

# Lecture 3: Reasoning, Logic and Inferences - An overview

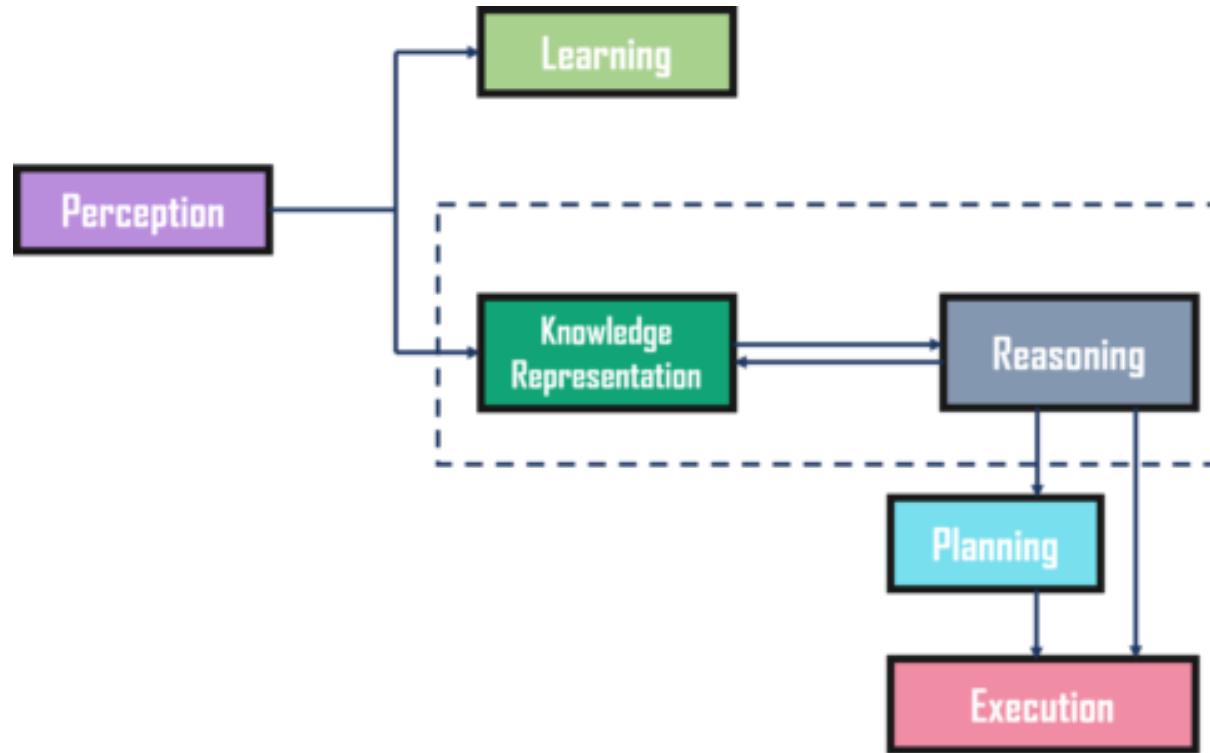
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INDRAPRASTHA INSTITUTE *of*  
INFORMATION TECHNOLOGY  
**DELHI**



# Why reasoning, logic, and inference?



# Knowledge Representation

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- What?
  - The process of representing knowledge in a way that can be interpreted and used by machines
  - Knowledge representation involves transforming knowledge into a structured format that can be processed and manipulated by computer programs
- Why is important?
  - Enables computers to reason, learn and make decisions based on knowledge
  - Helps in solving complex problems
  - Facilitates knowledge sharing and reuse



# Types of Knowledge Representation?

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- **Logic-based representation:** uses formal logic to represent knowledge, e.g., propositional logic, predicate logic
- **Semantic networks:** represent knowledge as nodes and links between them, e.g., concept maps
- **Frames and scripts:** organize knowledge into hierarchical structures with attributes and values, e.g., object-oriented programming
- **Rule-based systems:** represent knowledge as a set of rules or conditional statements, e.g., expert systems

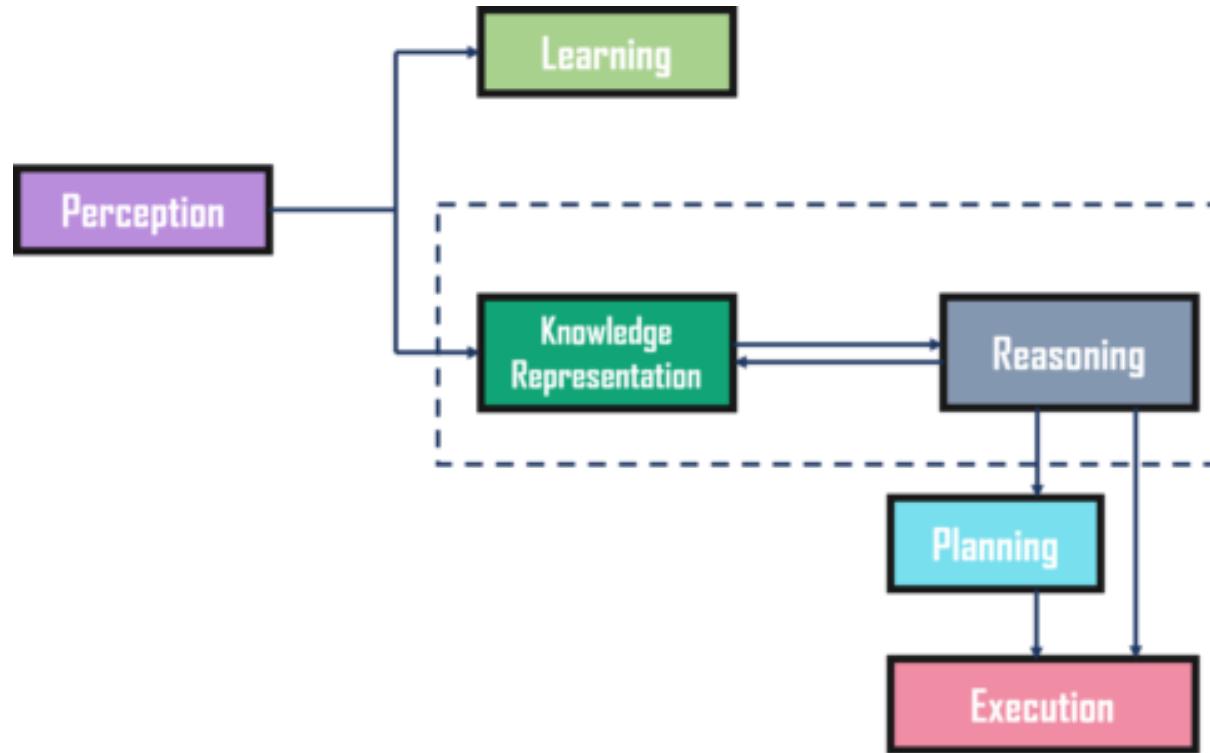
# Knowledge Representation: Logic

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- Logic provides a formal and precise framework for representing knowledge and reasoning in intelligent systems.
- Propositional logic uses statements or propositions to represent knowledge.
  - Each proposition is either true or false.
- Example:
  - All men are mortal [p]
  - Socrates is a man [q]
  - Therefore, Socrates is mortal. [r]
- Predicate logic uses predicates or relations to represent knowledge.
  - Predicates can take one or more arguments, called terms, which can be constants, variables, or other predicates.
- Example: All dogs are mammals
  - For all x, if Dog(x), then Mammal(x);  $\forall x [D(x) \rightarrow M(x)]$

# Why reasoning, logic, and inference?





# Reasoning

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- Reasoning is the cognitive process of making inferences, drawing conclusions, and arriving at judgments based on available information, evidence, and beliefs.
- It is the ability to use existing knowledge to analyze and solve problems, make decisions, and plan actions.
- Reasoning is a crucial component of intelligence and is utilized in various fields such as science, mathematics, law, philosophy, and everyday life.



# Traffic Light Example

- The traffic light at the busy intersection has a dramatic life—it's always flipping between colors, and it needs your help to formalize its behavior. Here's what we know:
  - At any given moment, the traffic light is either green, yellow, or red. It's never in more than one state at a time.
  - The traffic light switches from green to yellow, yellow to red, and red to green. There's no creative jumping around in the sequence—it sticks to its routine.
  - The traffic light cannot remain in the same state for more than 3 consecutive cycles. It gets bored easily.
- Represent these rules (highlighted in bold) clearly using Propositional Logic (PL) and another using FOL.

# Inference

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- Inference is the process of drawing conclusions based on available **Knowledge** and **reasoning**.





# Reasoning

- Enables IS to draw conclusions based on available information.

**Inductive**

**Deductive**

**Abductive**





# Deductive Reasoning

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- Deductive reasoning helps in making logical conclusions based on known facts and rules.
  - E.g., Deductive Reasoning in Crime Investigation
- Deductive reasoning starts with a general premise or statement, and then uses logical steps to arrive at a specific conclusion.
- In this type of reasoning, if the premises are true, then the conclusion must be true.
- Examples:
  - All birds have feathers. Penguins are birds.
    - Therefore, penguins have feathers.
  - If it rains, the streets will be wet. It is raining.
    - Therefore, the streets are wet.



# Inductive Reasoning



- Involves deriving general principles or rules from specific observations, instances, or patterns.
  - It is a process of generalizing from specific cases to make broader, more encompassing conclusions.
- Unlike deductive reasoning, it does not guarantee the truth of its conclusions but rather suggests likelihood based on observed patterns.
- **Example:**
  - Observation 1: The sun rose today.
  - Observation 2: The sun rose yesterday.
  - Observation 3: The sun rose every day in recorded history.
  - Conclusion: The sun always rises in the morning.
- Fundamental in scientific inquiry, where it helps researchers formulate hypotheses based on empirical data, observed patterns or trends.
  - These hypotheses are then subject to further testing and validation through experimentation and observation.



# Abductive Reasoning

- Form of reasoning that involves making educated guesses or hypotheses based on *limited information or incomplete data*.
- Example - Observation: The ground is wet.
  - Hypothesis 1: It rained last night.
  - Hypothesis 2: A sprinkler was turned on.
  - Hypothesis 3: A water pipe burst.
- Conclusion: It likely rained last night (based on the most plausible explanation given the context).
- It is used to generate plausible explanations for a particular observation or phenomenon,
  - there is insufficient evidence to support any single explanation definitively.
  - considers multiple explanations and selects the most likely one.
- Often used in medical diagnosis (e.g., inferring a disease from symptoms), fault detection (e.g., identifying the root cause of a system failure).

# Examples of Reasoning in IS



- Machine learning: ML algorithms use inductive reasoning to learn patterns and relationships in data.
  - For example, a classification algorithm may use historical data to identify patterns and then use these patterns to classify new data.
- Natural language processing: NLP systems use deductive reasoning to understand and interpret natural language.
  - For example, an NLP system may use a set of rules and logic to infer the meaning of a sentence based on its grammatical structure and the context in which it appears.
- Autonomous vehicles: Autonomous vehicles use a combination of deductive and inductive reasoning to navigate their environment and make decisions.
  - For example, a self-driving car may use deductive reasoning to interpret traffic signs and signals, and inductive reasoning to learn from past experiences and adjust its behavior accordingly.

# Propositional Logic



- Propositions are represented using propositional symbols or variables that can take on the values of true or false.
- Logical operators such as negation, conjunction, disjunction, implication, and equivalence are used to combine propositions and form complex statements.
- Truth tables are used in propositional logic to determine the truth value of a complex statement based on the truth values of its constituent propositions.

T	T	T
T	F	T
F	T	T
F	F	F



# Propositional Logic: Inference Rules

- Inference rules are used in propositional logic to derive new statements from existing ones.
- Example:
- Modus Ponens:
  - If  $p$  implies  $q$  and  $p$  is true, then  $q$  must be true as well.
  - Symbolically:  $(p \rightarrow q) \wedge p \rightarrow q$
  - Example:
    - If it is raining, the ground is wet. It is raining.
      - Therefore, the ground is wet.
- Modus Tollens:
  - If  $p$  implies  $q$  and  $q$  is false, then  $p$  must be false as well.
  - Symbolically:  $(p \rightarrow q) \wedge \neg q \rightarrow \neg p$
  - Example:
    - If it is raining, the ground is wet. The ground is not wet.
      - Therefore, it is not raining.

# Propositional Logic: Inference Rules

- Law of Syllogism:
  - If  $p$  implies  $q$  and  $q$  implies  $r$ , then  $p$  implies  $r$ .
  - Symbolically:  $(p \rightarrow q) \wedge (q \rightarrow r) \rightarrow (p \rightarrow r)$
  - Example:
  - If it is raining, the ground is wet. If the ground is wet, the shoes are muddy. Therefore, if it is raining, the shoes are muddy.



# Predicate Logic

- Predicates are expressions that are true or false of a given object, and variables are placeholders that stand for objects.
- Quantifiers are used in predicate logic to express the scope of a variable in a statement.
- The two main quantifiers in predicate logic are
  - the universal quantifier ( $\forall$ ), which means "for all,"
    - Example:  $\forall x, x + 2 > x$
    - For any value of  $x$ ,  $x + 2$  will always be greater than  $x$ .
  - the existential quantifier ( $\exists$ ), which means "there exists."
    - Example:  $\exists x, x^2 = 25$
    - There is at least one value of  $x$  that makes the statement true, in this case,  $x$  can be either 5 or -5.
- Combined quantification:
  - $\forall x \exists y, x + y = 10$

# Predicate Logic: Inference Rules



- Universal Instantiation:
  - Universal instantiation is a rule of inference that allows you to derive a specific instance of a universally quantified statement.
    - $\forall x (\text{dog}(x) \rightarrow \text{bark}(x))$
- Existential Instantiation:
  - Existential instantiation is a rule of inference that allows you to derive an instance of an existentially quantified statement.
    - $\exists x (\text{dog}(x) \wedge \text{bark}(x))$



# Putting it all together!



- If you get 95 on the final exam for IIS, then you get an A for the course.
  - Someone, call him/her say c, gets 95 on the final exam. Therefore c gets an A for IIS.

