AI & DS II Syllabus & Question Bank

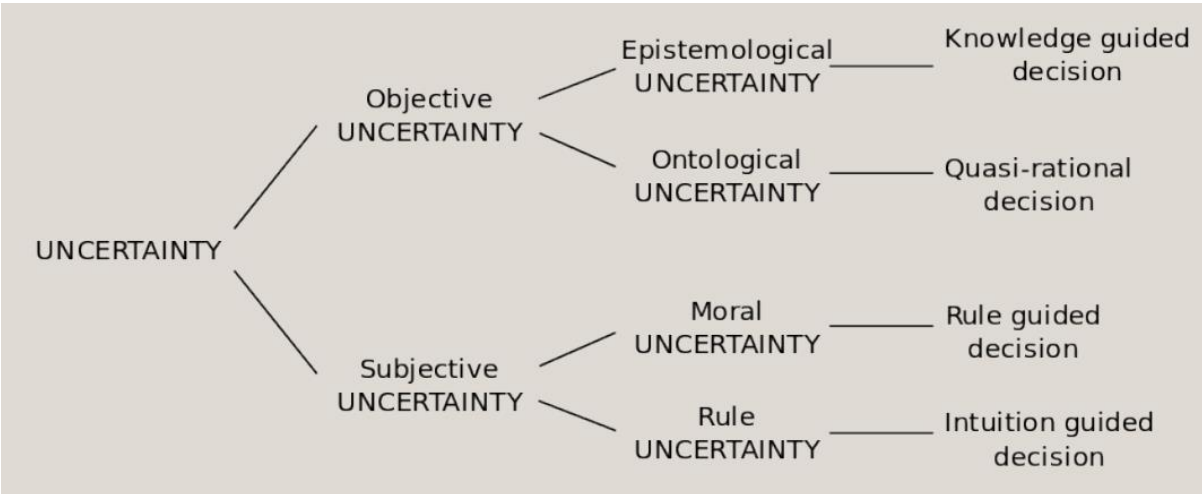
Unit 1: Uncertainty

1. Define uncertainty with two examples

   This mostly happens in those cases where the conditions are neither completely true nor completely false.
   Uncertainty arises when we are not 100 percent sure about the outcome of the decisions.

2. Mention some of the reason or all reasons for uncertainty
   • Partially observable environment
   • Dynamic environment
   • Incomplete knowledge of the agent
   • Inaccessible areas in the environment

3. Draw the taxonomy of uncertainty



4. What are the different methods to handle uncertainty
   • Fuzzy Logic
   • Probabilistic Reasoning
   • Hidden Markov Models
   • Neural Networks

5. List down the needs of probabilistic Reasoning in AI

   1.When there are unpredictable outcomes.
   2. When specifications or possibilities of predicates becomes too large to handle.
   3. When an unknown error occurs during an experiment.

6. Mention the terminologies in probability

1. **Event**: A subset of the sample space.
2. **Sample Space (S)**: The set of all possible outcomes of an experiment.
3. **Random Variable**: A variable that takes on different values based on the outcomes of a random experiment.
4. **Prior Probability**: The initial probability of an event before any new evidence is considered.
5. **Posterior Probability**: The probability of an event after taking into account new evidence.
6. **Conditional Probability**: The probability of event (A) given that event (B) has occurred. The formula is:

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

where (P(A ∩ B)) is the joint probability of (A) and (B), and (P(B)) is the marginal probability of (B) with (P(B) > 0).

7. What do you mean by full joint probability

Full Joint Probability refers to the probability distribution that describes the likelihood of every possible combination of outcomes for a set of random variables. It captures the complete relationship between all the variables in a probabilistic model.

In a full joint probability distribution, each entry represents the probability of a specific combination of outcomes occurring simultaneously. For example, if you have two random variables, X and Y, their full joint probability distribution would list the probabilities for all possible pairs of values $(X = x_i, Y = y_j)$.

Example:

Consider two binary random variables, A and B, where each can take the values 0 or 1. The full joint probability distribution would be:

$$P(A, B) = \begin{matrix} P(A=0, B=0) & P(A=0, B=1) \\ P(A=1, B=0) & P(A=1, B=1) \end{matrix}$$

This distribution would tell you the probability of each possible combination of values for A and B.

8. Compute the conditional probability of $P\ (cavity/\ toothache)$ for the table given below

	toothache		*¬toothache*	
	catch	*¬catch*	*catch*	*¬catch*
cavity	0.108	0.012	0.072	0.008
¬cavity	0.016	0.064	0.144	0.576

Concept:

Probability of an event A given that an event B has already occurred is denoted by :

$$P\left(\frac{A}{B}\right) = \frac{P(A \cap B)}{P(B)}$$

Explanation:

Probability of cavity given evidence of toothache is denoted here as:

Case1:

$$P\left(\frac{Cavity}{Toothache}\right) = \frac{P(cavity \cap Toothache)}{P(Toothache)}$$

P(Toothache) = 0.108 + 0.012 + 0.016 + 0.064 = 0.2

P(cavity ∩ Toothache) = 0.108 + 0.012 = 0.12

$$P\left(\frac{Cavity}{Toothache}\right) = \frac{0.12}{0.2} = 0.6$$

Case2:

$$P\left(\frac{\neg Cavity}{Toothache}\right) = \frac{P(\neg cavity \cap Toothache)}{P(Toothache)}$$

P(¬cavity ∩ Toothache) = 0.016 + 0.064 = 0.08

$$P\left(\frac{\neg Cavity}{Toothache}\right) = \frac{0.08}{0.2} = 0.4$$

9. In a class, there are 80% of the students who like English and 30% of the students who like English and Mathematics, and then what is the percentage of students who like English, also like mathematics?

E → English

M → Mathematics

$P(E) = 0.8$ $P(E \cap M) = 0.3$

To find :- $P(M|E) = \frac{P(E \cap M)}{P(E)} = \frac{0.3}{0.8} = 0.375$

37.5 %

10. Write a brief note on Bayes theorem

Bayes' Theorem is a fundamental concept in probability theory and statistics, named after the Reverend Thomas Bayes. It provides a way to update the probability of a hypothesis based on new evidence. The theorem is expressed mathematically as:

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

Where:

- (P(A|B)) is the posterior probability: the probability of event (A) occurring given that (B) is true.
- (P(B|A)) is the likelihood: the probability of event (B) occurring given that (A) is true.
- (P(A)) is the prior probability: the initial probability of event (A) before considering event (B).
- (P(B)) is the marginal probability: the total probability of event (B) occurring.

Bayes' Theorem is particularly useful in various fields such as medical diagnosis, machine learning, and decision-making processes, where it helps in updating the probability estimates as more information becomes available [1] [2] [3].

11. Write down the bayes theorem for any two variables of your choice
    Sure! Let's use two variables, (A) and (B). The Bayes' Theorem for these variables is given by:

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

    Where:

    - (P(A|B)) is the posterior probability: the probability of event (A) occurring given that (B) is true.
    - (P(B|A)) is the likelihood: the probability of event (B) occurring given that (A) is true.
    - (P(A)) is the prior probability: the initial probability of event (A) before considering event (B).
    - (P(B)) is the marginal probability: the total probability of event (B) occurring, ensuring (P(B) > 0).

12. A doctor is called to see a sick child. The doctor has prior information that 90% of sick children in that neighbourhood have the flu, while the other 10% are sick with measles. A well-known symptom of measles is a rash (the event of having which we denote R). Assume that the probability of having a rash if one has measles is P (R|M) = 0.95. However, occasionally children with flu also develop rash, and the probability of having a rash if one has flu is P (R | F) = 0.08. Upon examining the child, the doctor finds a rash.

What is the probability that the child has measles?

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Upon examining the child, the doctor finds a rash. What is the probability that the child has measles?

F → Flu $\quad P(F) = 0.90$

M → Measles $\quad P(M) = 0.10$

$P(R|M) = 0.95$

$P(R|F) = 0.08$

To find :- $P(M|R) = \dfrac{P(R|M)\,P(M)}{P(R|M) \cdot P(M) + P(R|F)\,P(F)}$

$= \dfrac{0.95 \times 0.10}{0.95 \times 0.10 + 0.08 \times 0.90} = \dfrac{0.095}{0.095 + 0.072}$

$= \underline{\underline{0.5688}}$

13. Explain Bayesian network in detail with an example with relevant graph

Bayesian Network: Overview

A **Bayesian Network** (also known as a Belief Network) is a probabilistic graphical model that represents a set of random variables and their conditional dependencies using a directed acyclic graph (DAG). Each node in the graph corresponds to a random variable, and each edge represents a conditional dependency between two variables. Bayesian Networks are used to model uncertainty, allowing for reasoning and inference about the relationships between variables.

Key Components:

1. **Nodes (Vertices):** Each node represents a random variable, which can be discrete or continuous.
2. **Edges (Arcs):** Directed edges between nodes represent conditional dependencies. If there is an edge from node A to node B, then B is conditionally dependent on A.
3. **Conditional Probability Tables (CPTs):** Associated with each node, these tables specify the probability of the node given its parent nodes. If a node has no parents, the CPT represents the prior probability of that node.

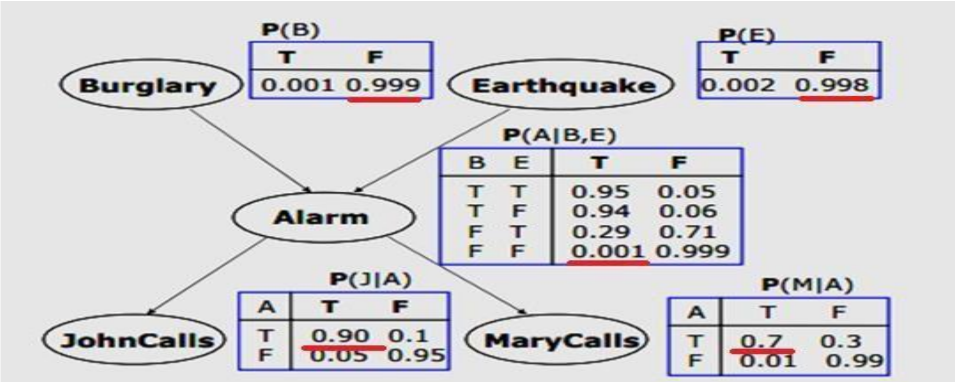
How Bayesian Networks Work:

Bayesian Networks use the **chain rule** of probability to decompose the full joint probability distribution into a product of conditional probabilities. Given a set of random variables $X_1, X_2, \ldots, X_n$, the joint probability is expressed as:

$$P(X_1, X_2, \ldots, X_n) = \prod_{i=1}^{n} P(X_i \mid \text{Parents}(X_i))$$

Here, $\text{Parents}(X_i)$ denotes the parent nodes of X_i in the graph.

14. List all the events occurring in this network



- **List of all events occurring in this network:**

❖ Burglary (B)
❖ Earthquake(E)
❖ Alarm(A)
❖ John Calls(J)
❖ Marry calls(M)

- We can write the events of problem statement in the form of probability:

$$P\left(M, J, A, B^{\circledcirc}, E^{\circledcirc}\right)$$

$$= P(M|A) \times P(J|A) \times P(A|B^{\circledcirc} \cap E^{\circledcirc}) \times P(B^{\circledcirc}) \times P(E^{\circledcirc})$$

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

$$= 0.00068045$$

15. Given a hypothesis *h* and data *D* which bears on the hypothesis:

P (*h* | *D*) = P (*D* | *h*) *P*(*h*) / *P*(*D*), mention the term for each term in bayes theorem

The formula you've provided is an expression of **Bayes' Theorem**, which relates the conditional probability of a hypothesis h given data D to the likelihood of the data given the hypothesis, the prior probability of the hypothesis, and the overall probability of the data.

Here's the breakdown of the formula:

$$P(h|D) = \frac{P(D|h) \cdot P(h)}{P(D)}$$

Where:

- $P(h)$: The **prior probability** of the hypothesis h. This is the probability of h being true before observing the data D.
- $P(D)$: The **marginal likelihood** or **evidence**, which is the independent probability of the data D. It represents the overall likelihood of observing the data under all possible hypotheses.
- $P(D|h)$: The **likelihood**. It is the probability of the data D being observed if the hypothesis h is true.
- $P(h|D)$: The **posterior probability** of the hypothesis h given the data D. This is what Bayes' Theorem allows you to calculate: the probability of the hypothesis being true after taking the data into account.

Unit 2: Cognitive Computing

16. What is Cognitive Computing (CC) and What Are Its 3 Fundamental Principles?

Cognitive Computing (CC) refers to the use of computerized models to simulate the human thought process in complex situations where the answers may be ambiguous or uncertain. It is analogous to how the human brain processes and analyzes different types of data, ranging from structured databases to unstructured data such as text, images, voice, sensor data, and video.

Three Fundamental Principles of CC:

1. **Learn:** Cognitive systems learn from training data and observations, improving over time without requiring reprogramming.
2. **Model:** To learn, the system creates a model or representation of the domain. This model is used to discover new insights or score hypotheses based on the system's assumptions and the learning algorithm used.
3. **Generate Hypotheses:** Cognitive systems recognize that there is no single correct answer; they generate and evaluate multiple hypotheses, continuously updating and refining them based on new data.

17. What Are the 3 Important Concepts That Help Design a Cognitive System (CS)?

Three important concepts that help design a Cognitive System (CS) are:

1. **Contextual Insight from Model:** The system must be able to understand the context in which data is analyzed, leveraging models to derive insights that are relevant to the situation.
2. **Hypothesis Generation:** The system should generate and test multiple hypotheses to address problems or answer questions, reflecting the probabilistic nature of real-world data.
3. **Continuous Learning:** The system must continuously learn from new data over time, improving its knowledge and performance without the need for reprogramming.

18. Explain the 3 Fundamental Principles in a Line or Two.

1. **Learn:** Cognitive systems learn based on training data and observation, adapting and improving over time.
2. **Model:** The system creates a model or representation of the domain to score hypotheses and discover new insights, dictated by the learning algorithm.
3. **Generate Hypotheses:** Cognitive systems generate and evaluate multiple hypotheses, recognizing that there may not be a single correct answer, and adapt based on continuously changing data.

19. Give at Least Two Examples or Applications of CS.

1. **Traffic Management Systems:** Cognitive systems are used in rerouting traffic, city management applications, and analyzing disrupted weather events to improve urban infrastructure.
2. **Medical Cognitive Healthcare:** These systems analyze text-based data sources (e.g., symptoms, disorders, diseases) and electronic medical records (EMRs) to aid doctors in

understanding treatment options, leading to better patient outcomes through continuous learning.

20. List All the Driving Factors of CS.

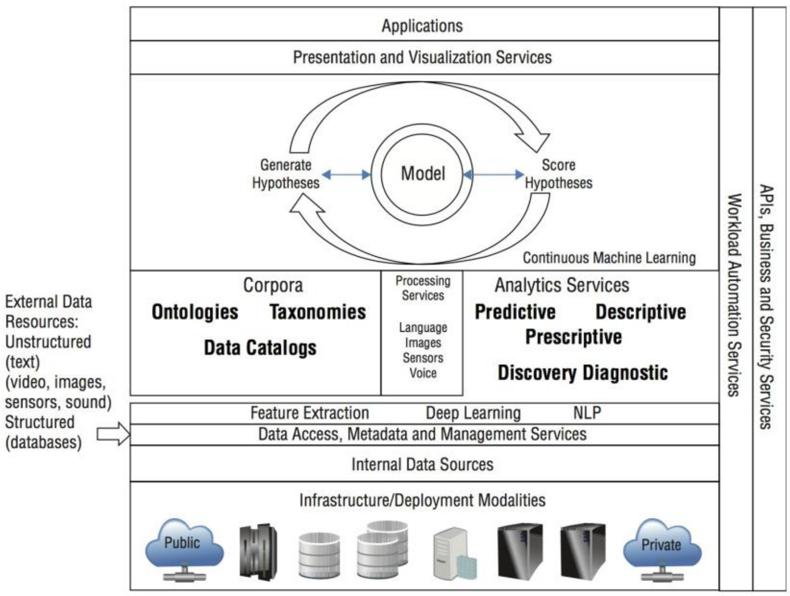
1. **Growth of Complex Unstructured Data:** The increase in unstructured multimedia data from machine learning, intelligent assistants, multimedia files, and precise sensing devices.
2. **Innovative Technology for Flexible Pricing:** The availability of innovative technology that offers flexible pricing rates for computation and storage.
3. **Emerging Research on Collaborative Learning:** In-depth research across the globe on collaborative learning and rapid discoveries in competitive environments.

21. Explain in Detail All the Features of a CS.

Features of a Cognitive System (CS) include:

- **Learning from Experience:** A CS learns from experience with data/evidence and improves its knowledge and performance without reprogramming.
- **Hypothesis Generation and Evaluation:** It generates and evaluates conflicting hypotheses based on its current knowledge state.
- **Justification of Conclusions:** The system reports its findings and justifies conclusions based on confidence levels and evidence.
- **Pattern Discovery:** It discovers patterns in data, with or without guidance, using various predictive analytic algorithms and statistical techniques.
- **Emulating Natural Systems:** The CS emulates processes or structures found in natural language systems, such as memory management and knowledge organization.
- **NLP and Deep Learning:** It uses natural language processing (NLP) to extract meaning from textual data and deep learning tools to extract features from images, videos, voices, and sensors

22. With help of neat diagram explain all the elements of CS



23. List All the Design Principles of CS.

Design principles of a Cognitive System (CS) include:

1. **Data Handling:** Define and optimize data characteristics, ensuring it is handled appropriately.
2. **Hypothesis Generation:** The system must be able to generate and evaluate hypotheses.
3. **Feature Extraction Using ML Models:** Use machine learning algorithms to extract relevant features from the data.
4. **Experimentation and Analytics:** Perform continuous experimentation and analytics.
5. **Hypothesis Validation:** Validate hypotheses against new data.
6. **Continuous Learning:** Learn continuously from new data without requiring reprogramming.
7. **Hypothesis Scoring:** Score hypotheses based on confidence and evidence.
8. **Presentation and Visualization:** Provide visualization services to present data and insights effectively.

24. Explain in detail the design detailing of a CS.

▪ The design needs to support different characteristics of data Access, Manage and Analyse data in context.

▪ Generate and score hypothesis on basis of accumulated knowledge.

▪ The system continuously updates based on user interaction and data and becomes smarter over time in an automated way.

25. Explain with an Example Hypothesis Generation and Scoring During a ML Process.

Hypothesis generation and scoring in a machine learning process involve generating multiple potential answers (hypotheses) based on the model's knowledge and scoring these hypotheses to determine their likelihood or accuracy. For example, in a medical diagnosis system, the CS might generate multiple possible diagnoses (hypotheses) for a set of symptoms and score them based on historical data and the patient's records to suggest the most likely diagnosis.

26. Discuss How NLP Supports CS.

NLP supports Cognitive Systems by enabling them to understand and process human language. This involves:

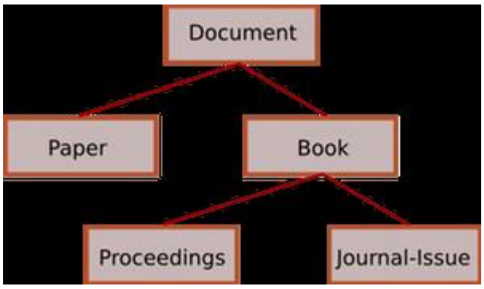
- **Language Identification and Tokenization:** Breaking down text into tokens and identifying the language.
- **Lexical Analysis:** Associating words with their dictionary meanings and determining frequent word patterns.
- **Syntactic Analysis:** Parsing sentences based on grammar rules.
- **Semantic and Pragmatic Analysis:** Understanding the meaning, intention, and context of content.
- **Discourse Analysis:** Analyzing the coherence of connected sentences and extracting meaning.
- **Hidden Markov Models (HMM):** Using statistical models for processing both image and speech understanding.

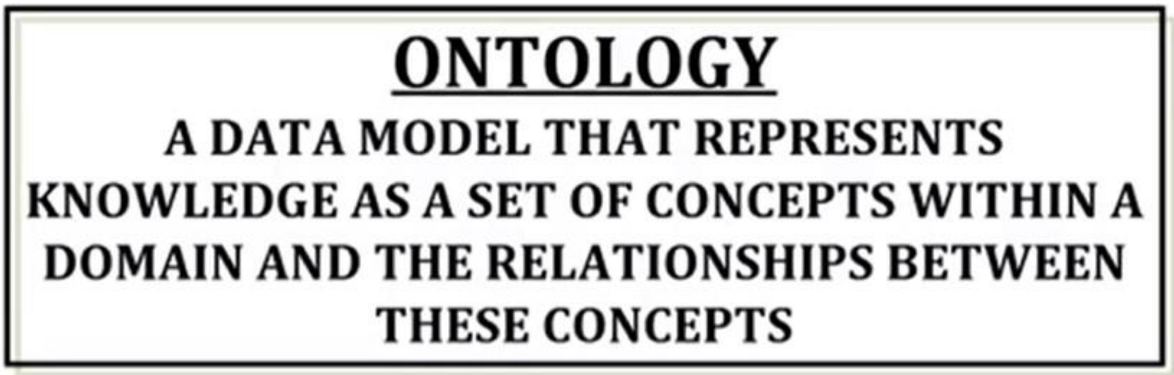
27. How Can We Apply NLP Technologies to Business Problems?

- **Enhancing Online Shopping Experience:** Improving search functionality and using chatbots to assist customers.
- **Leveraging IoT:** Using NLP for rerouting traffic under various circumstances.
- **Voice of Customer:** Understanding customer feedback through sentiment analysis.
- **Fraud Detection:** Detecting internal and external threats by analyzing databases to prevent theft of intellectual property.

16. Define taxonomy and ontology?

Taxonomy
Basic classification system in an hierarchical fashion the provides names to object and their relations





29. Explain in Detail How to Represent Knowledge in Taxonomy and Ontology.
Knowledge in taxonomy and ontology is represented by organizing concepts into classes and subclasses, which are then structured hierarchically. Ontology incorporates semantics, which adds meaning and relationships between these classes, allowing for more complex and meaningful representation of knowledge.

30. Define the Components of Ontology and Give an Example for Each.

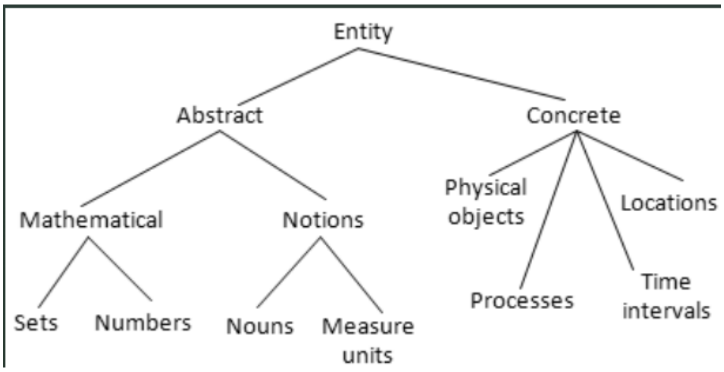
- **Classes:** High-level categories representing concepts within a domain (e.g., "Animal" as a class).
- **Subclasses:** Specific instances of classes that inherit properties from their parent class (e.g., "Dog" as a subclass of "Animal").
- **Attributes:** Characteristics or properties of classes (e.g., "Color" as an attribute of the "Dog" class).
- **Relationships:** Connections between classes and subclasses (e.g., "has-a" relationship between "Dog" and "Tail").

31. Write Down the Steps to Create the Ontology of Any Application.

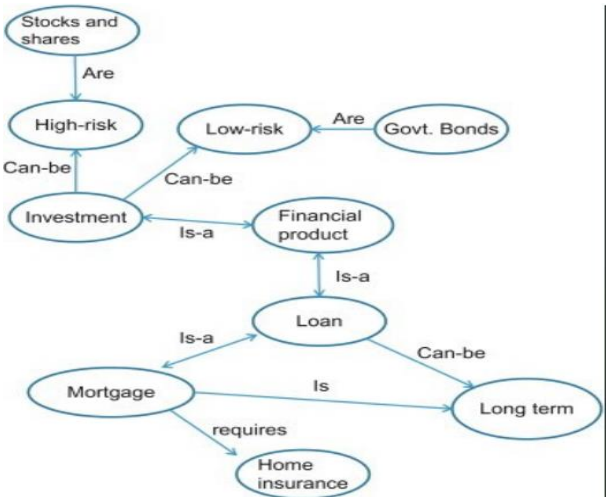
1. **Select the Use Case:** Define the domain of the ontology.
2. **Extract Classes:** Identify the high-level categories that encompass the concepts within the domain.
3. **Adapt Existing Taxonomy:** Modify the original taxonomy to fit hierarchically beneath each class.
4. **Incorporate Semantics:** Add semantics to the updated taxonomy for ontology transformation.
5. **Create Class Hierarchy:** Organize classes and subclasses hierarchically, ensuring subclasses inherit attributes from parent classes.
6. **Rinse and Repeat:** Regularly validate and evolve the ontology over time.

32. What Are the Different Methods to Represent Knowledge in CS?

- **Simple Tree:** A hierarchical structure representing knowledge with parent-child relationships.



- **Semantic Web:** A framework that allows data to be shared and reused across different domains and communities.



33. Write Down the Steps or Process to Build a Cognitive Application.

1. **Define the Objective:** Clearly outline the goals and purpose of the application.
2. **Define the Domain:** Identify the specific domain or area the application will focus on.
3. **Understand Users:** Determine the intended users and their attributes.
4. **Define Questions and Insights:** Formulate the questions the application will answer and the insights it will provide.
5. **Acquire Data Sources:** Gather relevant data sources required for the application.

6. **Create and Refine the Corpus:** Develop and refine the data corpus to be used for training the system.
7. **Training and Testing:** Train the system using the data corpus and test it to ensure accuracy and effectiveness.

Unit 3: Fuzzy Logics

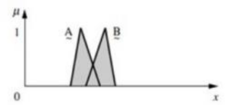
1. Define Fuzzy Logic?
   - The word "fuzzy" means "vaguness (ambiguity)".
   - Fuzziness occurs when the boundary of a piece of information is not clear-cut.
   - Fuzzy sets - 1965 Lotfi Zadeh as an extension of classical notation set.
   - Classical set theory allows the membership of the elements in the set in **binary terms**.
   - Fuzzy set theory permits membership function valued in the interval [0,1].
2. Explain all possible Fuzzy Set operation

Three fuzzy sets A , B, and C on the universe X

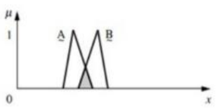
For a given element *x of the* universe, the following **function-theoretic operations** for the set-theoretic operations of union, intersection, and complement are defined for aA, B, and C on X

Union	$\mu_{\underset{\sim}{A}\cup\underset{\sim}{B}}(x) = \mu_{\underset{\sim}{A}}(x) \vee \mu_{\underset{\sim}{B}}(x)$
Intersection	$\mu_{\underset{\sim}{A}\cap\underset{\sim}{B}}(x) = \mu_{\underset{\sim}{A}}(x) \wedge \mu_{\underset{\sim}{B}}(x)$
Complement	$\mu_{\overline{\underset{\sim}{A}}}(x) = 1 - \mu_{\underset{\sim}{A}}(x)$

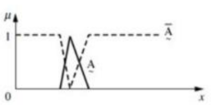
Standard fuzzy operations



Union of fuzzy sets A~ and B~



Intersection of fuzzy sets A~ and B~



Complement of fuzzy sets A~ and B~

3. Give some applications of fuzzy logic (FL)

   Applications of Fuzzy Logic:

1. **Automobiles:** Used for gear selection based on factors like engine load, road conditions, and driving style.
2. **Copy Machines:** Adjusts drum voltage according to humidity, picture density, and temperature.
3. **Medicine:** Aids in computer-assisted diagnosis using symptoms and medical history.
4. **Chemical Distillations:** Controls pH levels and temperature in distillation processes.

5. **Dishwashers:** Determines washing strategy and power needed based on the number of dishes and food residue level.
6. **Aerospace:** Manages altitude control for satellites and spacecraft considering environmental factors.
7. **Natural Language Processing (NLP):** Identifies semantic relationships between words and linguistic variables.
8. **Environmental Control Systems:** Regulates air conditioning and heating based on current and target temperatures.
9. **Business Rule Engines:** Streamlines decision-making according to predefined criteria.

4. Give the difference between fuzzy set ad classic set

Table

Aspect	Classic Set	Fuzzy Set
Membership	Binary (0 or 1)	Continuous (between 0 and 1)
Precision	Precise	Imprecise
Example	A person is either a student or not	A person can be somewhat tall
Logic	Bivalent (true/false)	Multivalent (degrees of truth)
Application	Digital systems, databases	Control systems, decision making
Boundary	Sharp boundaries	Gradual boundaries
Representation	Crisp values	Membership functions
Operations	Standard set operations (union, intersection, complement)	Extended operations (algebraic sum, product)

5. -Explain or write down the equation of a fuzzy logic membership function

- Membership function $\mu_A(x)$ defines degree of membership of x in A
- It assumes value in the range [0,1]

E.g. $\mu_A(x) = 0.6$

i.e. x belongs to Set A by 0.6 value

Common types of membership functions include:

1. **Triangular Membership Function**:

$$\mu_A(x) = \begin{cases} 0 & \text{if } x \le a \\ \frac{x-a}{b-a} & \text{if } a < x \le b \\ \frac{c-x}{c-b} & \text{if } b < x \le c \\ 0 & \text{if } x > c \end{cases}$$

   Where (a), (b), and (c) are the parameters defining the shape of the triangle.

2. **Gaussian Membership Function**:

$$\mu_A(x) = e^{-\frac{(x-c)^2}{2\sigma^2}}$$

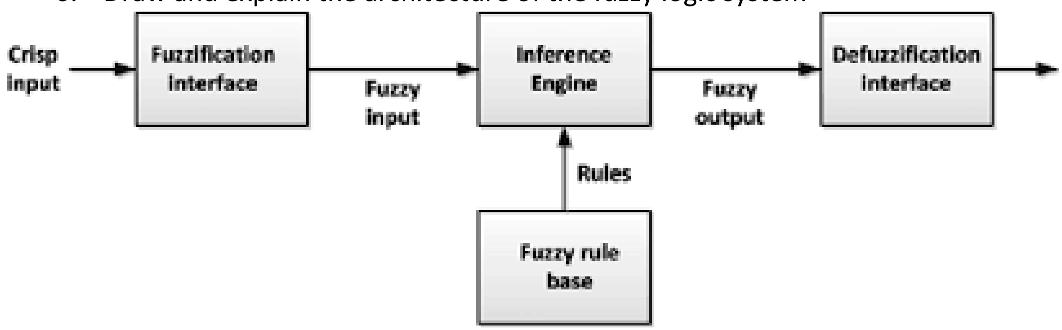
   Where (c) is the center and (\sigma) is the standard deviation.

3. **Trapezoidal Membership Function**:

$$\mu_A(x) = \begin{cases} 0 & \text{if } x \le a \\ \frac{x-a}{b-a} & \text{if } a < x \le b \\ 1 & \text{if } b < x \le c \\ \frac{d-x}{d-c} & \text{if } c < x \le d \\ 0 & \text{if } x > d \end{cases}$$

   Where (a), (b), (c), and (d) define the shape of the trapezoid.

6. Draw and explain the architecture of the fuzzy logic system



Architecture of a Fuzzy Logic System

1. **Rule Base**
   - Contains rules and membership functions that control decision-making.
2. **Fuzzification**
   - Converts crisp input into fuzzy values.
   - Divides input signals into categories like:
     - Large positive
     - Large negative
     - Medium positive
     - Medium negative
     - Small
3. **Inference Engine**
   - Matches fuzzy input with rules.
   - Determines which rules to apply and combines them for controlled action.

4. **Defuzzification**
   - Converts fuzzy output back into a crisp value.

7. Mention any 5 advantage and disadvantage of FL system.

Advantages

1. **Easy to Understand**: The structure of fuzzy logic is simple and intuitive, making it easy to understand and implement.
2. **Commercial and Practical Use**: Widely used in various commercial and practical applications, such as control systems and consumer electronics.
3. **Control of Machines and Products**: Helps in controlling machines and consumer products effectively by mimicking human decision-making.
4. **Handles Uncertainty**: Provides acceptable reasoning and helps deal with uncertainty in engineering and other fields.
5. **Robustness**: Mostly robust since it does not require precise input, making it adaptable to various situations.

Disadvantages

1. **Complexity in Implementation**: Sometimes difficult to implement due to the lack of a systematic approach.
2. **Accuracy Issues**: Results may not always be accurate and are often based on assumptions.
3. **Dependence on Expert Knowledge**: Requires expert knowledge to define the rules and membership functions.
4. **Computationally Intensive**: Can be computationally intensive, especially for large systems with many rules.
5. **Limited Learning Capability**: Unlike machine learning systems, fuzzy logic systems do not learn from data

8. Explain what is fuzzy set theory?

   Fuzzy Set Theory

   Fuzzy set theory extends classical set theory to handle the concept of partial membership. In a fuzzy set, each element has a degree of membership ranging from 0 to 1, representing the extent to which the element belongs to the set. This allows for more flexible and nuanced modeling of real-world situations where boundaries are not clear-cut.

9. What are various shapes of a fuzzy membership function

   Various Shapes of Fuzzy Membership Functions

   Fuzzy membership functions can take various shapes, including:

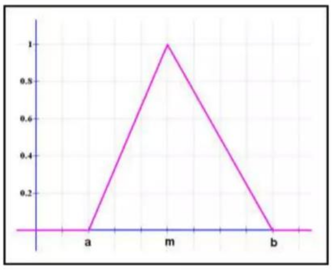
1. **Triangular**
2. **Trapezoidal**
3. **Gaussian**
4. **Bell-shaped**
5. **Sigmoidal**

10. Draw and explain the fuzzy function and all their mathematical derivation for any number of any number of parameters between {0,1}

Triangular function:

defined by a lower limit **a**, an upper limit **b**, and a value **m**, where **a < m < b**.

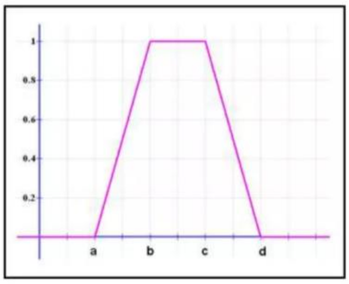
$$\mu_A(x) = \begin{cases} 0, & x \le a \\ \frac{x-a}{m-a}, & a < x \le m \\ \frac{b-x}{b-m}, & m < x < b \\ 0, & x \ge b \end{cases}$$



Trapezoidal function:

defined by a lower limit **a**, an upper limit **d**, a lower support limit **b**, and an upper support limit **c**, where **a < b < c < d**.

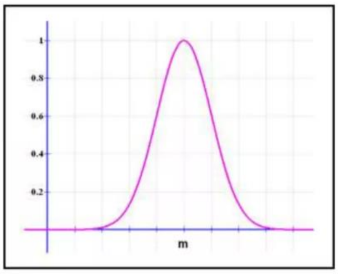
$$\mu_A(x) = \begin{cases} 0, & (x < a) \text{ or } (x > d) \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \frac{d-x}{d-c}, & c \le x \le d \end{cases}$$



Gaussian function:

defined by a central value **m** and a standard deviation **k > 0**. The smaller k is, the narrower the "bell" is.

$$\mu_A(x) = e^{-\frac{(x-m)^2}{2k^2}}$$



NOTE: The function used in the previous link to draw gaussian functions uses a different *k'* parameter. The mapping between both parameters is: $k' = 1 / 2k^2$

11. Can the membership function can be chosen at random or based on users experience to represent the set

Membership functions can be chosen based on the user’s experience or expert knowledge to represent the set. They are not chosen at random but are designed to best capture the characteristics of the data.

12. What are the various methods to represent a fuzzy set?

Methods to Represent a Fuzzy Set

1. **Membership Function**: Graphical representation of the degree of membership.
2. **Alpha-Cut**: Represents the set of elements with membership values greater than or equal to a certain threshold.
3. **Support**: The set of elements with non-zero membership values.
4. **Core**: The set of elements with full membership (membership value of 1).
5. **Height**: The maximum membership value in the fuzzy set.

13. List done all the properties of Fuzzy set

Properties of Fuzzy Sets

1. **Normality**: A fuzzy set is normal if at least one element has a membership value of 1.
2. **Convexity**: A fuzzy set is convex if for any two elements, the membership value of any element between them is at least as great as the minimum of their membership values.
3. **Support**: The set of elements with non-zero membership values.
4. **Alpha-Cut**: The set of elements with membership values greater than or equal to a certain threshold.
5. **Height**: The maximum membership value in the fuzzy set.

14. Consider these fuzzy sets

A={0.6/a,02/b,0.3/c,0.1/d}

B={0.3/a,0.4/b,0.5/c}

Now perform the operation AUB, A∩B, A’, B’

- **Union (A ∪ B)**: ({0.6/a, 0.4/b, 0.5/c, 0.1/d})
- **Intersection (A ∩ B)**: ({0.3/a, 0.2/b, 0.3/c})
- **Complement (A’)**: ({0.4/a, 0.8/b, 0.7/c, 0.9/d})
- **Complement (B’)**: ({0.7/a, 0.6/b, 0.5/c})

15. If age is a linguistic variable, then its term set are?

- If ***age*** is a linguistic variable then its term set is
- *T(age) = { young, not young, very young, not very young,…… middle aged, not middle aged, … old, not old, very old, more or less old, not very old,…not very young and not very old,…}.*

16. How to represent fuzzy relations using matrices.

Fuzzy Relations

Let $\underline{X} = \{x_1, x_2, \ldots, x_n\}$, $\underline{Y} = \{y_1, y_2, \ldots, y_m\}$. The fuzzy relation $\underset{\sim}{R}(\underline{X}, \underline{Y})$ can be expressed by $n \times m$ matrix called ***Fuzzy Matrix*** denoted as:

$$\underset{\sim}{R}(\underline{X}, \underline{Y}) = \begin{bmatrix} \mu_{\underline{R}}(x_1, y_1) & \mu_{\underline{R}}(x_1, y_2) & \ldots & \mu_{\underline{R}}(x_1, y_m) \\ \mu_{\underline{R}}(x_2, y_1) & \mu_{\underline{R}}(x_2, y_2) & \ldots & \mu_{\underline{R}}(x_2, y_m) \\ \ldots & \ldots & \ldots & \ldots \\ \mu_{\underline{R}}(x_n, y_1) & \mu_{\underline{R}}(x_n, y_2) & \ldots & \mu_{\underline{R}}(x_n, y_m) \end{bmatrix}$$

17. Solve, Let A= B= C= {0,2,4,6}, and the relation R, S, T is defined as follows:
    R $\subseteq$ A X B, R= {(a, b) | a - b is an even number}}
    S $\subseteq$ A X B, R= (a, b) | b = (a +3) MOD 2}
    T $\subseteq$ A X B, R= (a, b) | |a - b|= 2}

Given the sets $A = B = C = \{0, 2, 4, 6\}$ and the relations R, S, and T defined as follows:

- **Relation R:** $R = \{(a, b) \mid a - b \text{ is an even number}\}$
- **Relation S:** $S = \{(a, b) \mid b = (a + 3) \mod 2\}$
- **Relation T:** $T = \{(a, b) \mid |a - b| = 2\}$

Let's solve each relation.

Relation R

For R, the pair (a, b) is in R if the difference $a - b$ is an even number.

To find R, we check the differences for all pairs (a, b) where $a, b \in \{0, 2, 4, 6\}$:

$$
\begin{aligned}
&\text{For } a = 0: \\
&\qquad (0, 0) \text{ because } 0 - 0 = 0 \text{ (even)} \\
&\qquad (0, 2) \text{ because } 0 - 2 = -2 \text{ (even)} \\
&\qquad (0, 4) \text{ because } 0 - 4 = -4 \text{ (even)} \\
&\qquad (0, 6) \text{ because } 0 - 6 = -6 \text{ (even)} \\
&\text{For } a = 2: \\
&\qquad (2, 0) \text{ because } 2 - 0 = 2 \text{ (even)} \\
&\qquad (2, 2) \text{ because } 2 - 2 = 0 \text{ (even)} \\
&\qquad (2, 4) \text{ because } 2 - 4 = -2 \text{ (even)} \\
&\qquad (2, 6) \text{ because } 2 - 6 = -4 \text{ (even)} \\
&\text{For } a = 4: \\
&\qquad (4, 0) \text{ because } 4 - 0 = 4 \text{ (even)} \\
&\qquad (4, 2) \text{ because } 4 - 2 = 2 \text{ (even)} \\
&\qquad (4, 4) \text{ because } 4 - 4 = 0 \text{ (even)} \\
&\qquad (4, 6) \text{ because } 4 - 6 = -2 \text{ (even)} \\
&\text{For } a = 6: \\
&\qquad (6, 0) \text{ because } 6 - 0 = 6 \text{ (even)} \\
&\qquad (6, 2) \text{ because } 6 - 2 = 4 \text{ (even)} \\
&\qquad (6, 4) \text{ because } 6 - 4 = 2 \text{ (even)} \\
&\qquad (6, 6) \text{ because } 6 - 6 = 0 \text{ (even)}
\end{aligned}
$$

Thus, the relation R is:

$$R = \{(0, 0), (0, 2), (0, 4), (0, 6), (2, 0), (2, 2), (2, 4), (2, 6), (4, 0), (4, 2), (4, 4), (4, 6), (6, 0)$$

Relation S

For S, the pair (a, b) is in S if $b = (a+3) \mod 2$.

Calculate $(a+3) \mod 2$ for each a:

$$\begin{aligned} a = 0: &\quad (0+3) \mod 2 = 1 \\ a = 2: &\quad (2+3) \mod 2 = 1 \\ a = 4: &\quad (4+3) \mod 2 = 1 \\ a = 6: &\quad (6+3) \mod 2 = 1 \end{aligned}$$

Since for all a, $(a+3) \mod 2 = 1$, b must be 1, but 1 is not in the set $\{0, 2, 4, 6\}$. Hence, there are no valid pairs.

Thus, the relation S is:

$$S = \emptyset$$

Relation T

For T, the pair (a, b) is in T if $|a - b| = 2$.

Calculate $|a - b|$ for all pairs (a, b) where $a, b \in \{0, 2, 4, 6\}$:

$$\begin{aligned} &\text{For } a = 0: \\ &\qquad (0,2) \text{ because } |0-2| = 2 \\ &\qquad (0,4) \text{ because } |0-4| = 4 \\ &\qquad (0,6) \text{ because } |0-6| = 6 \\ &\text{For } a = 2: \\ &\qquad (2,0) \text{ because } |2-0| = 2 \\ &\qquad (2,4) \text{ because } |2-4| = 2 \\ &\qquad (2,6) \text{ because } |2-6| = 4 \\ &\text{For } a = 4: \\ &\qquad (4,0) \text{ because } |4-0| = 4 \\ &\qquad (4,2) \text{ because } |4-2| = 2 \\ &\qquad (4,6) \text{ because } |4-6| = 2 \\ &\text{For } a = 6: \\ &\qquad (6,0) \text{ because } |6-0| = 6 \\ &\qquad (6,2) \text{ because } |6-2| = 4 \\ &\qquad (6,4) \text{ because } |6-4| = 2 \end{aligned}$$

Thus, the relation T is:

$$T = \{(0,2), (2,0), (2,4), (4,2), (4,6), (6,4)\}$$

18. Using the same fuzzy set-in question 17, try to solve using matrices for $T_{R\cup S}$, $T_{R\cap S}$ $T_{B'}$

19. Use the fuzzy set in Question number 17 to solve for Fuzzy Composition

20. Assume that input to a washing machine is weight of clothes, amount of washing powder. Use three descriptors for input variable and 5 descriptors for output variable. Design a fuzzy controller step to determine the wash time of a domestic washing machine.

https://youtu.be/THAk1O3HBDc?si=a9QkrbFuxF9POCi

a. Composition : Find the Dot Product

R	a	b	c	d
1	0.1	0.2	0.0	1.0
2	0.3	0.3	0.0	0.2
3	0.8	0.9	0.1	0.4

S	**α**	***β***	**γ**
a	0.9	0.0	0.3
b	0.2	1.0	0.8
c	0.8	0.0	0.7
d	0.4	0.2	0.3

21. 1) Find the compliment

A = { ((x,0.5) (x,0.7) (x,0) }

2) A = { 1.0 , 0.20 , 0.75 }

B = { 0.20, 0.45 , 0.50 }

find : (i) A U B (ii) A ⋂ B

(i) Union $A \cup B$

The union of two fuzzy sets is given by taking the maximum value for each corresponding element:

$$A \cup B = \{\max(1.0, 0.20), \max(0.20, 0.45), \max(0.75, 0.50)\}$$

So:

$$A \cup B = \{1.0, 0.45, 0.75\}$$

(ii) Intersection $A \cap B$

The intersection of two fuzzy sets is given by taking the minimum value for each corresponding element:

$$A \cap B = \{\min(1.0, 0.20), \min(0.20, 0.45), \min(0.75, 0.50)\}$$

So:

$$A \cap B = \{0.20, 0.20, 0.50\}$$

22. Given : : S = { (0 , 0) (0, 2) (1 , 1) (1 , 3) (2 , 0) (2, 2) (3 , 1) (3 , 3) }
S = { (0 , 2) (1, 0) (2, 1) (3 , 2) }
Find : (i) R U S (ii) R ∩ S

(i) Union $R \cup S$

The union of two relations is found by combining all pairs from both relations. For each pair, include the pair in the union set if it exists in either relation:

$$R \cup S = \{(0,0),(0,2),(1,1),(1,3),(2,0),(2,2),(3,1),(3,3),(1,0),(2,1),(3,2)\}$$

Removing duplicates:

$$R \cup S = \{(0,0),(0,2),(1,1),(1,3),(2,0),(2,2),(3,1),(3,3)\}$$

(ii) Intersection $R \cap S$

The intersection of two relations includes only the pairs that are present in both relations:

$$R \cap S = \{(0,2),(1,0),(2,1),(3,2)\}$$

23. Given : : S = { (0 , 2) (1, 0) (2, 1) (3 , 2) }
T = { (0 , 1) (1, 2) (2, 3) (1 , 0) (2, 1) (3 , 2) }
Find : (i)S U T (ii) S ∩ T

(i) Union $S \cup T$

The union of two relations is found by combining all pairs from both relations. For each pair, include the pair in the union set if it exists in either relation:

$$S \cup T = \{(0,2),(1,0),(2,1),(3,2),(0,1),(1,2),(2,3),(3,2)\}$$

Removing duplicates:

$$S \cup T = \{(0,2),(1,0),(2,1),(3,2),(0,1),(1,2),(2,3)\}$$

(ii) Intersection $S \cap T$

The intersection of two relations includes only the pairs that are present in both relations:

$$S \cap T = \{(0,1),(1,0),(2,1),(3,2)\}$$

24. Find the composition of fuzzy set A & B

A	a	b	c
1	0.5	0.0	0.0
2	0.45	0.2	0.0
3	0.0	0.7	0.0

B	a	b	c

1	0.3	0.0	0.0
2	0.2	0.0	0.0
3	0.0	0.0	0.9

Composition $C = A \circ B$

To find the composition $C = A \circ B$, we use the following formula:

$$C_{ij} = \max_k (\min(A_{ik}, B_{kj}))$$

Where:

- C_{ij} is the membership degree of the relation between i and j in the composition.
- A_{ik} is the membership degree of the element i in fuzzy set A for the variable k.
- B_{kj} is the membership degree of the variable k in fuzzy set B for the element j.

Let's compute C element by element:

1. Compute C_{1a}:

$$C_{1a} = \max (\min(A_{1a}, B_{aa}), \min(A_{1b}, B_{ba}), \min(A_{1c}, B_{ca}))$$

$$C_{1a} = \max (\min(0.5, 0.3), \min(0.0, 0.0), \min(0.0, 0.0))$$

$$C_{1a} = \max (0.3, 0.0, 0.0) = 0.3$$

2. Compute C_{1b}:

$$C_{1b} = \max\left(\min(A_{1a}, B_{ab}), \min(A_{1b}, B_{bb}), \min(A_{1c}, B_{cb})\right)$$

$$C_{1b} = \max\left(\min(0.5, 0.0), \min(0.0, 0.0), \min(0.0, 0.0)\right)$$

$$C_{1b} = \max\left(0.0, 0.0, 0.0\right) = 0.0$$

3. Compute C_{1c}:

$$C_{1c} = \max\left(\min(A_{1a}, B_{ac}), \min(A_{1b}, B_{bc}), \min(A_{1c}, B_{cc})\right)$$

$$C_{1c} = \max\left(\min(0.5, 0.0), \min(0.0, 0.0), \min(0.0, 0.9)\right)$$

$$C_{1c} = \max\left(0.0, 0.0, 0.0\right) = 0.0$$

4. Compute C_{2a}:

$$C_{2a} = \max\left(\min(A_{2a}, B_{aa}), \min(A_{2b}, B_{ba}), \min(A_{2c}, B_{ca})\right)$$

$$C_{2a} = \max\left(\min(0.45, 0.3), \min(0.2, 0.0), \min(0.0, 0.0)\right)$$

$$C_{2a} = \max\left(0.3, 0.0, 0.0\right) = 0.3$$

5. Compute C_{2b}:

$$C_{2b} = \max\left(\min(A_{2a}, B_{ab}), \min(A_{2b}, B_{bb}), \min(A_{2c}, B_{cb})\right)$$

$$C_{2b} = \max\left(\min(0.45, 0.0), \min(0.2, 0.0), \min(0.0, 0.0)\right)$$

$$C_{2b} = \max\left(0.0, 0.0, 0.0\right) = 0.0$$

6. Compute C_{2c}:

$$C_{2c} = \max\left(\min(A_{2a}, B_{ac}), \min(A_{2b}, B_{bc}), \min(A_{2c}, B_{cc})\right)$$

$$C_{2c} = \max\left(\min(0.45, 0.0), \min(0.2, 0.0), \min(0.0, 0.9)\right)$$

$$C_{2c} = \max\left(0.0, 0.0, 0.0\right) = 0.0$$

7. Compute C_{3a}:

$$C_{3a} = \max\left(\min(A_{3a}, B_{aa}), \min(A_{3b}, B_{ba}), \min(A_{3c}, B_{ca})\right)$$

$$C_{3a} = \max\left(\min(0.0, 0.3), \min(0.7, 0.0), \min(0.0, 0.0)\right)$$

$$C_{3a} = \max\left(0.0, 0.0, 0.0\right) = 0.0$$

8. Compute C_{3b}:

$$C_{3b} = \max\left(\min(A_{3a}, B_{ab}), \min(A_{3b}, B_{bb}), \min(A_{3c}, B_{cb})\right)$$

$$C_{3b} = \max\left(\min(0.0, 0.0), \min(0.7, 0.0), \min(0.0, 0.0)\right)$$

$$C_{3b} = \max\left(0.0, 0.0, 0.0\right) = 0.0$$

9. Compute C_{3c}:

$$C_{3c} = \max\left(\min(A_{3a}, B_{ac}), \min(A_{3b}, B_{bc}), \min(A_{3c}, B_{cc})\right)$$

$$C_{3c} = \max\left(\min(0.0, 0.0), \min(0.7, 0.0), \min(0.0, 0.9)\right)$$

$$C_{3c} = \max\left(0.0, 0.0, 0.0\right) = 0.0$$

Fuzzy Composition Matrix C:

C	a	b	c
1	0.3	0.0	0.0
2	0.3	0.0	0.0
3	0.0	0.0	0.0