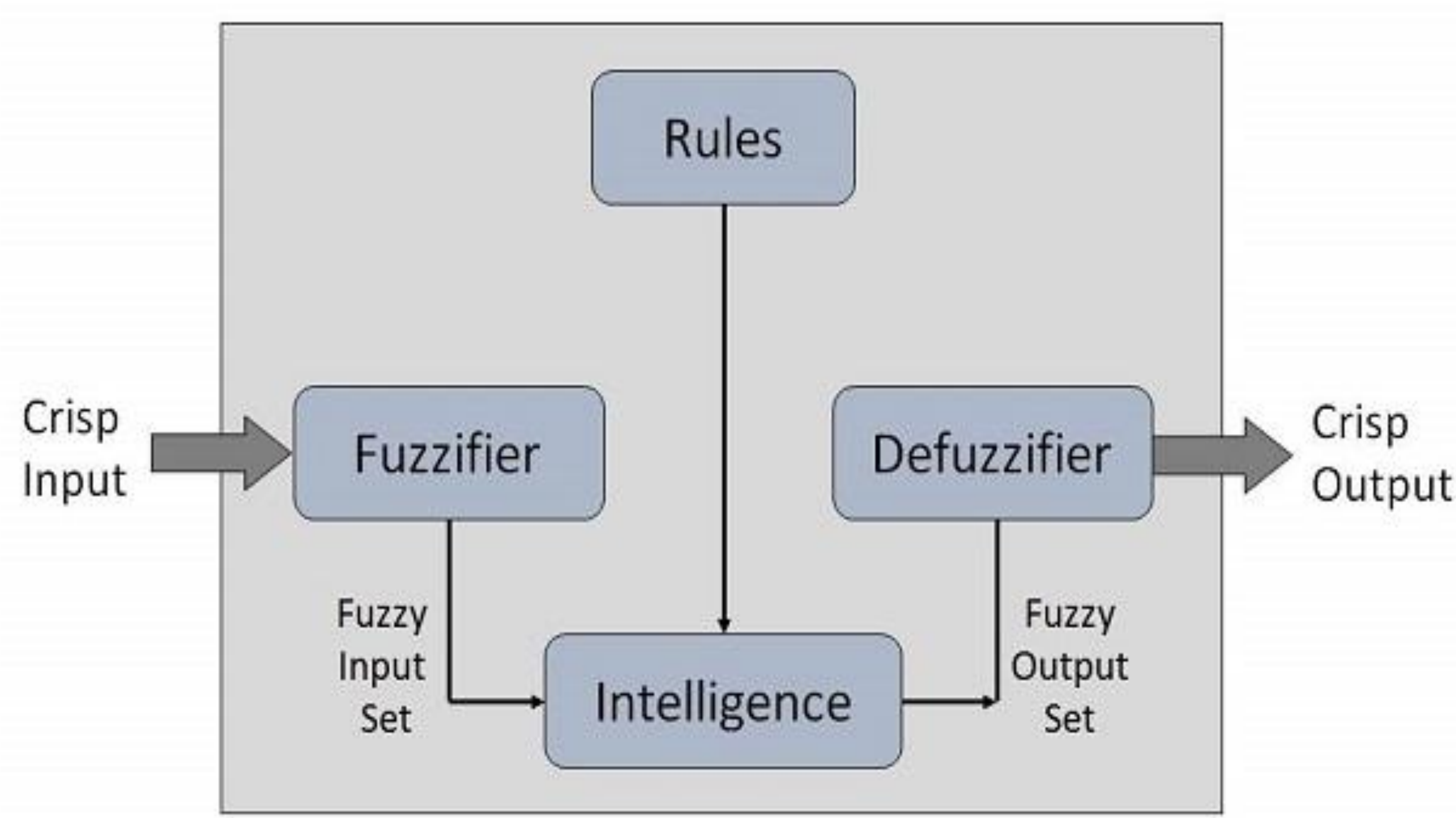
What is Fuzzy Logic?

- Fuzzy Logic is a method of reasoning that resembles human decision-making.
- Unlike classical logic (True/False), it deals with degrees of truth.
- Useful for handling imprecise or uncertain data.
- Example:
- Classical Logic: Is it hot? Yes/No
- Fuzzy Logic: It is 'moderately hot' or 'slightly warm.'

Why Fuzzy Logic?

- Mimics human thinking in uncertain environments.
- Helps in systems like weather prediction, control systems, and AI.
- Operates on vague concepts like 'warm,' 'high,' or 'low.'

Fuzzy Logic Process Diagram



Fuzzy Logic Process

Steps:

1. Crisp Input: Precise data fed into the system.
2. Fuzzification: Converts crisp input into fuzzy sets.
3. Inference Engine(Intelligence): It simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.
4. Rule Evaluation: Applies fuzzy rules to derive conclusions.
5. Defuzzification: Converts fuzzy outputs into crisp values.

Key Terms

- 1. Crisp Input: Clear numerical value. Example: Room temperature = 25°C.
- 2. Fuzzification: Transforms input into fuzzy values. Example: '25°C is moderately warm.'
- 3. Fuzzy Sets: Represents ranges, e.g., 'cold,' 'warm,' 'hot.'
- 4. Defuzzification: Converts fuzzy values back into a precise result. Example: 'Set AC to 22°C.'

Real-Life Example

- Scenario: Air Conditioner Control System

- Input: Room temperature (Crisp Input).
- Fuzzification: 'Cool,' 'Moderate,' 'Hot.'
- Rule Evaluation:
- If 'Hot,' set AC to high cooling.
- If 'Moderate,' set AC to low cooling.

- Defuzzification: AC adjusts to 18°C.

Membership Function

In fuzzy logic, a **membership function** defines how each input value maps to a degree of belonging in a fuzzy set, expressed between 0 (completely not in the set) and 1 (fully in the set). It quantifies vague terms like "warm" or "cold."

Example:

If "warm" is a fuzzy set for room temperature:

- 20°C might have a membership value of 0.2 (slightly warm).
- 25°C might have a value of 0.8 (quite warm).
- 30°C might have a value of 1.0 (fully warm).

This allows us to handle concepts with gradual transitions instead of strict boundaries.

If we have fuzzy sets like **Cold**, **Warm**, and **Hot**:

- 20°C may belong to **Cold** (membership = 0.7) **and Warm** (membership = 0.3).
- It won't belong to **Hot** (membership = 0.0).

This overlap is a key feature of fuzzy logic. Each fuzzy set is defined by its **membership function**, and a value like 20°C can belong to multiple sets to varying degrees, or it may not belong to some at all.

Advantages of Fuzzy Logic

- Handles imprecision effectively.
- Easy to design and implement.
- Works well in control systems.

Limitations of Fuzzy Logic

- Requires well-defined rules.
- Output precision depends on the system design.
- Computationally intensive for complex systems.

Summary

- Fuzzy Logic bridges the gap between human thinking and machine processing.
- Useful for systems requiring flexibility and uncertainty management.
- Found in AI, robotics, weather forecasting, and more.

References

1. https://youtu.be/hEZjPZ-Ze0A?si=n9HsgA2LF-j5J88-
2. https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_fuzzy_logic_systems.htm