

Introduction to AI

Lecture 18

Reasoning and Uncertainty

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Reasoning in AI

- Until now we have learned various ways of knowledge representation in artificial intelligence. Now we will learn the various ways to reason on this knowledge using different logical schemes.
- The reasoning is the mental process of deriving logical conclusions 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, reasoning is essential so that the machine can also think rationally as a human brain, and can perform like a human.

Types of Reasoning

- 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 a 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 mostly starts from the general premises to the specific conclusion, which can be explained as an example.

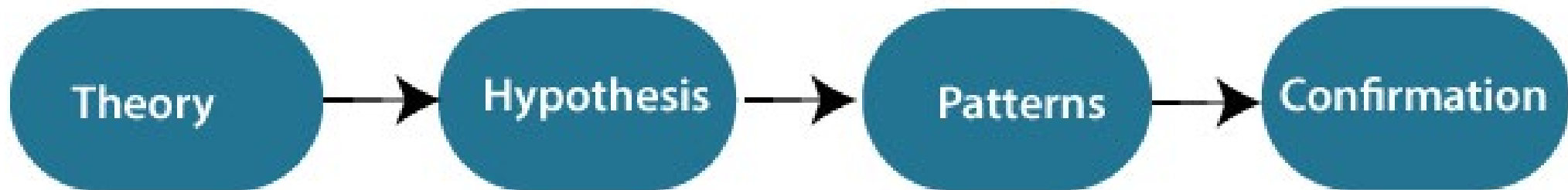
Example

Premise-1: All the human eats veggies

Premise-2: Suresh is human.

Conclusion: Suresh eats veggies.

The general process of deductive reasoning is given below:



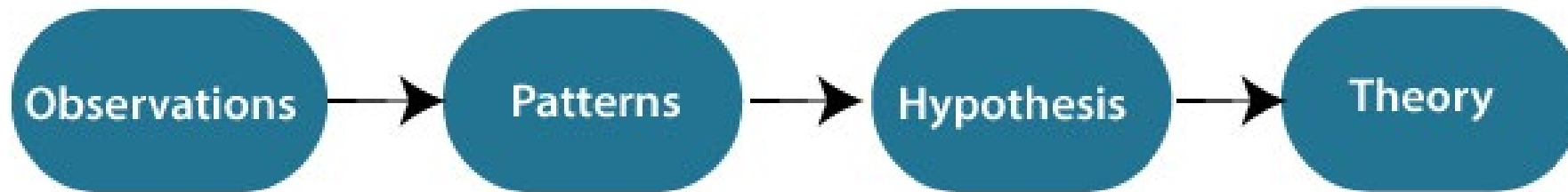
Inductive Reasoning

- 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 a series of specific facts or data and reaches 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 support to the conclusion, so the truth of premises does not guarantee the truth of the conclusion.

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 that starts with single or multiple observations and 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 that occur every day.
- It relies on good judgment rather than exact logic and operates on **heuristic knowledge** and **heuristic rules**.

Example:

1. One person can be at one place at a time.

2. If I put my hand in a fire, then it will burn.

- The above two statements are 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 a valid conclusion from the available facts only, and it will not be affected by new facts.
- Monotonic reasoning is not useful for real-time systems, as in real-time, facts get changed, so we cannot use monotonic reasoning.
- Any theorem proving is an example of monotonic reasoning.
- **Example:**
- **Earth revolves around the Sun.**
- It is a fact, and it cannot be changed even if we add another sentence in the knowledge base like, "The moon revolves around the earth" Or "Earth is not round," etc.

Non-monotonic Reasoning

- In Non-monotonic reasoning, some conclusions may be invalidated if we add some more information to 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.
- **Example:** Let's 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 another sentence into the knowledge base "**Pitty is a penguin**", which concludes "**Pitty cannot fly**", it invalidates the above conclusion.

Difference between Inductive and Deductive reasoning

Basis for comparison	Deductive Reasoning	Inductive Reasoning
Definition	Deductive reasoning is the form of valid reasoning, to deduce new information or conclusion from known related facts and information.	Inductive reasoning arrives at a conclusion by the process of generalization using specific facts or data.
Approach	Deductive reasoning follows a top-down approach.	Inductive reasoning follows a bottom-up approach.
Starts from	Deductive reasoning starts from Premises.	Inductive reasoning starts from the Conclusion.
Validity	In deductive reasoning conclusion must be true if the premises are true.	In inductive reasoning, the truth of premises does not guarantee the truth of conclusions.
Usage	Use of deductive reasoning is difficult, as we need facts which must be true.	Use of inductive reasoning is fast and easy, as we need evidence instead of true facts. We often use it in our daily life.
Process	Theory → hypothesis → patterns → confirmation.	Observations → patterns → hypothesis → Theory.
Argument	In deductive reasoning, arguments may be valid or invalid.	In inductive reasoning, arguments may be weak or strong.
Structure	Deductive reasoning reaches from general facts to specific facts.	Inductive reasoning reaches from specific facts to general facts.

Probabilistic reasoning in AI

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: Information occurred from unreliable sources.

1. Experimental Errors
2. Equipment fault
3. Temperature variation
4. 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.
- 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.

Need of probabilistic reasoning in AI

- When there are unpredictable outcomes.
- When specifications or possibilities of predicates become 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**
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- As probabilistic reasoning uses probability and related terms, 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 which represents ideal uncertainties.

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

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

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

• We can find the probability of an uncertain event by using the below formula,

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

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

• $P(\neg A) + P(A) = 1$.

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

• **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 the probability computed before observing new information.

• **Posterior Probability:** The probability that is calculated after all evidence or information has been taken into account. It is a combination of prior probability and new information.

Conditional probability

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

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

- **Where $P(A \cap B)$ = 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:

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

- It can be explained by using the 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 **$P(A \cap B)$ by $P(B)$** .

Example

- In a class, there are 70% of the students like English and 40% of the students like English and mathematics, and then what is the percentage of students 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.

