



Knowledge Representation and Reasoning (KRR)

Dr. Nasima Begum
Assistant 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**.
- Is a technique for representing information about the real world so that a computer can:
 - i) **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**.

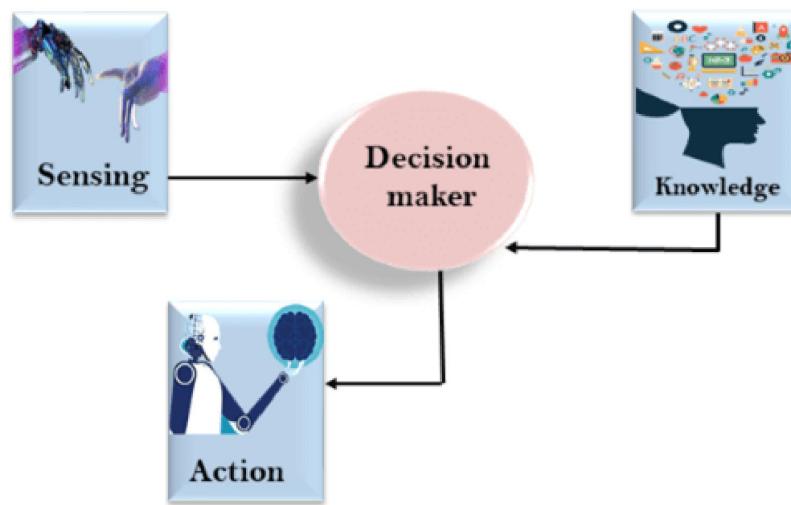
KR and Reasoning (KRR)

- **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:

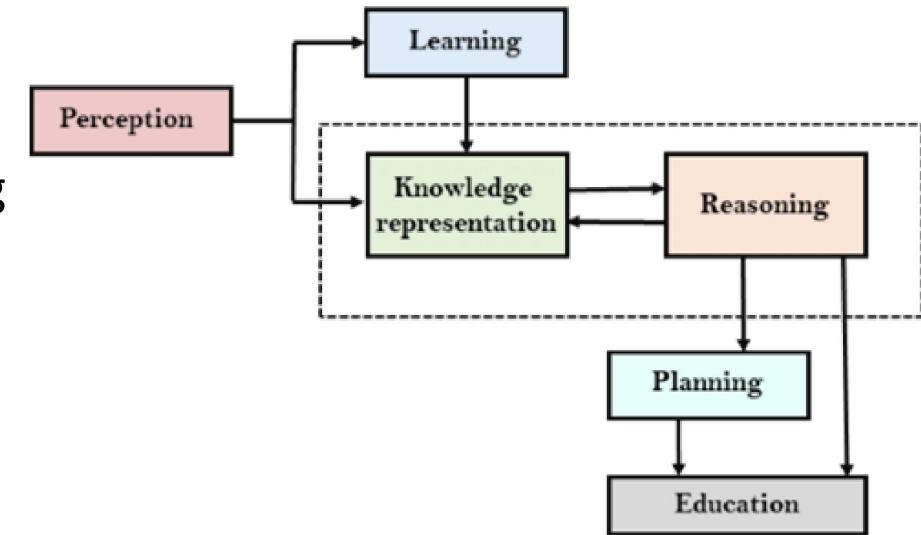


- The **decision maker** **act** by sensing the environment and using knowledge.
- But if the **knowledge** part is not present then, it **cannot** display **intelligent behavior**.

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 help it to show intelligence.

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: $\sim P$
 - 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 -> \sim sentence | (sentence \wedge sentence) | (sentence \vee sentence) | (sentence \rightarrow sentence) | (sentence \leftrightarrow sentence)
- Precedence relation operators: \sim , \wedge , \vee , \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	$\sim F$	$\sim T$
3	T AND T'	F AND a
4	T OR a	a AND F
5	a OR T	F or F'
6	$a \rightarrow T$	$T \rightarrow F$
7	$F \rightarrow a$	$T \leftrightarrow F$
8	$T \leftrightarrow T'$	$F \leftrightarrow T$
9	$F \leftrightarrow F'$	

Properties of Statements

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

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

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

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 $P \rightarrow Q$ is true, then we can infer that Q will be true. It can be represented as:

$$\begin{array}{c} \text{■ } \frac{P \rightarrow Q, P}{\therefore Q} \quad \{((P \rightarrow Q) \wedge P) \rightarrow Q\} \end{array}$$

- Hence, we can say that, if $P \rightarrow Q$ is true and P is true then Q will be true.

- **Modus Tollens:** This rule state that if $P \rightarrow Q$ is true and $\neg Q$ is true, then $\neg P$ will also true. It can be represented as:

$$\begin{array}{c} \text{■ } \frac{P \rightarrow Q, \neg Q}{\therefore \neg P} \quad \{((P \rightarrow Q) \wedge \neg Q) \rightarrow \neg P\} \end{array}$$

Rules of Inference

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

Example:

Statement-1: "If I am sleepy then I go to bed" $\Rightarrow P \rightarrow Q$

Statement-2: "I am sleepy" $\Rightarrow P$

Conclusion: "I go to bed." $\Rightarrow Q$.

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

Rules of Inference

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

Example:

Statement-1: "If I am sleepy then I go to bed" $\Rightarrow P \rightarrow Q$

Statement-2: "I do not go to the bed." $\Rightarrow \neg Q$

Statement-3: Which infers that "I am not sleepy" $\Rightarrow \neg P$

Rules of Inference

- **Hypothetical Syllogism (H. S.):** This rule state that if $P \rightarrow R$ is true whenever $P \rightarrow Q$ is true, and $Q \rightarrow R$ 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. $P \rightarrow Q$

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

Conclusion: If you have my home key then you can take my money. $P \rightarrow R$

Rules of Inference

- **Disjunctive Syllogism (D. S.):** The Disjunctive syllogism rule state that if $P \vee Q$ is true, and $\neg P$ is true, then Q will be true. It can be represented as:

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

□ Example:

Statement-1: Today is Sunday or Monday. $\Rightarrow P \vee Q$

Statement-2: Today is not Sunday. $\Rightarrow \neg P$

Conclusion: Today is Monday. $\Rightarrow Q$

Rules of Inference

■ Example (Modus Ponens)

P: Mr. Chowdhury is a father.

Q: Mr. Chowdhury has a child.

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

■ Example (Modus Tollens)

P: Mr. Chowdhury has no child.

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

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

- 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.

$$\begin{array}{c} \blacksquare \quad (P \rightarrow Q) \wedge (Q \rightarrow R) \\ \hline \therefore P \rightarrow R \end{array}$$

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

Rules of Inference

- Example (Disjunctive Syllogism (D. S.))

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

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