Semantic and Reasoning

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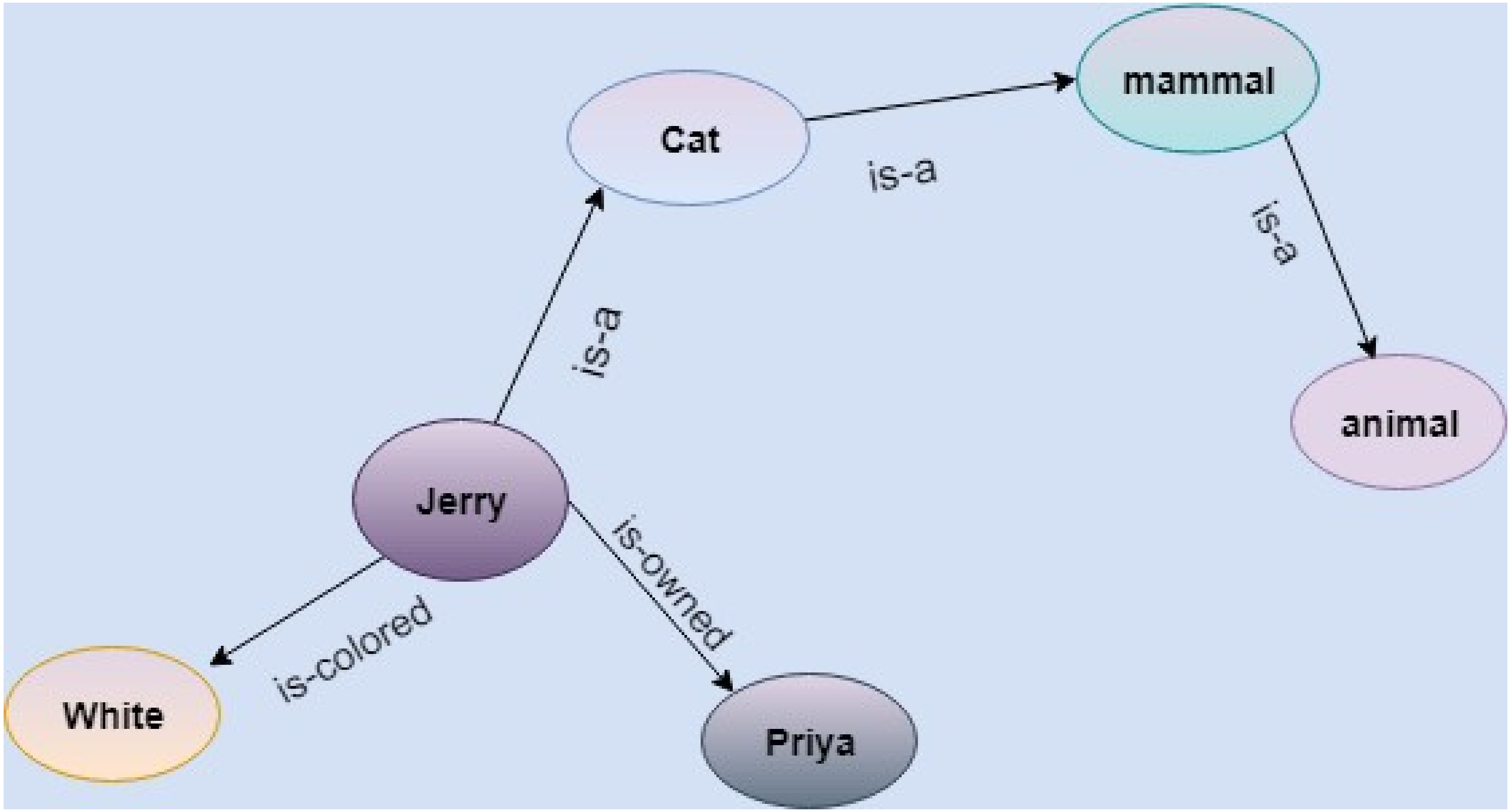
Semantic Network Representation

- Semantic networks are alternative of predicate logic for knowledge representation.
- In Semantic networks, we can represent our knowledge in the form of graphical networks.
- This network consists of nodes representing objects and arcs which describe the relationship between those objects.
- Semantic networks can categorize the object in different forms and can also link those objects.
- Semantic networks are easy to understand and can be easily extended.

Semantic Network Representation

- This representation consist of mainly two types of relations:
  - IS-A relation (Inheritance)
  - Kind-of-relation
- Example: Following are some statements which we need to represent in the form of nodes and arcs.
- Statements:
  - Jerry is a cat.
  - Jerry is a mammal
  - Jerry is owned by Priya.
  - Jerry is brown colored.
  - All Mammals are animal.

Semantic Network Representation



Drawbacks in Semantic representation

- Semantic networks take more computational time at runtime as we need to traverse the complete network tree to answer some questions. It might be possible in the worst case scenario that after traversing the entire tree, we find that the solution does not exist in this network.
- Semantic networks try to model human-like memory (Which has 1015 neurons and links) to store the information, but in practice, it is not possible to build such a vast semantic network.
- These types of representations are inadequate as they do not have any equivalent quantifier, e.g., for all, for some, none, etc.
- Semantic networks do not have any standard definition for the link names.
- These networks are not intelligent and depend on the creator of the system.

Advantages of Semantic representation

- Semantic networks are a natural representation of knowledge.
- Semantic networks convey meaning in a transparent manner.
- These networks are simple and easily understandable.

Reasoning

- The reasoning is the mental process of deriving logical conclusion and making predictions from available knowledge, facts, and beliefs.
- Or we can say, "Reasoning is a way to infer facts from existing data." It is a general process of thinking rationally, to find valid conclusions.
- In artificial intelligence, the reasoning is essential so that the machine can also think rationally as a human brain, and can perform like a human.

Types

- In artificial intelligence, reasoning can be divided into the following categories:
  - Deductive reasoning
  - Inductive reasoning
  - Abductive reasoning
  - Common Sense Reasoning
  - Monotonic Reasoning
  - Non-monotonic Reasoning

Deductive reasoning

- Deductive reasoning is deducing new information from logically related known information.
- It is the form of valid reasoning, which means the argument's conclusion must be true when the premises are true.
- Deductive reasoning is a type of propositional logic in AI, and it requires various rules and facts.
- It is sometimes referred to as top-down reasoning, and contradictory to inductive reasoning.
- In deductive reasoning, the truth of the premises guarantees the truth of the conclusion.

Deductive reasoning

- Deductive reasoning mostly starts from the general premises to the specific conclusion, which can be explained as below example
- Example:

  Premise-1: All the human eats veggies

  Premise-2: Suresh is human.

  Conclusion: Suresh eats veggies.

Deductive reasoning

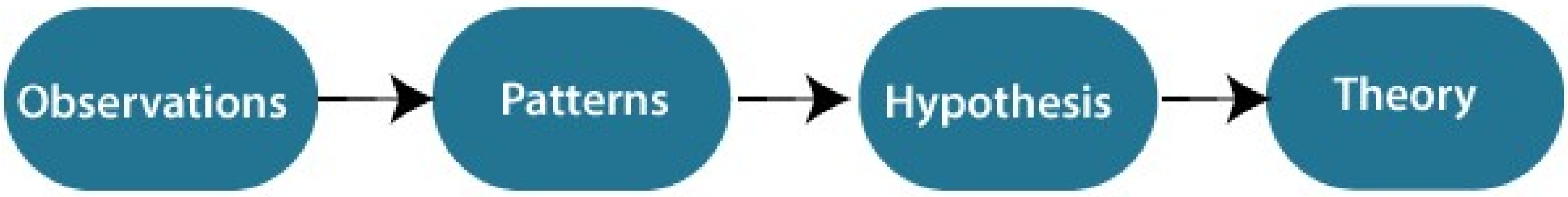
- The general process of deductive reasoning is given below:

Inductive Reasoning

- Inductive reasoning is a form of reasoning to arrive at a conclusion using limited sets of facts by the process of generalization. It starts with the series of specific facts or data and reaches to a general statement or conclusion.
- Inductive reasoning is a type of propositional logic, which is also known as cause-effect reasoning or bottom-up reasoning.
- In inductive reasoning, we use historical data or various premises to generate a generic rule, for which premises support the conclusion.
- In inductive reasoning, premises provide probable supports to the conclusion, so the truth of premises does not guarantee the truth of the conclusion.

Inductive Reasoning

- Example:
- Premise: All of the pigeons we have seen in the zoo are white.
- Conclusion: Therefore, we can expect all the pigeons to be white.



Abductive reasoning

- Abductive reasoning is a form of logical reasoning which starts with single or multiple observations then seeks to find the most likely explanation or conclusion for the observation.
- Abductive reasoning is an extension of deductive reasoning, but in abductive reasoning, the premises do not guarantee the conclusion.
- Example:

  Implication: Cricket ground is wet if it is raining

  Axiom: Cricket ground is wet.

  Conclusion It is raining.

Common Sense Reasoning

- Common sense reasoning is an informal form of reasoning, which can be gained through experiences.
- Common Sense reasoning simulates the human ability to make presumptions about events which occurs on every day.
- It relies on good judgment rather than exact logic and operates on heuristic knowledge and heuristic rules.

Common Sense Reasoning

- Example:
  - One person can be at one place at a time.
  - If I put my hand in a fire, then it will burn.
- The above two statements are the examples of common sense reasoning which a human mind can easily understand and assume.

Monotonic Reasoning

- In monotonic reasoning, once the conclusion is taken, then it will remain the same even if we add some other information to existing information in our knowledge base. In monotonic reasoning, adding knowledge does not decrease the set of prepositions that can be derived.
- To solve monotonic problems, we can derive the valid conclusion from the available facts only, and it will not be affected by new facts.
- Monotonic reasoning is not useful for the real-time systems, as in real time, facts get changed, so we cannot use monotonic reasoning.

Monotonic Reasoning

- Monotonic reasoning is used in conventional reasoning systems, and a logic-based system is monotonic.
- Any theorem proving is an example of monotonic reasoning.
- Example:
  - Earth revolves around the Sun.
- It is a true fact, and it cannot be changed even if we add another sentence in knowledge base like, "The moon revolves around the earth" Or "Earth is not round," etc.

Monotonic Reasoning

- Advantages of Monotonic Reasoning:
  - In monotonic reasoning, each old proof will always remain valid.
  - If we deduce some facts from available facts, then it will remain valid for always.
- Disadvantages of Monotonic Reasoning:
  - We cannot represent the real world scenarios using Monotonic reasoning.
  - Hypothesis knowledge cannot be expressed with monotonic reasoning, which means facts should be true.
  - Since we can only derive conclusions from the old proofs, so new knowledge from the real world cannot be added.

Non-monotonic Reasoning

- In Non-monotonic reasoning, some conclusions may be invalidated if we add some more information to our knowledge base.
- Logic will be said as non-monotonic if some conclusions can be invalidated by adding more knowledge into our knowledge base.
- Non-monotonic reasoning deals with incomplete and uncertain models.
- "Human perceptions for various things in daily life, "is a general example of non-monotonic reasoning.

Non-monotonic Reasoning

- Example: Let suppose the knowledge base contains the following knowledge:
  - Birds can fly
  - Penguins cannot fly
  - Pitty is a bird
- So from the above sentences, we can conclude that Pitty can fly.
- However, if we add one another sentence into knowledge base "Pitty is a penguin", which concludes "Pitty cannot fly", so it invalidates the above conclusion.

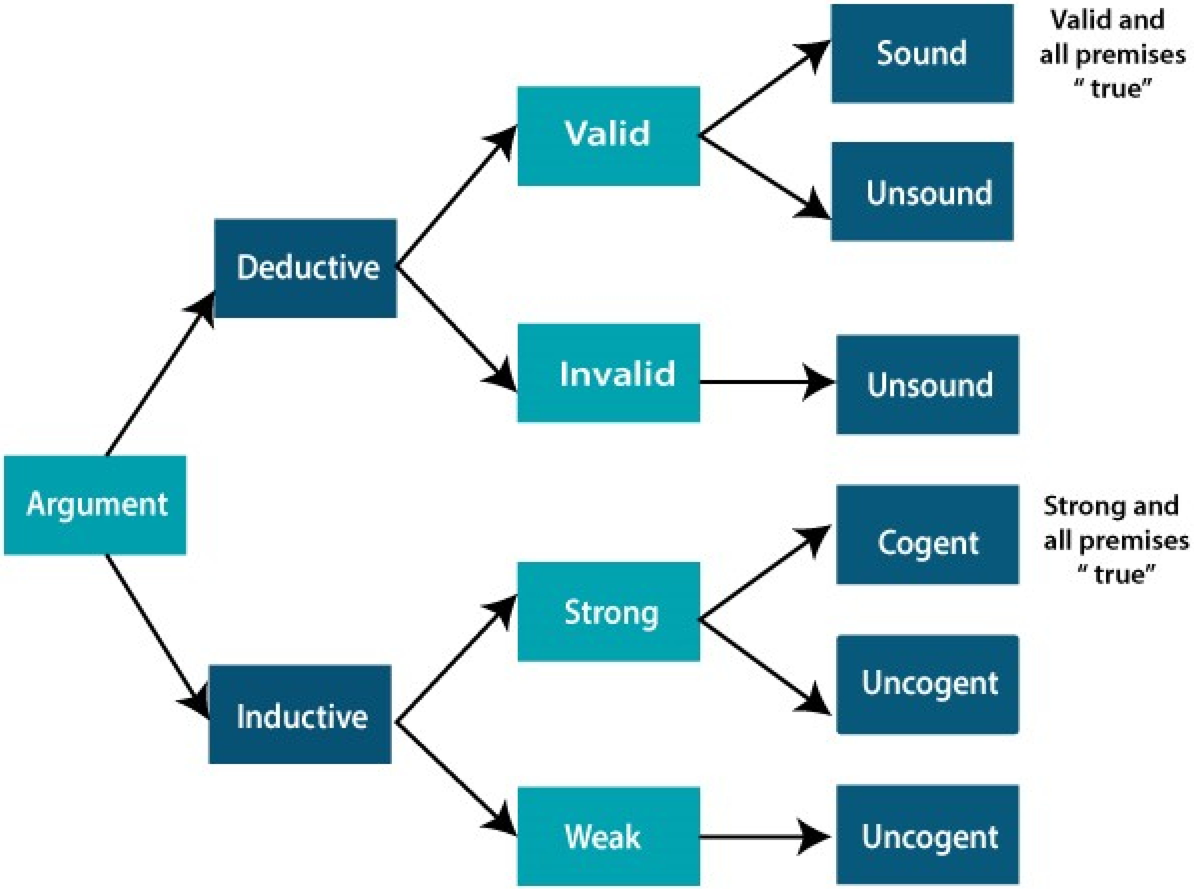
Non-monotonic Reasoning

- Advantages of Non-monotonic reasoning:
  - For real-world systems such as Robot navigation, we can use non-monotonic reasoning.
  - In Non-monotonic reasoning, we can choose probabilistic facts or can make assumptions.
- Disadvantages of Non-monotonic Reasoning:
  - In non-monotonic reasoning, the old facts may be invalidated by adding new sentences.
  - It cannot be used for theorem proving.

Inductive vs. Deductive reasoning

- Deductive reasoning uses available facts, information, or knowledge to deduce a valid conclusion, whereas inductive reasoning involves making a generalization from specific facts, and observations.
- Deductive reasoning uses a top-down approach, whereas inductive reasoning uses a bottom-up approach.
- Deductive reasoning moves from generalized statement to a valid conclusion, whereas Inductive reasoning moves from specific observation to a generalization.
- In deductive reasoning, the conclusions are certain, whereas, in Inductive reasoning, the conclusions are probabilistic.
- Deductive arguments can be valid or invalid, which means if premises are true, the conclusion must be true, whereas inductive argument can be strong or weak, which means conclusion may be false even if premises are true.

Inductive vs. Deductive reasoning



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→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.
  - Information occurred from unreliable sources.
  - Experimental Errors
  - Equipment fault
  - Temperature variation
  - 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.
- We use probability in probabilistic reasoning because it provides a way to handle the uncertainty that is the result of someone's laziness and ignorance.

Probabilistic reasoning

- Need of probabilistic reasoning in AI:
  - When there are unpredictable outcomes.
  - When specifications or possibilities of predicates becomes too large to handle.
  - When an unknown error occurs during an experiment.
- In probabilistic reasoning, there are two ways to solve problems with uncertain knowledge:
  - Bayes' rule
  - Bayesian Statistics

Probabilistic reasoning

- As probabilistic reasoning uses probability and related terms, so before understanding probabilistic reasoning, let's understand some common terms:
- 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.

  $0 \le P(A) \le 1$, where P(A) is the probability of an event A.

  $P(A) = 0$, indicates total uncertainty in an event A.

  $P(A) = 1$, indicates total certainty in an event A.

Probabilistic reasoning

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

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

$P(\neg A)$ = probability of a not happening event.

$P(\neg A) + P(A) = 1$.

- Event: Each possible outcome of a variable is called an event.

Probabilistic reasoning

- Sample space: The collection of all possible events is called sample space.
- Random variables: Random variables are used to represent the events and objects in the real world.
- Prior probability: The prior probability of an event is probability computed before observing new information.
- Posterior Probability: The probability that is calculated after all evidence or information has taken into account. It is a combination of prior probability and new information.

Conditional Probability

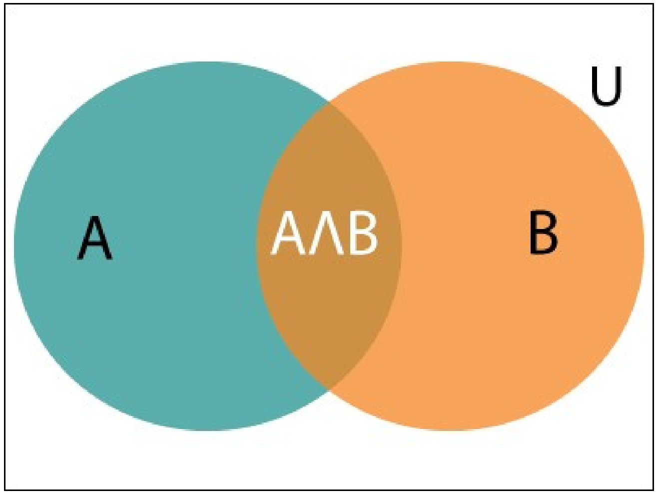
- Conditional probability is a probability of occurring an event when another event has already happened.
- Let's suppose, we want to calculate the event A when event B has already occurred, "the probability of A under the conditions of B", it can be written as:

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

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

Conditional Probability

- 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:

- 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.

Thank you

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