Knowledge Representation and Reasoning (KRR)

Dr. Nasima Begum
Associate Professor
Dept. of CSE, UAP

Knowledge Representation (KR)

- Logic: Propositional Logic, Predicate Logic
- Rules : If then
- Semantic Net (meaningful graph): Google Graph
- Frames: Slots and fillers (object and attributes)
- Scripts (details of frame)
- Fuzzy Logic (Handles degree of truth in-between 0~1)

KR and Reasoning (KRR)

- **What is Knowledge Representation and Reasoning (KR&R)?**
- Symbolic encoding of propositions believed by some agent and their manipulation to produce propositions that are believed by the agent but not explicitly stated in the KB.
- A technique for representing information about the real world so that a computer can: understand and can utilize this knowledge to solve the complex real world problems such as **diagnosis a medical condition** or **communicating with humans** in natural language.
- Knowledge representation is not just storing data into some database, but it also enables an intelligent machine **to learn** from that knowledge and experiences so that it can **behave intelligently like a human**.

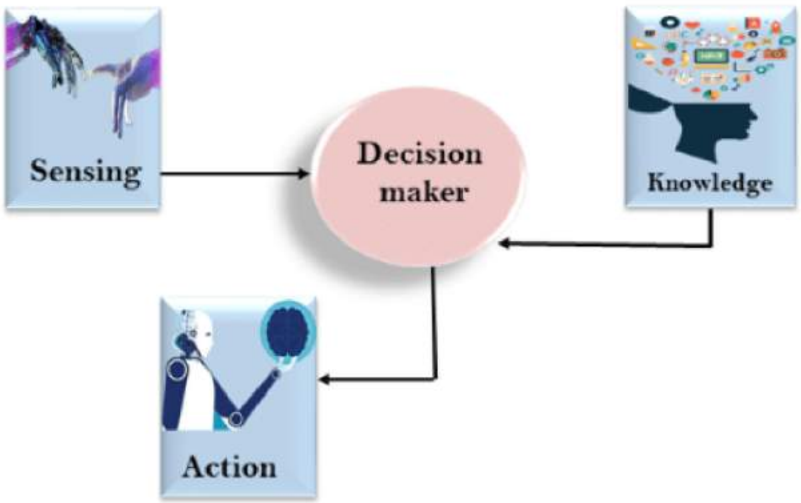
KR and Reasoning (KRR)

- **What is Knowledge Representation and Reasoning (KR&R)?**
- Symbolic encoding of propositions believed by some agent and their manipulation to produce propositions that are believed by the agent but not explicitly stated.
- **Why KR&R?:**
  - Large amounts of knowledge are used to understand the world around us.
  - Reasoning provides compression in the knowledge we need to store.
  - Without reasoning we would have to store an infeasible amount of information:

Example: Elephants can’t fit into teacups, Elephants can’t fit into cars, instead of just knowing that larger objects can’t fit into smaller objects.

KR and Reasoning (KRR)

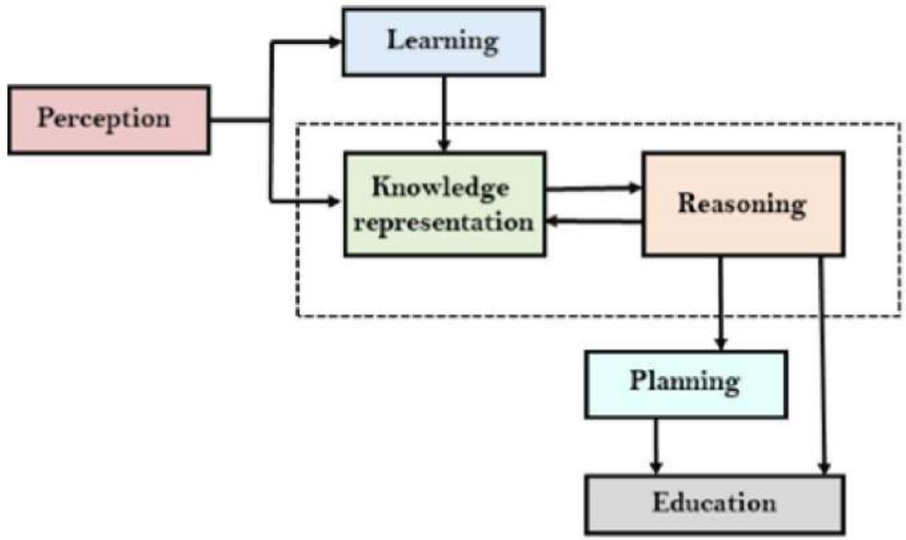
- Relation between knowledge and intelligence:



- The **decision maker act** by sensing the environment and using knowledge (KB).
- But if the knowledge part is not present then, it cannot display intelligent behavior.

KR and Reasoning (KRR)

- **AI Knowledge Cycle (AKC):** An Artificial intelligence system needs the following **components** for displaying intelligent behavior:
- Perception
- Learning
- Knowledge Representation and Reasoning
- Planning
- Execution



- This diagram is showing how an AI system can interact with the real world and what components make it possible to show intelligent behavior.

Knowledge Representation (KR)

- **Propositional Logic (either true or false, not both)**
- Predicate Logic
- Semantic Networks
- Frames
- Scripts
- Fuzzy Logic

Propositional Logic

- A formal method of reasoning, which represents knowledge, allowing automated inference and problem solving.
- **Concepts are translated into symbolic representations which closely approximate the meaning**.
- These symbolic structures can be **manipulated** in programs to deduce various facts, to **carry out** a form of **automated reasoning**.
- Propositional logic is the simplest.
  - Symbols represent whole propositions (facts): P, Q, R, S, etc.
  - These are joined by logical connectives (and, or, implication) e.g., $P \wedge Q$; $Q \rightarrow R$
  - Given some statements in the logic we can deduce new facts

    (e.g., from above deduce R)

Propositional Logic: Semantics

- Propositions
  - Sentences and truth values
  - **Propositional connectives and their truth tables**
    - Negation: ~P
    - Conjunction: $P \wedge Q$
    - Disjunction: $P \vee Q$ (inclusive or)
    - Implication: $P \rightarrow Q$ ($\sim P \vee Q$)
    - Equivalence: $P \leftrightarrow Q$
  - Other propositional connectives
    - $P \oplus Q$ (exclusive or), $P \downarrow Q$ (nor), $P \uparrow Q$ (nand), etc.

Propositional Logic

- Propositions are some elementary atomic sentences. Propositions may be either true or false. In propositional logic, a world is represented as knowledge using a list of facts.
- **Syntax of PL :**
- symbol -> P | Q | R | S | ...
- atomic sentence -> TRUE | FALSE
- sentence -> atomic sentence | complex sentence
- complex sentences -> ~ sentence | (sentence ^ sentence) | (sentence v sentence) | (sentence $\rightarrow$ sentence) | (sentence $\leftrightarrow$ sentence)
- Precedence relation operators: ~, ^, v, $\rightarrow$, $\leftrightarrow$.

Propositional Logic: Examples

- My car is painted red.
- Snow is white.
- People live on the moon.
- Logical connectives:
- It is raining and the wind is blowing.
- I shall go there or ask kamal to visit him.
- If you study heard you will be successful.
- The sum of 20 and 30 is not 100.
- The car belongs to the VC is painted silver.

Semantic Rules for Statements

Rule No.	True Statements	False Statements
1	T	F
2	~ F	~ T
3	T AND T′	F AND a
4	T OR a	a AND F
5	a OR T	F or F′
6	a → T	T → F
7	F → a	T ↔ F
8	T ↔ T′	F ↔ T
9	F ↔ F ′	

Properties of Statements

1) Satisfiable: A statement is satisfiable if there is some interpretation for which it is true.

2) **Contradiction:** A statement is said to be contradictory (unsatisfiable) if there is no interpretation for which it is true.

3) **Valid:** A statement is valid if it is true for every interpretations. Valid statements are also called tautologies.

4) **Equivalence:** Two sentences are equivalent if they have the same truth value under every interpretation.

Semantics and Interpretations

P	Q	$P \wedge Q$	$P \vee Q$	$\sim P$	$P \rightarrow Q$ $(\sim P \vee Q)$	$P \leftrightarrow Q$ $(P = Q)$
F	F	F	F	T	T	T
F	T	F	T	T	T	F
T	F	F	T	F	F	F
T	T	T	T	F	T	T

Meaning of Statements

- What would be the meaning of the following statement, if some interpretation imply true to P, false to Q and R? $((P \wedge \sim Q) \rightarrow R) \vee Q$

- **Assignments:**

1. Find the meaning of the statement: $(\sim P \vee Q) \wedge R \rightarrow S \vee (\sim R \wedge Q)$ for each of the interpretations given below:

   I1: P is true, Q is true, R is false, S is true.

   I2: P is true, Q is false, R is true, S is true.

2. Determine whether each of the following sentence is: (a) satisfiable (b) contradictory or (c) valid

   S1: $(P \wedge Q) \vee \sim (P \wedge Q)$ S2: $(P \vee Q) \rightarrow (P \wedge Q)$

   S3: $(P \wedge Q) \rightarrow R \vee \sim Q$ S4: $(P \vee Q) \wedge (P \vee \sim Q) \vee P$

   S5: $P \rightarrow Q \rightarrow \sim P$ S6: $P \vee Q \wedge \sim P \vee \sim Q \wedge P$

Meaning of Statements

- If the earth moves round the sun or the sun moves round the earth, then Copernicus might be a mathematician but wasn't an astronomer.

- Inspite of having French nationality, B. Russel was a critic of imperialism, then either he was not a bachelor or he was a universal lover.

Rules of Inference

- The rules of inference (also known as inference rules) are **a logical form or guide consisting of premises (or hypotheses) and draws a conclusion.**

- **9 rules of inference**
  a) Modus Ponens (M.P.) -If P then Q. -P. ...
  b) Modus Tollens (M.T.) -If P then Q. ...
  c) Hypothetical Syllogism (H.S.) -If P then Q. ...
  d) Disjunctive Syllogism (D.S.) -P or Q. ...
  e) Conjunction (Conj.) -P. ...
  f) Constructive Dilemma (C.D.) -(If P then Q) and (If R then S) ...
  g) Simplification (Simp.) -P and Q. ...
  h) Absorption (Abs.) -If P then Q.
  i) Addition (Add.) –P then P or Q

Rules of Inference

- **Modus Ponens:** One of the most important rules of inference, and it states that if P and P → Q is true, then we can infer that Q will be true. It can be represented as:
- $\dfrac{P \rightarrow Q,\ P}{\therefore Q}$ $\{((P \rightarrow Q) \land P) \rightarrow Q\}$
- Hence, we can say that, if P→ Q is true and P is true then Q will be true.

- **Modus Tollens:** This rule state that if P→ Q is true and ¬ Q is true, then ¬ P will also true. It can be represented as:
- $\dfrac{P \rightarrow Q,\ \sim Q}{\therefore \sim P}$ $\{((P \rightarrow Q) \land \sim Q) \rightarrow \sim P\}$

Rules of Inference

- **Modus Ponens:** One of the most important rules of inference, and it states that if P and P → Q is true, then we can infer that Q will be true. It can be represented as:
- $$\frac{P \rightarrow Q,\ P}{\therefore Q} \qquad \{((P \rightarrow Q) \land P) \rightarrow Q\}$$
- Hence, we can say that, if P→ Q is true and P is true then Q will be true

Example:

Statement-1: "If I am sleepy then I go to bed" ==> P→ Q

Statement-2: "I am sleepy" ==> P

Conclusion: "I go to bed." ==> Q.

Hence, we can say that, if P→ Q is true and P is true then Q will be true.

Rules of Inference

- **Modus Tollens:** This rule state that if P→ Q is true and ¬ Q is true, then ¬ P will also true. It can be represented as:
- $$\frac{P \rightarrow Q, \sim Q}{\therefore \sim P} \qquad \{((P \rightarrow Q) \wedge \sim Q) \rightarrow \sim P\}$$

Example:

Statement-1: "If I am sleepy then I go to bed" ==> P→ Q

Statement-2: "I do not go to the bed."==> ~Q

Statement-3: Which infers that "I am not sleepy" => ~P

Rules of Inference

- **Hypothetical Syllogism (H. S.):** This rule state that if P→R is true whenever P→Q is true, and Q→R is true. It can be represented as the following notation:
- $$\frac{(P \rightarrow Q) \wedge (Q \rightarrow R)}{\therefore P \rightarrow R}$$

- **Example:**

Statement-1: If you have my home key then you can unlock my home. P→Q

Statement-2: If you can unlock my home then you can take my money. Q→R

Conclusion: If you have my home key then you can take my money. P→R

Rules of Inference

- **Disjunctive Syllogism (D. S.):** The Disjunctive syllogism rule state that if PVQ is true, and ¬P is true, then Q will be true. It can be represented as:
- $$\frac{(P \vee Q) \quad \sim P}{\therefore Q}$$

Example:

Statement-1: Today is Sunday or Monday. ==>PVQ

Statement-2: Today is not Sunday. ==> ¬P

Conclusion: Today is Monday. ==> Q

Rules of Inference

- **Example (Modus Ponens)**

  P: Mr. Chowdhury is a father.

  Q: Mr. Chowdhury has a child.

$$\frac{(P \rightarrow Q)\,,\, P}{\therefore Q} \qquad \{((P \rightarrow Q) \wedge P) \rightarrow Q\}$$

- **Example (Modus Tollens)**

  P: Mr. Chowdhury has no child.

  Q: So, Mr. Chowdhury is not a father.

$$\frac{P \rightarrow Q,\, \sim Q}{\sim P} \qquad \{((P \rightarrow Q) \wedge \sim Q) \rightarrow \sim P\}$$

- Modus Ponens & Modus Tollens are valid statement.

Rules of Inference

- **Example (Hypothetical Syllogism (H. S.))**

  C++ like java programming and java like pascal programming. So, C++ like pascal programming.

  P: C++ like java programming .

  Q: java like pascal programming.

  R: C++ like pascal programming.

- $$\frac{(P \rightarrow Q) \wedge (Q \rightarrow R)}{\therefore P \rightarrow R}$$

Q: Check whether it is valid or satisfiable or what?

Rules of Inference

- **Example (Disjunctive Syllogism (D. S.))**
- (P V Q), ~ P

$$\frac{(P \vee Q),\ \sim P}{\therefore Q}$$

P: Tagor got Nobel prize in 1913 .

Q: Tagor got Nobel prize in 1930 .

$$\frac{(P \vee Q),\ \sim P}{\therefore Q}$$

Q: Check whether it is valid or satisfiable or what?

Drawbacks of Propositional Logic (PL)

- **We cannot represent relations like ALL, some, or none with propositional logic**.
  Example:
  All the girls are intelligent.
  Some apples are sweet.
- Propositional logic has limited expressive power.
- In propositional logic, we cannot describe statements in terms of their properties or logical relationships.
- Propositional logic isn't powerful enough as a general knowledge representation technique.
- Impossible to make general statements.
  E.g., "all student sits in the exams" or
  "if any student sits an exam they either pass or fail".

- So we **need predicate logic**.

Acknowledgement

- AIMA = Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norving (3rd edition)
- U of toronto
- Other online resources

Thank You