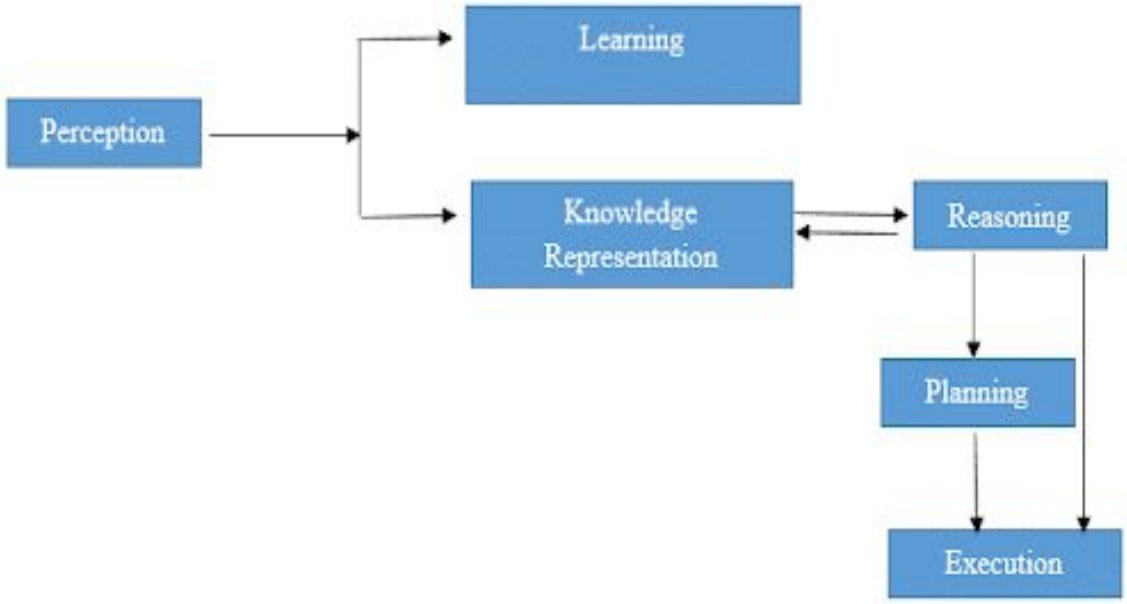
Semantic networks

Introduction

- How machines understand, interpret, reason come under knowledge representation and reasoning.
- 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.
- 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.
- Knowledge plays an important role in demonstrating intelligent behavior in AI agents.
- An agent is only able to accurately act on some input when he has some knowledge or experience about that input.

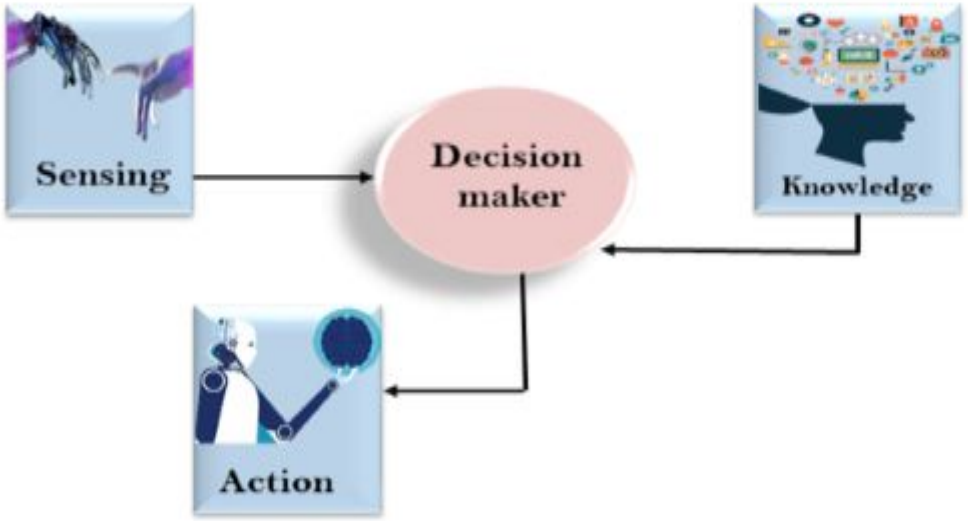
Different Types of Knowledge

The Cycle of Knowledge Representation



- Interaction of the artificial intelligence system with the real world and the components involved in showing the intelligence.
- Knowledge representation is all about understanding intelligence.

Relation between knowledge and Intelligence



Why is knowledge representation used in AI?

AI agents can express intelligent behavior only if they acquire the knowledge and experiences that we, humans, have gained from the real world around us.

Knowledge representation allows AI programs to use the information they've learned to:

>> Derive information that is implied by the AI agent,

>> Communicate with people in natural language,

>> Decide what to do next,

>> Plan future activities, and

>> Solve problems in areas that normally require human expertise.

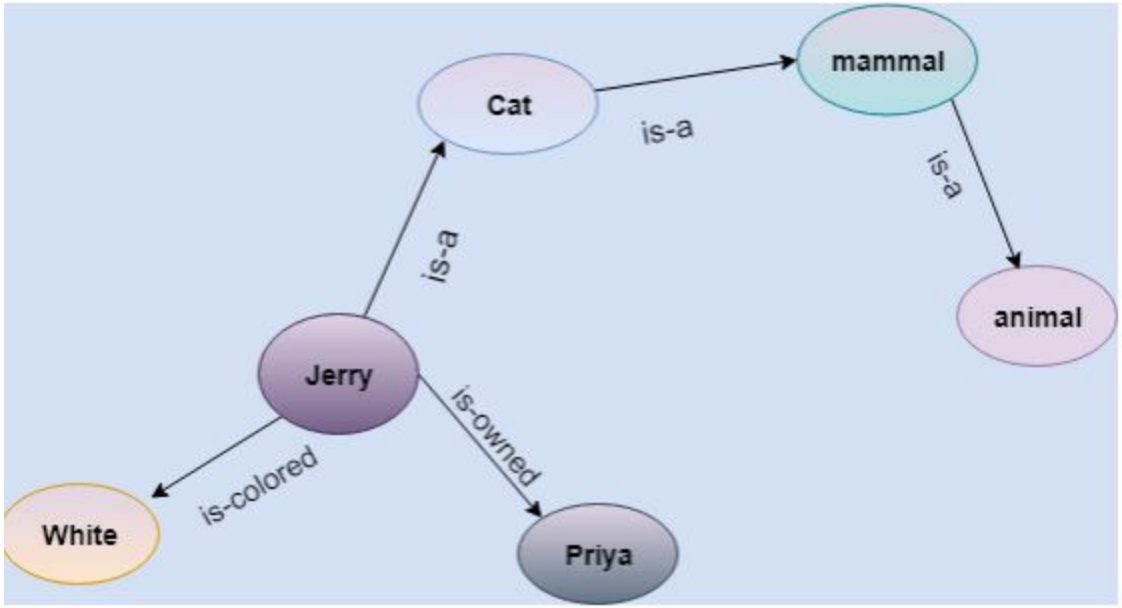
Semantic networks are significant in natural language processing, knowledge representation, and information retrieval systems. They focus on capturing the context and meaning of words.

Semantic Networks

- Semantic networks are a powerful tool in the field of AI, used to represent knowledge and understand relationships between different concepts.
- Graphical representations that connect nodes (representing concepts) with edges (representing relationships). such as "is a," "part of," or "related to.“
- *For example, in a simple semantic network, the concept "Dog" might be connected to "Animal" with an "is a" relationship, indicating that a dog is a type of animal.*
- Semantic networks are widely used in natural language processing (NLP), knowledge representation, and reasoning systems.
- In business, this capability provides better product search functionality, making customer service more effective.

Semantic Network Representation

- Statements: Jerry is a cat; Jerry is a mammal; Jerry is owned by Priya; Jerry is brown colored; All Mammals are animal.



- Knowledge in the form of nodes and arcs.
- Each object is connected with another object by some relation.

Types of Semantic Networks

- **Definitional Networks** used to represent hierarchical relationships, often used in taxonomies or ontologies.
- They define concepts by their relationships to more general or more specific concepts.
- In a definitional network, "Dog" might be defined as a type of "Mammal," which is in turn a type of "Animal."
- **Assertional networks** represent specific facts or assertions about individual instances of concepts.
- They often describe properties or attributes of specific entities.
- An assertional network might represent the fact that "Rex is a Dog" and "Rex has Brown Fur."
- **Implicational networks** focus on representing logical implications between concepts. They are used to infer new knowledge from existing relationships.
- If "All Dogs are Mammals" and "Rex is a Dog," an implicational network can infer that "Rex is a Mammal."

- **Executable networks** are designed to represent procedural knowledge, where the relationships include actions or sequences that can be executed by an AI system.
- An executable network might represent the steps in a recipe, such as "Add Water to Pot" followed by "Boil Water.“
- **Learning networks** are dynamic and evolve as the AI system learns new information. They update relationships and nodes based on new data or experiences.
- In a learning network, an AI might update its understanding of "Dog" as it encounters new breeds or characteristics.
- **Hybrid networks** combine elements from two or more of the above types, allowing for more complex and versatile representations of knowledge.
- A hybrid network might integrate definitional and assertional aspects, representing both the general concept of "Dog" and specific instances like "Rex."

Components of Semantic Networks

- **Lexical Components**
  - **Nodes**: The fundamental units of a semantic network, representing concepts, entities, or objects within the domain of knowledge. Examples include "Dog," "Animal," or "Tree."
  - **Labels**: Descriptive names or identifiers associated with the nodes, providing a way to refer to the concepts they represent.
- **Structural Components**
  - **Edges/Links**: The connections between nodes, representing relationships such as "is a," "part of," "causes," or "associated with."
  - **Types of Relationships**: These can include hierarchical relationships (e.g., "is a"), associative relationships (e.g., "related to"), and functional relationships (e.g., "causes" or "results in").

Examples of Semantic Networks in AI

- **Technology Stack Classification**
- **Nodes**: Frontend, Backend, HTML, CSS, JavaScript, Python, Django, API
- **Links**: “is a” relation, “uses” relation
- **Labels**: Web Development, Framework, Language

- **Programming Concepts**
- **Nodes**: Programming Language, Python, Java, Data Types, Integer
- **Links**: “is a” relation, “has” relation
- **Labels**: High-Level Language, Variable, Numeric Type

- **Semantic Components**
  - **Meanings of Nodes**: The specific meanings or interpretations of the nodes within the context of the network.
  - **Interpretation of Relationships**: The understanding of what the edges or links between nodes signify in real-world terms, ensuring the relationships are meaningful and accurately reflect the domain.
- **Procedural Part**
  - **Inference Rules**: Rules that allow the network to derive new knowledge from existing relationships. For example, if "Dog is a Mammal" and "Mammal is an Animal," the network can infer that "Dog is an Animal."
  - **Query Mechanisms**: Procedures for retrieving information from the network based on specific queries or criteria.
  - **Update Mechanisms**: Rules and processes for adding, modifying, or removing nodes and links as new information is introduced.

Applications

- **Natural Language Processing (NLP)**: In NLP, semantic networks help in understanding the meaning of words and sentences by representing the relationships between different words and concepts.
- **Expert Systems**: In expert systems, semantic networks are used to represent the knowledge of human experts, enabling the system to make decisions or provide recommendations based on that knowledge.
- **Ontology Development**: Ontologies, which define the structure of knowledge in a particular domain, often use semantic networks to represent the relationships between concepts within that domain.
- **Information Retrieval**: Semantic networks enhance information retrieval by allowing systems to understand the context and relationships between different pieces of information, leading to more accurate search results.
- **Machine Learning**: In some machine learning applications, semantic networks are used to improve the interpretability of models by providing a structured representation of the knowledge the model has learned.

Key Issues in Semantic Representation

- How meaning is represented, fundamental questions are:

(1) How are word meanings related to conceptual structures? (2) How is the meaning of each word represented? (3) How are the meanings of different words related to one another? (4) Can the same principles of organisation hold in different content domains (e.g., words referring to objects, words referring to actions, words referring to properties)?

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.

Advantages of Semantic network

- Semantic networks are a natural representation of knowledge.
- Semantic networks convey meaning in a transparent manner.

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.

Facets

- Facets: The various aspects of a slot is known as Facets.
- Facets are features of frames which enable us to put constraints on the frames.
- Example: IF-NEEDED facts are called when data of any particular slot is needed.
- A frame may consist of any number of slots, and a slot may include any number of facets and facets may have any number of values.
- A frame is also known as slot-filter knowledge representation in artificial intelligence.
- Frames are derived from semantic networks and later evolved into our modern-day classes and objects. A single frame is not much useful.

- Frames system consist of a collection of frames which are connected.
- In the frame, knowledge about an object or event can be stored together in the knowledge base.
- The frame is a type of technology which is widely used in various applications including Natural language processing and machine visions.
- Example: Let's take an example of a frame for a book
- Slots Filters
- Title Artificial Intelligence
- Genre Computer Science
- Author Peter Norvig
- EditionThird Edition
- Year 1996
- Page 1152