

Artificial Intelligence

Knowledge Representation: Proposition and Predicate Logic, Theorem Proving (Resolution), Semantic Network, Production Rules, Frames and Scripts

1.1 Goals of Artificial Intelligence:

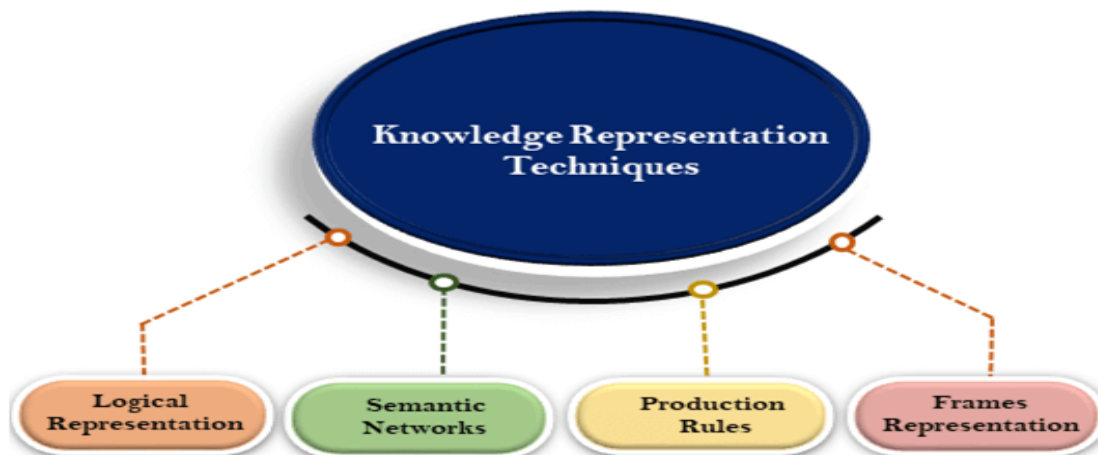
Following are the main goals of Artificial Intelligence:

- Replicate human intelligence
- Solve Knowledge-intensive tasks
- An intelligent connection of perception and action
- Building a machine which can perform tasks that requires human intelligence such as:
- Proving a theorem
- Playing chess
- Plan some surgical operation
- Driving a car in traffic
- Creating some system which can exhibit intelligent behavior, learn new things by itself, demonstrate, explain, and can advise to its user

1.2 Techniques of knowledge representation

There are mainly four ways of knowledge representation which are given as follows:

1. Logical Representation
2. Semantic Network Representation
3. Frame Representation
4. Production Rules.



Artificial Intelligence**1.2.1 Logical Representation:**

Logical representation is a language with some concrete rules which deal with propositions and has no ambiguity in representation. Logical representation means drawing a conclusion based on various conditions. This representation lays down some important communication rules. It consists of precisely **defined syntax and semantics** which supports the sound inference. Each sentence can be translated into logics using syntax and semantics.

التمثيل المنطقي

التمثيل المنطقي هو لغة بها بعض القواعد الملموسة التي تتعامل مع المقترحات وليس لديها غموض في التمثيل. التمثيل المنطقي يعني التوصل إلى نتيجة بناءً على شروط مختلفة. هذا التمثيل يضع بعض قواعد الاتصال الهامة. وهو يتألف من بناء الجملة والدلالات المحددة بدقة والتي تدعم استنتاج الصوت. يمكن ترجمة كل جملة إلى المنطق باستخدام بناء الجملة والدلالات.

- **Syntax:**
 1. Syntaxes are the rules which decide how we can construct legal sentences in logic.
 2. It determines which symbol we can use in knowledge representation.
 3. How to write those symbols.
- **Semantics:**
 1. Semantics are the rules by which we can interpret the sentence in the logic.
 2. Semantic also involves assigning a meaning to each sentence.

The logical representation can be categorized into mainly two logics:

- **Propositional Logics**
- **Predicate logics**

We will discuss Propositional Logics and Predicate logics in last chapter.

What are advantage and disadvantage of logical representation:

Advantages of logical representation:	Disadvantages of logical Representation:
<ol style="list-style-type: none"> 1. Logical representation enables us to do logical reasoning. يمكننا من التفكير والاستنتاج العقلي المنطقي 2. Logical representation is the basis for the programming languages. هو اساس لغات البرمجة بصورة عامة 	<ol style="list-style-type: none"> 1. Logical representations have some restrictions and are challenging to work with. 2. Logical representation technique may not be very natural, and inference may not be so efficient.

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Do not be confused with **logical representation** and **logical reasoning** as logical representation is a representation language and reasoning is a process of thinking logically.

logical representation is a representation language (يعتبر لغة التمثيل المستخدمة)

logical reasoning is a process of thinking logically.(يعتبر هو عملية التفكير المنطقي)

1.3 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.

- شبكة دلالات الالفاظ يمكن اعتبارها بديلا عن المنطق الاصلي لتمثيل المعرفة.
- يمكننا في هذا النوع تمثيل معرفتنا على شكل شبكات ورسوم
- تتكون هذه الشبكة من عقد لرسم الكائنات والاشياء
- والاقواس من خلالها توصف العلاقة بين تلك الكائنات والاشياء
- ويمكن وصف الكائنات باشكات مختلفة ويمكن ربطها
- وهي سهلة الفهم ويمكن توسيعها لتشمل مواضيع مختلفة

This representation consists of **mainly two types** of relations:

1. IS-A relation (Inheritance)

2. Kind-of-relation

Example: Following are some statements which we need to represent in the form of nodes and arcs.

مثال: فيما يلي بعض العبارات التي نحتاج إلى ان نمثلها على شكل العقد او الأقواس والاسهم بطريقة .

Artificial Intelligence**Statements:**

Jerry is a cat.

جيري هو قطة.

Jerry is a mammal

جيري هو حيوان ثديي

Jerry is owned by Priya.

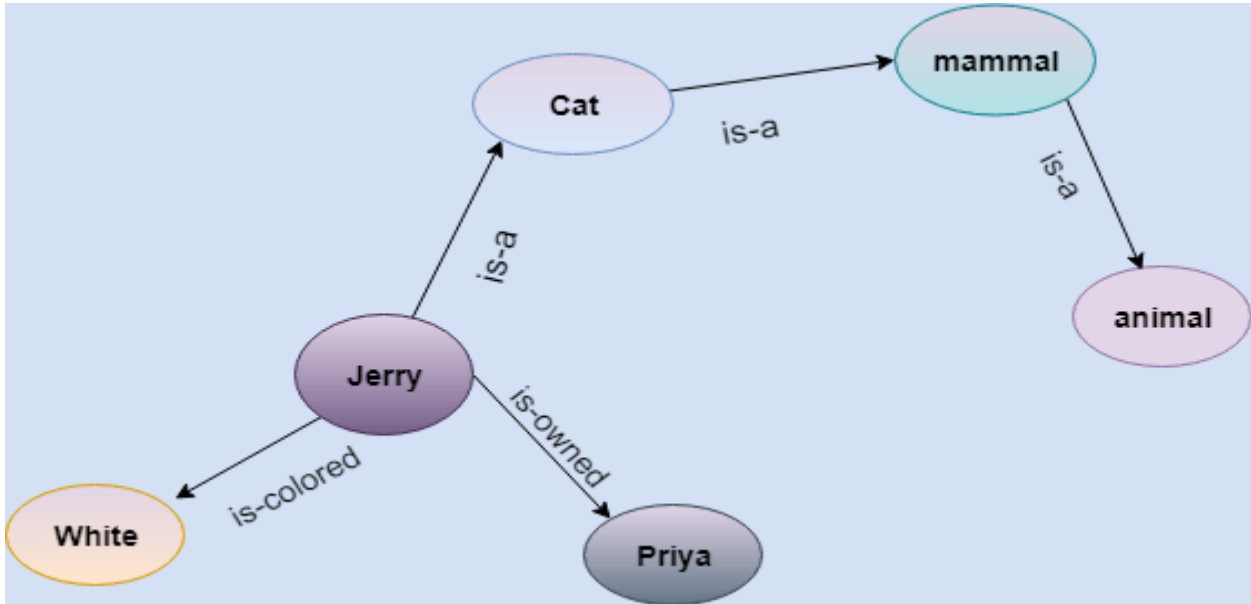
جيري مملوكة لبريا.

Jerry is White colored.

جيري ابيض اللون.

All Mammals are animal.

جميع الثدييات حيوانات.



In the above diagram, we have represented the different types of knowledge in the form of nodes and arcs. Each object is connected with another object by some relation.

في الرسم البياني أعلاه ، قمنا بتمثيل أنواع مختلفة من المعرفة بطريقة semantic العقد والأقواس. يرتبط كل كائن بكائن آخر عن طريق بعض العلاقة.

Artificial Intelligence❖ **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.

عيوب التمثيل الدلالي:

- تستغرق الشبكات الدلالية وقتاً أكبر في وقت التشغيل حيث نحتاج إلى اجتياز شجرة الشبكة الكاملة للإجابة على بعض الأسئلة. قد يكون من الممكن في أسوأ السيناريوهات أنه بعد اجتياز الشجرة بأكملها ، نجد أن الحل غير موجود في هذه الشبكة.
- تحاول الشبكات الدلالية نمذجة ذاكرة شبيهة بالإنسان (التي تحتوي على 1015 خلية عصبية وروابط) لتخزين المعلومات ، لكن من الناحية العملية ، لا يمكن بناء مثل هذه الشبكة الدلالية الواسعة.
- هذه الأنواع من العروض غير كافية لأنها لا تحتوي على أي مقياس مكافئ ، على سبيل المثال ، بالنسبة للبعض ، بالنسبة للبعض ، لا شيء ، إلخ.
- لا تحتوي الشبكات الدلالية على أي تعريف قياسي لأسماء الارتباطات.
- هذه الشبكات ليست ذكية وتعتمد على منشئ النظام

❖ **Advantages of Semantic network:**

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

- الشبكات الدلالية هي تمثيل طبيعي للمعرفة.
- تنتقل الشبكات الدلالية المعنى بطريقة شفافة.
- هذه الشبكات بسيطة وسهلة الفهم

Artificial Intelligence**1.4 Frame Representation**

A frame is a record like structure which consists of a collection of attributes and its values to describe an entity in the world. Frames are the AI **data structure** which divides knowledge into substructures by representing stereotypes situations. It **consists of a collection of slots and slot values. These slots may be of any type and sizes. Slots have names and values which are called facets.**

تمثيل الإطار

الإطار هو السجل يشبه هيكل الذي يتكون من مجموعة من السمات او الصفات والحقول وقيمته لوصف كيان في العالم الحقيقي . الإطارات هي بنية بيانات الذكاء الاصطناعي التي تقسم المعرفة إلى بنى أساسية عن طريق تمثيل مواقف الصور النمطية. يتكون من مجموعة من **slots and slot values**. قد تكون هذه **slots** من أي نوع وأحجام. **slot values** لها أسماء وقيم تسمى **facets** **اوجه**.

Example: 1

Let's take an example of a frame for a book, (using Frame technique to describe book).

Let's take an example of a frame for a book

Slots	Filters
Title	Artificial Intelligence
Genre	Computer Science
Author	Peter Norvig
Edition	Third Edition
Year	1996
Page	1152

Artificial Intelligence**Example 2:**

Let's suppose we are taking an entity, Peter. Peter is a Doctor as a profession, and his age is 25, His marital status, and His weight 78. So following is the frame representation for this:

لنفترض أننا نأخذ كياناً او شيء يراد تمثيل معرفته وليكون الشخص بيتر. بيتر مهندس هذه مهنته ، وعمره 25 عاماً ، يعيش في مدينة لندن ، والبلاد هي إنجلترا. فيما يلي تمثيل الإطار لهذا:

Slots	Filter
Name	Peter
Profession	Doctor
Age	25
Marital status	Single
Weight	78

❖ Advantages & Disadvantages of frame representation:

Advantages	Disadvantages
<ol style="list-style-type: none"> 1. The frame knowledge representation makes the programming easier by grouping the related data. 2. The frame representation is comparably flexible and used by many applications in AI. 3. It is very easy to add slots for new attribute and relations. 4. It is easy to include default data and to search for missing values. 5. Frame representation is easy to understand and visualize. 	<ol style="list-style-type: none"> 1. In frame system inference mechanism is not be easily processed. 2. Inference mechanism cannot be smoothly proceeded by frame representation. 3. Frame representation has a much generalized approach.

Artificial Intelligence**1.5 Production Rules**

Production rules system consist of (*condition, action*) pairs which mean,

"If condition then action".

It has mainly three parts:

1. The set of production rules
2. Working Memory
3. The recognize-act-cycle

In production rules agent checks for the condition and if the condition exists then production rule fires and corresponding action is carried out. The condition part of the rule determines which rule may be applied to a problem. And the action part carries out the associated problem-solving steps. This complete process is called a recognize-act cycle.

The working memory contains the description of the current state of problems-solving and rule can write knowledge to the working memory. This knowledge match and may fire other rules.

If there is a new situation (state) generates, then multiple production rules will be fired together, this is called conflict set. In this situation, the agent needs to select a rule from these sets, and it is called a conflict resolution.

Example:

1. **IF** (at bus stop AND bus arrives) **THEN** action (get into the bus)

إذا انت في محطة الباصات و الباص وصل , عليك الدخول في الباص (وهذا هو الفعل المطلوب منك)

2. **IF** (on the bus AND paid AND empty seat) **THEN** action (sit down).

إذا انت في الحافلة وهناك مقعد فارغ ومدفوع ثمنه عليك الجلوس

3. **IF** (on bus AND unpaid) **THEN** action (pay charges).

إذا انت في الباص ولم تدفع الاجرة عليك دفع الاجرة

4. **IF** (bus arrives at destination) **THEN** action (get down from the bus).

إذا وصل الباص الى جهة المقصودة عليك ان تنزل

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❖ Advantages & Disadvantages of Production rule:

Advantages	Disadvantages
<ol style="list-style-type: none"> 1. The production rules are expressed in natural language. 2. The production rules are highly modular, so we can easily remove, add or modify an individual rule. 	<ol style="list-style-type: none"> 1. Production rule system does not exhibit any learning capabilities, as it does not store the result of the problem for the future uses. 2. During the execution of the program, many rules may be active hence rule-based production systems are inefficient.

EXPLAIN:**Propositional logic in Artificial intelligence**

Propositional logic (PL) is the simplest form of logic where all the statements are made by propositions. A proposition is a declarative statement which is either true or false. It is a technique of knowledge representation in logical and mathematical form.

منطق الاقتراح (PL) هو أبسط شكل من أشكال المنطق حيث يتم إجراء جميع البيانات عن طريق المقترحات. الاقتراح عبارة عن بيان توضيحي صحيح أو خطأ. إنها تقنية لتمثيل المعرفة في الشكل المنطقي والرياضي

Example:

- a) It is Sunday.
- b) The Sun rises from West (False proposition)
- c) $3+3=7$ (False proposition)
- d) 5 is a prime number.

في هذا المثال يوجد توضيح للحقائق والمقترحات سوى كانت صحيحة او خاطئة المهم تمثيل للمعرفة بشكل منطقي او رياضي .

Artificial Intelligence❖ **Following are some basic facts about propositional logic:**

فيما يلي بعض الحقائق الأساسية حول المنطق المقترح :

- ✓ Propositional logic is also called Boolean logic as it works on 0 and 1.
- ✓ In propositional logic, we use symbolic variables to represent the logic, and we can use any symbol for a representing a proposition, such A, B, C, P, Q, R, etc.
- ✓ Propositions can be either true or false, but it cannot be both.
- ✓ Propositional logic consists of an object, relations or function, and **logical connectives**.
- ✓ These connectives are also called logical operators.
- ✓ The propositions and connectives are the basic elements of the propositional logic.
- ✓ Connectives can be said as a logical operator which connects two sentences.
- ✓ A proposition formula which is always true is called **tautology**, and it is also called a valid sentence.
- ✓ A proposition formula which is always false is called **Contradiction**.
- ✓ A proposition formula which has both true and false values is called
- ✓ Statements which are questions, commands, or opinions are not propositions such as "**Where is Rohini**", "**How are you**", "**What is your name**", are not propositions.

❖ **Syntax of propositional logic:**

The syntax of propositional logic defines the allowable sentences for the knowledge representation. There are two types of Propositions:

بناء جملة المنطق المقترح:

يحدد بناء الجملة المنطقي المقترح الجمل المسموح بها لتمثيل المعرفة. هناك نوعان من المقترحات

أ. المقترحات الذرية

ب. المقترحات المركبة

- a. **Atomic Propositions**
- b. **Compound propositions**

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- **Atomic Proposition:** Atomic propositions are the simple propositions. It consists of a single proposition symbol. These are the sentences which must be either true or false.

الاقتراح الذري: المقترحات الذرية هي الافتراضات البسيطة. وهو يتألف من رمز اقتراح واحد. هذه هي الجمل التي يجب أن تكون صحيحة أو خاطئة

Example:

- a) $2+2$ is 4, it is an atomic proposition as it is a **true** fact.
- b) "The Sun is cold" is also a proposition as it is a **false** fact.

- **Compound proposition:** Compound propositions are constructed by combining simpler or atomic propositions, using parenthesis and logical connectives.

الاقتراح المركب: يتم إنشاء المقترحات المركبة من خلال الجمع بين المقترحات الأكثر بساطة أو الذرية ، باستخدام الأقواس والموصلات المنطقية

Example:

- a) "It is raining today, and street is wet."
- b) "Ankit is a doctor, and his clinic is in Mumbai."

هذه اقتراحات معرفية مركبة من خلال جمع مقترحات تدل على معرفة ومنطق

❖ Logical Connectives:

Logical connectives are used to connect two simpler propositions or representing a sentence logically. We can create compound propositions with the help of logical connectives. There are mainly five connectives, which are given as follows:

يتم استخدام الروابط المنطقية للاتصال بين اقتراحين أبسط أو تمثيل جملة منطقية. يمكننا إنشاء مقترحات مركبة بمساعدة الروابط المنطقية. يوجد بشكل أساسي خمسة وصلات ، والتي يتم تقديمها على النحو التالي:

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1. **Negation:** A sentence such as $\neg P$ is called negation of P. A literal can be either Positive literal or negative literal.

النفي: جملة مثل $\neg P$ تسمى نفي P الحرف يمكن أن يكون حرفيًا موجبًا أو سالبًا

2. **Conjunction:** A sentence which has \wedge connective such as, $P \wedge Q$ is called a conjunction.

الترابط: الجملة التي لها علاقة \wedge مثل $P \wedge Q$ تسمى الترابط او الدمج

Example:

Ali is intelligent and hardworking. It can be written as,

علي ذكي ويعمل بجد , ولكن يمكن كتابتها بالطريقة التالية :

P= Ali is intelligent,

Q= Ali is hardworking.

$\rightarrow P \wedge Q.$

3. **Disjunction:** A sentence which has \vee connective, such as $P \vee Q$. is called disjunction, where P and Q are the propositions.

الفصل او الانفصال: هو الجملة التي لها ترابط بالشكل التالي \vee وكما مبين بالمثال التالي

$P \vee Q.$ is called disjunction, where P and Q are the propositions.

Example:

"Ali is a doctor or Engineer",

Here P= Ali is Doctor. Q= Ali is Engineer, so we can write it as $P \vee Q.$

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4. **Implication:** A sentence such as $P \rightarrow Q$, is called an implication. Implications are also **known** as if-then rules. It can be represented as

If it is raining, **then** the street is wet.

Let P= It is raining, and

Q= Street is wet,

so it is represented as $P \rightarrow Q$

التضمين: جملة مثل $P \rightarrow Q$ ، تسمى التضمين. تُعرف الآثار أيضًا بقواعد if-then. يمكن تمثيلها كـ إذا كانت السماء تمطر ، فإن الشارع مبلل.

5. **Biconditional:**

A sentence such as $P \Leftrightarrow Q$ is a **Biconditional** sentence, example

If I am breathing, then I am alive

P= I am breathing,

Q= I am alive,

it can be represented as $P \Leftrightarrow Q$.

ثنائي الشرط: جملة مثل $P \Leftrightarrow Q$ عبارة عن جملة ثنائية الشرط ، مثال إذا كنت أتنفس ، فأنا على قيد الحياة ، P = أنا أتنفس ، Q = أنا حي ، يمكن تمثيله كـ $P \Leftrightarrow Q$

❖ Following is the summarized table for Propositional Logic Connectives:

Connective symbols	Word	Technical term	Example
\wedge	AND	Conjunction	$A \wedge B$
\vee	OR	Disjunction	$A \vee B$
\rightarrow	Implies	Implication	$A \rightarrow B$
\Leftrightarrow	If and only if	Biconditional	$A \Leftrightarrow B$
\neg or \sim	Not	Negation	$\neg A$ or $\sim B$

Artificial Intelligence❖ **Truth Table:**

In propositional logic, we need to know the truth values of propositions in all possible scenarios. We can combine all the possible combination with logical connectives, and the representation of these combinations in a tabular format is called **Truth table**. Following are the truth table for all logical connectives:

For Negation:

P	$\neg P$
True	False
False	True

For Conjunction:

P	Q	$P \wedge Q$
True	True	True
True	False	False
False	True	False
False	False	False

For disjunction:

P	Q	$P \vee Q$
True	True	True
False	True	True
True	False	True
False	False	False

For Implication:

P	Q	$P \rightarrow Q$
True	True	True
True	False	False
False	True	True
False	False	True

For Biconditional:

P	Q	$P \leftrightarrow Q$
True	True	True
True	False	False
False	True	False
False	False	True

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❖ **Truth table with three propositions:**

We can build a proposition composing three propositions P, Q, and R. This truth table is made-up of 8n Tuples as we have taken three proposition symbols.

P	Q	R	$\neg R$	$P \vee Q$	$P \vee Q \rightarrow \neg R$
True	True	True	False	True	False
True	True	False	True	True	True
True	False	True	False	True	False
True	False	False	True	True	True
False	True	True	False	True	False
False	True	False	True	True	True
False	False	True	False	False	True
False	False	False	True	False	True

❖ **Precedence of connectives:**

Just like arithmetic operators, there is a precedence order for propositional connectors or logical operators. This order should be followed while evaluating a propositional problem. Following is the list of the precedence order for operators:

Precedence	Operators
First Precedence	Parenthesis
Second Precedence	Negation
Third Precedence	Conjunction(AND)
Fourth Precedence	Disjunction(OR)
Fifth Precedence	Implication
Six Precedence	Biconditional

Artificial Intelligence❖ **Logical equivalence:**

Logical equivalence is one of the features of propositional logic. Two propositions are said to be logically equivalent if and only if the columns in the truth table are identical to each other.

Let's take two propositions A and B, so for logical equivalence, we can write it as $A \Leftrightarrow B$. In below truth table we can see that column for $\neg A \vee B$ and $A \rightarrow B$, are identical hence A is Equivalent to B

A	B	$\neg A$	$\neg A \vee B$	$A \rightarrow B$
T	T	F	T	T
T	F	F	F	F
F	T	T	T	T
F	F	T	T	T

❖ **Properties of Operators:**

- **Commutativity:**
 - $P \wedge Q = Q \wedge P$, or
 - $P \vee Q = Q \vee P$.
- **Associativity:**
 - $(P \wedge Q) \wedge R = P \wedge (Q \wedge R)$,
 - $(P \vee Q) \vee R = P \vee (Q \vee R)$
- **Identity element:**
 - $P \wedge \text{True} = P$,
 - $P \vee \text{True} = \text{True}$.
- **Distributive:**
 - $P \wedge (Q \vee R) = (P \wedge Q) \vee (P \wedge R)$.
 - $P \vee (Q \wedge R) = (P \vee Q) \wedge (P \vee R)$.
- **DE Morgan's Law:**
 - $\neg (P \wedge Q) = (\neg P) \vee (\neg Q)$
 - $\neg (P \vee Q) = (\neg P) \wedge (\neg Q)$.
- **Double-negation elimination:**
 - $\neg (\neg P) = P$.

Artificial Intelligence**❖ Limitations of Propositional logic:**

- We cannot represent relations like ALL, some, or none with propositional logic. Example:
 - a. **All the girls are intelligent.**
 - b. **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

References:

1. <https://www.javatpoint.com/ai-techniques-of-knowledge-representation>
2. https://en.wikipedia.org/wiki/Knowledge_representation_and_reasoning