KNOWLEDGE REPRESENTATION

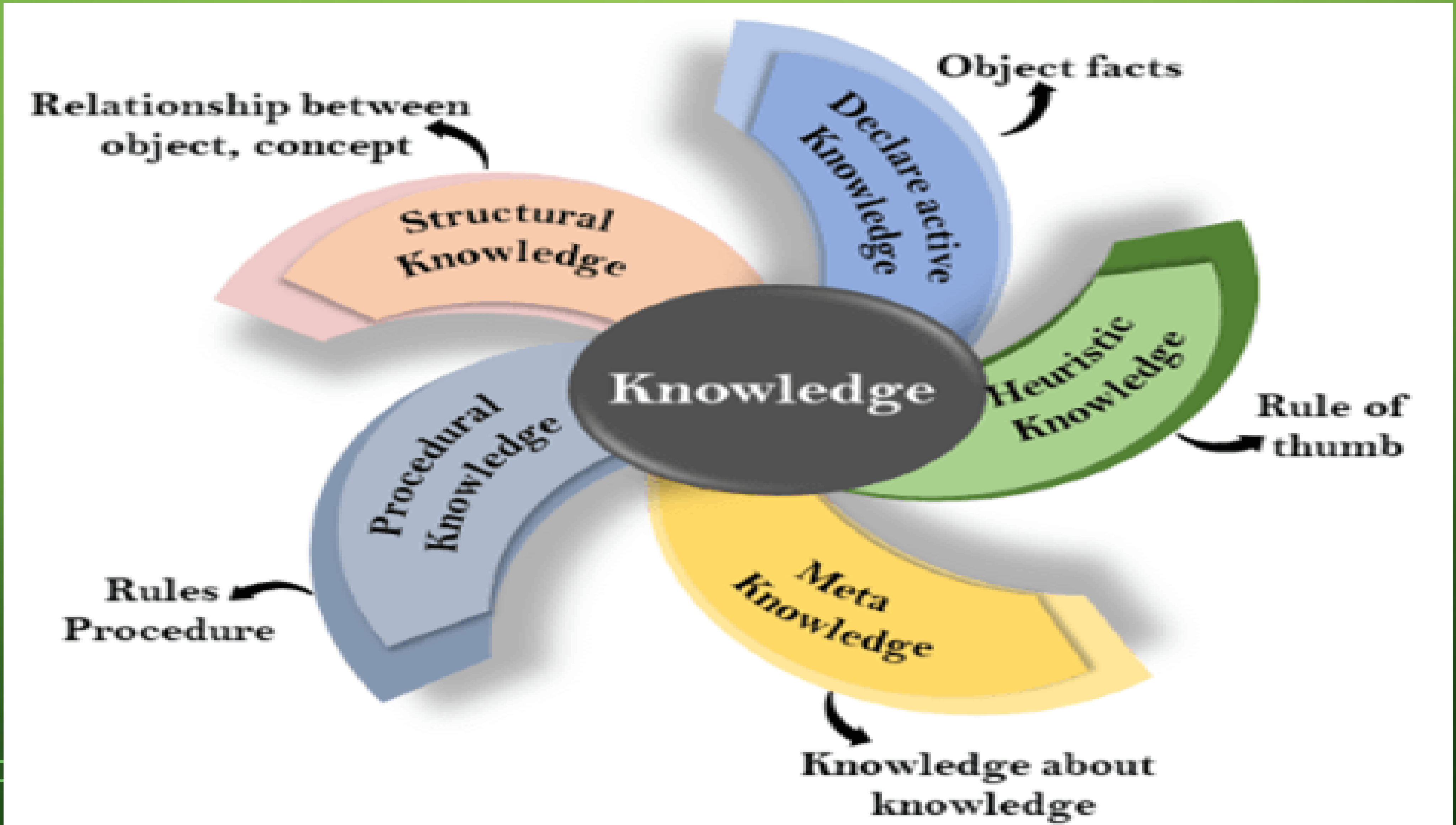
UNIT 2

- Humans are best at understanding, reasoning, and interpreting knowledge.
- Human knows things, which is knowledge and as per their knowledge they perform various actions in the real world.

- Knowledge representation and reasoning (KR, KRR) is the part of Artificial intelligence which concerned with AI agents thinking and how thinking contributes to intelligent behavior of agents.
- It is responsible 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.
- It is also a way which describes how we can represent knowledge in artificial intelligence. 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.

WHAT TO REPRESENT

- **Object:** All the facts about objects in our world domain. E.g., Guitars contains strings, trumpets are brass instruments.
- **Events:** Events are the actions which occur in our world.
- **Performance:** It describe behavior which involves knowledge about how to do things.
- **Meta-knowledge:** It is knowledge about what we know.
- **Facts:** Facts are the truths about the real world and what we represent.
- **Knowledge-Base:** The central component of the knowledge-based agents is the knowledge base. It is represented as KB. The Knowledgebase is a group of the Sentences (Here, sentences are used as a technical term and not identical with the English language).


Object facts
Relationship between
object, concept
Declare active
Knowledge
Structural
Knowledge
Knowledge
Heuristic
Knowledge
Rule of
thumb
Procedural
Knowledge
Rules
Procedure
Meta
Knowledge
Knowledge about
knowledge

1. Declarative Knowledge:

- Declarative knowledge is to know about something.
- It includes concepts, facts, and objects.
- It is also called descriptive knowledge and expressed in declarativesentences.
- It is simpler than procedural language.

2. Procedural Knowledge

- It is also known as imperative knowledge.
- Procedural knowledge is a type of knowledge which is responsible for knowing how to do something.
- It can be directly applied to any task.
- It includes rules, strategies, procedures, agendas, etc.
- Procedural knowledge depends on the task on which it can be applied.

3. Meta-knowledge:

- Knowledge about the other types of knowledge is called Meta-knowledge.

4. Heuristic knowledge:

- Heuristic knowledge is representing knowledge of some experts in a filed or subject.
- Heuristic knowledge is rules of thumb based on previous experiences, awareness of approaches, and which are good to work but not guaranteed.

5. Structural knowledge:

- Structural knowledge is basic knowledge to problem-solving.
- It describes relationships between various concepts such as kind of, part of, and grouping of something.
- It describes the relationship that exists between concepts or objects.

ISSUES IN KNOWLEDGE REPRESENTATION

The fundamental goal of knowledge Representation is to facilitate inference (conclusions) from knowledge.

- The issues that arise while using KR techniques are many. Some of these are

Important Attributed:

- Any attribute of objects so basic that they occur in almost every problem domain

Relationship among attributes:

- Any important relationship that exists among object attributed,The attributes we use to describe objects

Choosing Granularity(The level of detail at which data is stored):

- At what level of detail should the knowledge be represented

Set of objects:

- How should sets of objects be represented

Finding Right structure:

- Given a large amount of knowledge stored in a database, how can relevant parts are accessed when they are needed

HILL CLMBING ALGORITHM

Hill climbing is a heuristic search algorithm used to solve optimization problems. It is often employed in problems where the goal is to maximize or minimize an objective function.

- how the hill climbing algorithm is applied in AI:
- **Initialize:** Start with an initial solution. This could be a randomly generated solution or a predefined one.
- **Evaluate:** Evaluate the current solution by calculating the value of the objective function.
- **Generate neighbors:** Generate neighboring solutions by making small changes (mutations) to the current solution. These changes can include adding or removing elements, modifying values, or other operations depending on the problem.

- **Select the best neighbor:** Among the generated neighbors, select the one that optimizes (minimizes or maximizes) the objective function the most.
- **Update:** If the best neighbor improves the current solution, move to that neighbor and update the current solution to be the best neighbor. Otherwise, stop the algorithm.
- **Repeat:** Repeat steps 2-5 until a stopping criterion is met, such as reaching a maximum number of iterations or no significant improvement in the objective function value.

LIMITATIONS

- **Local Optima:** One of the main limitations of hill climbing is that it tends to get stuck in local optima. If the search space is rugged or contains multiple peaks, the algorithm may converge to a suboptimal solution without exploring other potentially better solutions.
- **Plateaus:** In plateau regions of the search space where the objective function remains constant over a large area, hill climbing can struggle to make progress. It may get stuck moving back and forth between neighboring solutions without making significant improvements.
- **Greedy Approach:** Hill climbing is a greedy algorithm, meaning it only considers immediate improvements in the objective function without considering the long-term consequences. This can lead to suboptimal solutions, especially in problems where a series of non-optimal moves are required to reach the global optimum.
- **Initial Solution Dependency:** The performance of hill climbing can be highly dependent on the initial solution. If the initial solution is far from the global optimum, the algorithm may fail to find the best solution, even if it exists within the search space.

- **Limited Exploration:** Hill climbing focuses on exploring solutions that are close to the current solution. This limited exploration can prevent the algorithm from discovering diverse regions of the search space that may contain better solutions.
- **No Memory:** Hill climbing does not have memory of past moves or solutions. This means that it can repeat the same or similar moves, even if they do not lead to improvements, wasting computational resources.
- **Constraint Handling:** Hill climbing does not handle constraints well. If the search space contains constraints, such as boundary limits or logical constraints, hill climbing may violate these constraints while searching for solutions.
- **Slow Convergence:** In some cases, hill climbing can converge slowly to an optimal solution, especially in high-dimensional search spaces where the number of possible solutions is large.

MAPPING

- Mapping in knowledge representation in AI is a two-way link between facts and representations. This link is called a representation mapping. A forward representation mapping maps facts to representations, while a backward representation mapping goes the other way,
- Knowledge maps provide a visual representation of thoughts or ideas that can be challenging to communicate. This makes it easier for teams to share information so that they can spend more time focusing on solutions

FRAME PROBLEM

Frames are data structures used in artificial intelligence to organize knowledge into categories. A frame contains slots that describe aspects of the category, with default values that can be overridden.

A problem known as the **frame problem** within artificial intelligence concerns the application of knowledge about the past to draw inferences (guess or opinion that's formed because of known facts or evidence) about the future.

In artificial intelligence (AI), inference is the process of using logical rules to analyze new information.

The Frame problem can lead to several issues that can impact the effectiveness of an AI system. Some of these problems are:

- **The Qualification Problem:** The inability to produce accurate truths about the present environment is the Representational Problem
- **The Inferential Problem:** Difficulty with examining the methods by which the world is judged is the Inferential Problem
- **The Ramification Problem:** This problem explains how behavior might lead to changes in the surroundings.
- **The Predictive Problem:** The Predictive Problem deals with the benefits of predictions. That is, it is uncertain if a given prediction will cause a positive change in the environment. If the change will not be positive, "either the laws or description of the given situation must be imperfect

PREDICATE LOGIC

- Predicate logic in AI is mainly used as a foundational framework for representation of knowledge and reasoning. First-order logic(Predicate logic) is another way of knowledge representation in artificial intelligence and is sufficiently expressive to represent the natural language statements in a concise way
- develops information about the objects in a more easy way and can also express the relationship between those objects.

- In predicate logic, we have the following components:
- **Variables:** Symbols (often denoted by lowercase letters) that represent objects or elements in a domain.
- **Constants:** Specific objects in the domain (e.g., individuals, numbers).
- **Predicates:** Expressions that assert properties or relations between objects. Predicates can be unary (apply to one object) or n-ary (apply to n objects).
- **Quantifiers:** Symbols that indicate the extent of the variables in a statement. The two main quantifiers are the existential quantifier (∃, "there exists") and the universal quantifier (∀, "for all").
- **Connectives:** Logical operators such as ∧ (conjunction), ∨ (disjunction), → (implication), and ¬ (negation) that combine statements.
- **Functions:** Symbols that represent operations on objects, returning another object as a result.

- Predicate logic allows us to formalize statements such as **"For all x, if x is a human, then x is mortal" as ∀x (Human(x) → Mortal(x)), where Human(x) and Mortal(x)** are predicates representing the properties of being human and mortal, respectively.
- Predicate logic is more expressive than propositional logic because it allows us to quantify over objects and make statements about classes of objects. It is widely used in various fields, including artificial intelligence

CONVERTING A LOGICAL STATEMENT INTO CONJUNCTIVE NORMAL FORM (CNF) AND DRAWING A RESOLUTION TREE

- **Convert to Negation Normal Form (NNF):** Start by converting the logical statement to Negation Normal Form (NNF), which eliminates all negations inside the statement.
- **Convert to CNF:**
  - Use the distributive law to move disjunctions (∨) inside conjunctions (∧).
  - Use De Morgan's laws to eliminate negations.
  - Ensure that the statement is in CNF, where each clause is a conjunction of literals, and the whole statement is a disjunction of these clauses.

Draw Resolution Tree:

- Represent each clause in the CNF as a node in the resolution tree.
- Use resolution inference rules to derive new clauses until either the empty clause (representing a contradiction) is derived or no further resolutions are possible.

EXAMPLE

- Logical statement: $(A \land B) \rightarrow (C \lor \neg D)$
- Convert to NNF:
  - Apply implication elimination: $\neg(A \land B) \lor (C \lor \neg D)$
  - Apply De Morgan's laws: $(\neg A \lor \neg B) \lor (C \lor \neg D)$
- Convert to CNF:
  - Distribute disjunctions: $(\neg A \lor \neg B \lor C) \lor (\neg A \lor \neg B \lor \neg D)$
- Draw Resolution Tree:
  - Start with initial clauses: $(\neg A \lor \neg B \lor C)$ and $(\neg A \lor \neg B \lor \neg D)$
  - Apply resolution rule to derive new clauses:
    - Resolve on $\neg A$: $(\neg B \lor C)$ and $(\neg B \lor \neg D)$
    - Resolve on $\neg B$: (C) and $(\neg D)$
  - No further resolutions are possible, so the tree is complete.

FACTS IN LOGIC

logic serves as "the compass steering the ship of AI development". It provides a robust framework to define rules, constraints, and relationships within a system. This structured approach is necessary, especially in scenarios where clear decision paths are vital.

INSTANCE

In artificial intelligence (AI), an instance is a specific example or case used to train machine learning models. This could be a particular set of input data along with its corresponding output or classification.

Two attributes **isa** and **instance** play an important role in many aspects of knowledge representation. The reason for this is that they support property inheritance. isa-- used to show class inclusion, e.g.isa(mega_star,rich). instance-- used to show class membership, e.g.instance(prince,mega_star).

- **Class inclusion** refers to the ability to classify objects into two or more categories simultaneously. For example, the ability to recognise that large categories such as 'cars' includes smaller sub-categories such as 'blue cars' or 'red cars' or different manufacturers.

- the term "class membership" refers to the categorization or labeling of an instance, object, or data point as belonging to a specific class or category within a predefined set of classes. Classes represent the outcomes or categories that an algorithm tries to predict or classify instances into, based on the features or attributes of those instances. Class membership is crucial in classification problems, where the goal is to accurately assign instances to one of several classes based on their attributes.

- Representing instances and "is-a" relationships effectively allows AI systems to model the real world more accurately, perform logical reasoning, and infer new knowledge based on the hierarchical structure of information.

Instance Representation

- An **instance** represents a specific example or occurrence of a concept or class. It is an individual entity characterized by properties and values that distinguish it from other instances. In AI, instances are represented in various ways depending on the context and the data model being used

"Is-A" Relationship Representation

- The **"is-a"** relationship is a fundamental hierarchical relationship that represents inheritance or subclassing in knowledge representation. It signifies that an entity (the subclass or instance) is a specific type of another entity (the superclass or category). This relationship is crucial for organizing knowledge in a hierarchy, allowing for inheritance of properties and facilitating reasoning about categories and instances.

RESOLUTION

- resolution is a fundamental rule of inference that allows for deriving conclusions from a set of logical sentences. It is primarily used in propositional logic and first-order logic. Resolution plays a crucial role in theorem proving, automated deduction systems, and certain algorithms in AI that require logical reasoning capabilities.
- resolution is a powerful method in AI for deriving conclusions from logical statements, with broad applications across different domains of AI, from theorem proving to natural

Uses of Resolution in AI

- Resolution is widely used in AI for various purposes:
- **Automated Theorem Proving:** It's a core technique in software that aims to prove or disprove logical statements automatically.
- **Knowledge Representation and Reasoning:** Resolution helps in inferring new knowledge from existing facts and rules within a knowledge base.
- **Logic Programming:** Languages like Prolog rely on resolution as their primary mechanism for query processing and solving logical queries.
- **Natural Language Processing (NLP):** Resolution can be involved in understanding and generating natural language by applying logical inference to natural language statements.

PROCEDURAL KNOWLEDGE

- **Procedural** or **imperative knowledge** clarifies how to perform a certain task. It lays down the steps to perform. Thus, the procedural knowledge provides the essential control information required to implement the knowledge.

Declarative Knowledge?

- **Declarative** or **functional knowledge** clarifies what to do to perform a certain task. It lays down the function to perform. Thus, in the declarative knowledge, only the knowledge is provided but not the control information to implement the knowledge. Thus, in order to use the declarative knowledge, we have to add the declarative knowledge with a program which provides the control information.
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MATCHING

- Matching is the process of comparing two or more structures to discover their likenesses or differences. The structures may represent a wide range of objects including physical entities, words or phrases in some language, complete classes of things, general concepts, relations between complex entities, and the like. The representations will be given in one or more of the formalisms like FOPL, networks, or some other scheme, and matching will involve comparing the component parts of such structures.

- Matching is used in a variety of programs for different reasons. It may serve to control the sequence of operations, to identify or classify objects, to determine the best of a number of different alternatives, or to retrieve items from a database. It is an essential operation such diverse programs as speech recognition, natural language understanding, vision, learning, automated reasoning, planning, automatic programming, and expert systems, as well as many others.

CONTROL KNOWLEDGE

Control knowledge is a declarative component of a module that's responsible for several activities. These activities include: meta-reasoning, order in evaluation of facts and rules, determination of which rules to use, and other control tasks

meta-reasoning is reasoning about reasoning, which means making intelligent decisions about how to think

SYMBOLIC REASONING UNDER UNCERTAINTY

- Symbolic reasoning under uncertainty in artificial intelligence (AI) is a technique for solving problems with incomplete and uncertain models

- Symbolic reasoning under uncertainty in AI refers to the process of using symbolic logic, which involves symbols representing various elements of a problem, to make decisions or draw conclusions when there is uncertainty or incomplete information. This approach is often used in areas such as expert systems, where rules and logic are used to make decisions based on uncertain or incomplete information.
- In symbolic reasoning under uncertainty, techniques such as probabilistic logic or fuzzy logic may be used to represent and reason with uncertain information. These techniques allow AI systems to handle uncertainty in a structured and logical manner, enabling them to make informed decisions even when complete information is not available.

REASONING:

- The reasoning is the mental process of deriving logical conclusion 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.

NON-MONOTONIC REASONING

Monotonic means something that does not vary or change.

Non-Monotonic means something which can vary according to the situation or condition.

MONOTONIC REASONING

- Monotonic Reasoning is the process that does not change its direction or can say that it moves in the one direction.
- Monotonic Reasoning will move in the same direction continuously means it will either move in increasing order or decrease.
- But since Monotonic Reasoning depends on knowledge and facts, It will only increase and will never decrease in this reasoning.
- Example:
  - Sun rises in the East and sets in the West.

NON-MONOTONIC REASONING

- Non-monotonic Reasoning is the process that changes its direction or values as the knowledge base increases.
- It is also known as NMR in Artificial Intelligence.
- Non-monotonic Reasoning will increase or decrease based on the condition.
- Since that Non-monotonic Reasoning depends on assumptions, It will change itself with improving knowledge or facts.
- Example:
  - Consider a bowl of water, If we put it on the stove and turn the flame on it will obviously boil hot and as we will turn off the flame it will cool down gradually.

STATISTICAL REASONING

- Statistical reasoning in artificial intelligence (AI) involves using statistical methods to analyze data, identify patterns, and make predictions. AI systems use statistical reasoning to learn from data and generalize knowledge

Statistical reasoning in AI typically involves the following steps:

- **Data Collection:** Gathering relevant data from various sources.
- **Data Preprocessing:** Cleaning, transforming, and preparing the data for analysis.
- **Exploratory Data Analysis (EDA):** Analyzing and visualizing the data to understand its properties and relationships.
- **Statistical Modeling:** Building mathematical models that describe the relationships within the data.
- **Inference:** Drawing conclusions or making predictions based on the statistical models and the data.
- **Evaluation:** Assessing the performance of the models and the validity of the conclusions.

- Statistical reasoning is essential in AI because it allows systems to learn from data, make informed decisions, and deal with uncertainty and variability in real-world problems.

Some common applications include:

- **Machine Learning:** Statistical reasoning is at the core of machine learning algorithms. It is used to train models on data, make predictions, and evaluate the performance of the models.
- **Natural Language Processing (NLP):** In NLP, statistical reasoning is used for tasks such as text classification, sentiment analysis, and machine translation. Statistical models help in understanding the structure and meaning of language.

- **Computer Vision:** Statistical reasoning is used in computer vision for tasks such as object detection, image classification, and image segmentation. Statistical models help in recognizing patterns and objects in images.
- **Healthcare:** In healthcare, statistical reasoning is used for tasks such as disease diagnosis, prognosis, and treatment planning. Statistical models help in analyzing medical data and making informed decisions.
- **Finance:** In finance, statistical reasoning is used for tasks such as risk assessment, stock price prediction, and fraud detection. Statistical models help in analyzing financial data and making investment decisions.
- **Marketing and Advertising:** In marketing and advertising, statistical reasoning is used for tasks such as customer segmentation, campaign optimization, and personalized recommendations. Statistical models help in understanding customer behavior and targeting the right audience.

ASSIGNMENT 2

1. Describe mapping in AI with some examples.
2. What are facts in logic.
3. Differentiate between procedural and declarative knowledge.
4. Elaborate control knowledge with some example.
5. Define statistical reasoning with the help of example.