Introduction to Knowledge Representation and Reasoning

Introduction

- Human beings are good at understanding, reasoning and interpreting knowledge.
- And using this knowledge, they are able to perform various actions in the real world. But how do machines perform the same?

What is Knowledge Representation

- Knowledge Representation in AI describes the representation of knowledge.
- Basically, it is a study of how the beliefs, intentions, and judgments of an intelligent agent can be expressed suitably for automated reasoning.
- One of the primary purposes of Knowledge Representation includes modeling intelligent behavior for an agent.

What is Knowledge Representation

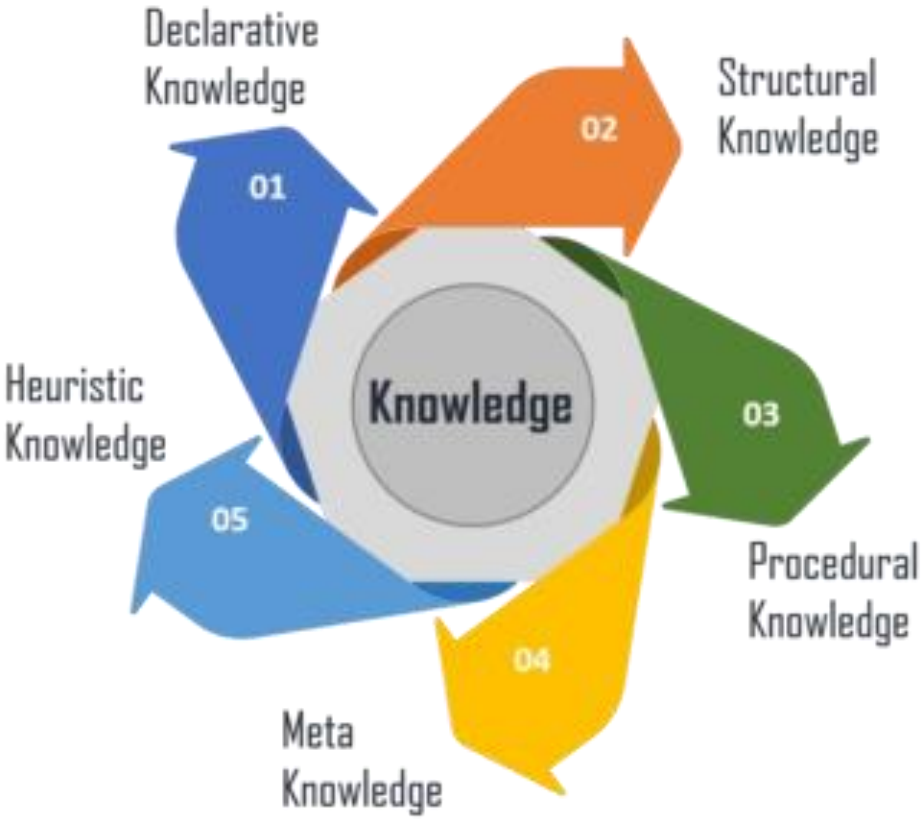
- Knowledge Representation and Reasoning (KR, KRR) represents information from the real world for a computer to understand and then utilize this knowledge to solve complex real-life problems like communicating with human beings in natural language.

Knowledge representation in AI is not just about storing data in a database, it allows a machine to learn from that knowledge and behave intelligently like a human being.

What is Knowledge Representation?

- The different kinds of knowledge that need to be represented in AI include:
  - Objects
  - Events
  - Performance
  - Facts
  - Meta-Knowledge
  - Knowledge-base

Types of Knowledge



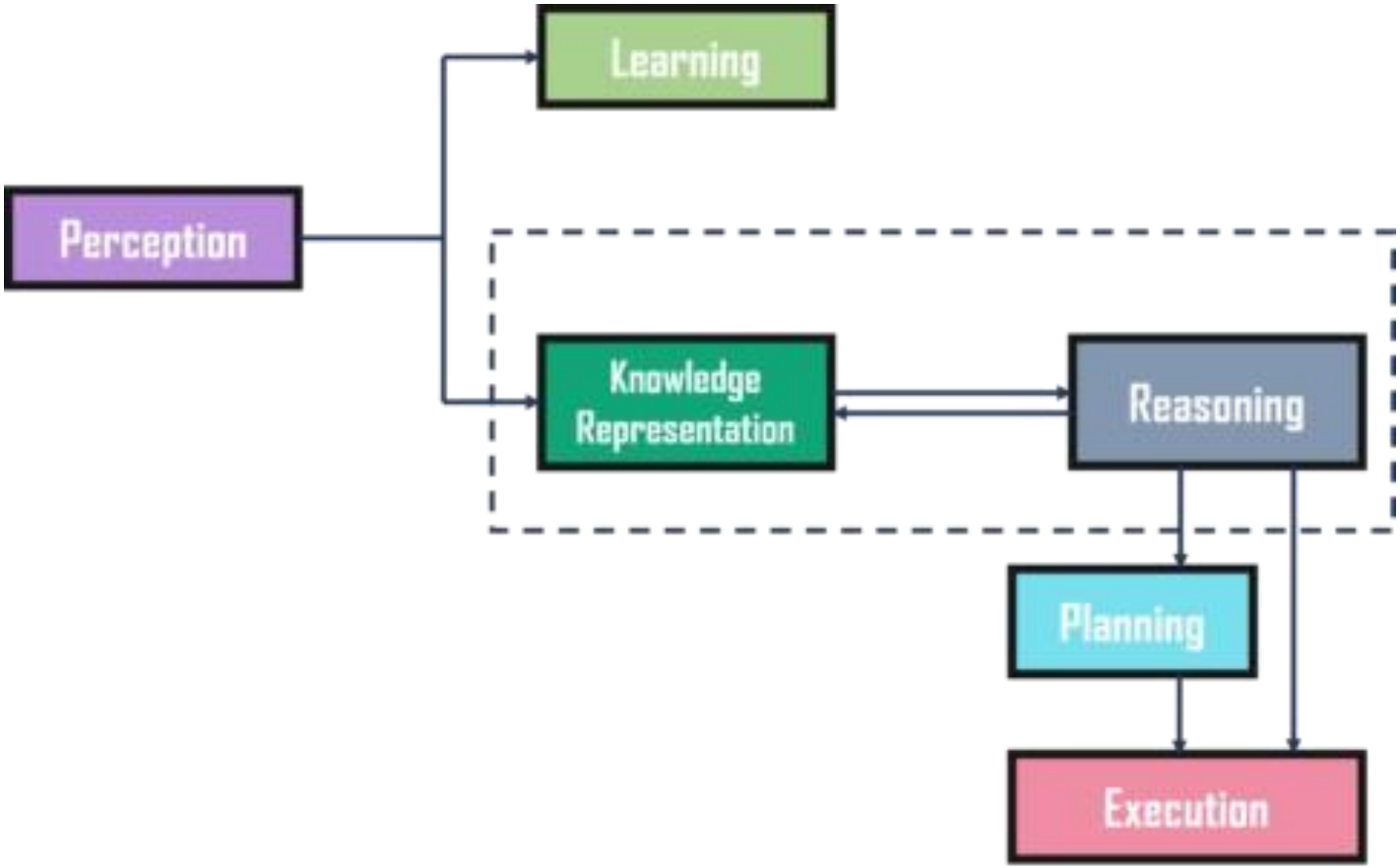
Types of Knowledge

- Declarative Knowledge – It includes concepts, facts, and objects and expressed in a declarative sentence.
- Structural Knowledge – It is a basic problem-solving knowledge that describes the relationship between concepts and objects.
- Procedural Knowledge – This is responsible for knowing how to do something and includes rules, strategies, procedures, etc.
- Meta Knowledge – Meta Knowledge defines knowledge about other types of Knowledge.
- Heuristic Knowledge – This represents some expert knowledge in the field or subject.

Cycle of Knowledge Representation in AI

- Artificial Intelligent Systems usually consist of various components to display their intelligent behavior. Some of these components include:
  - Perception
  - Learning
  - Knowledge Representation & Reasoning
  - Planning
  - Execution

Example:


Learning
Perception
Knowledge Representation
Reasoning
Planning
Execution

Example

- The Perception component retrieves data or information from the environment.
- with the help of this component, you can retrieve data from the environment, find out the source of noises and check if the AI was damaged by anything.
- Also, it defines how to respond when any sense has been detected.

Example

- Then, there is the Learning Component that learns from the captured data by the perception component.
- The goal is to build computers that can be taught instead of programming them. Learning focuses on the process of self-improvement.
- In order to learn new things, the system requires knowledge acquisition, inference, acquisition of heuristics, faster searches, etc.

Example

- The main component in the cycle is Knowledge Representation and Reasoning which shows the human-like intelligence in the machines.
- Knowledge representation is all about understanding intelligence.
- Instead of trying to understand or build brains from the bottom up, its goal is to understand and build intelligent behavior from the top-down and focus on what an agent needs to know in order to behave intelligently.
- Also, it defines how automated reasoning procedures can make this knowledge available as needed.

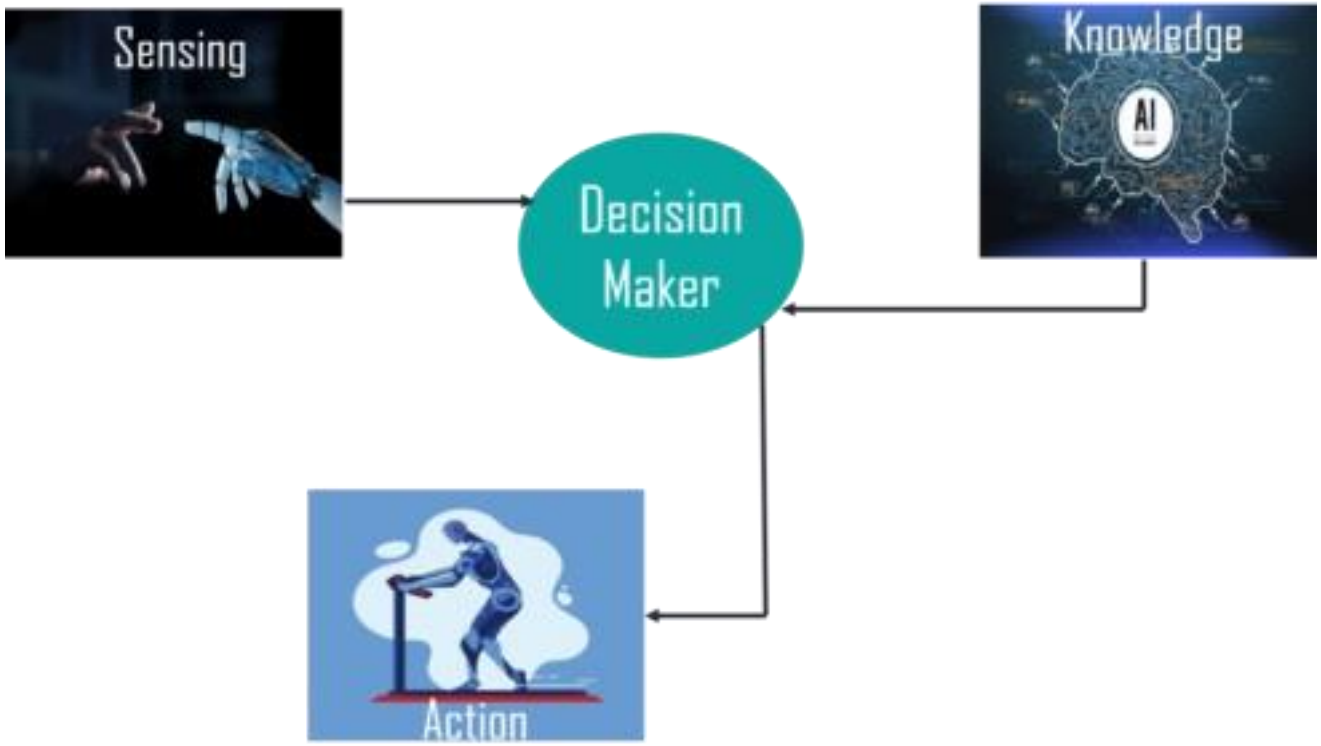
Example

- The Planning and Execution components depend on the analysis of knowledge representation and reasoning.
- Here, planning includes giving an initial state, finding their preconditions and effects, and a sequence of actions to achieve a state in which a particular goal holds.
- Now once the planning is completed, the final stage is the execution of the entire process.

Relation between Knowledge & Intelligence

- In the real world, knowledge plays a vital role in intelligence as well as creating artificial intelligence.
- It demonstrates the intelligent behavior in AI agents or systems.
- It is possible for an agent or system to act accurately on some input only when it has the knowledge or experience about the input.

Example



Example

- In this example, there is one decision-maker whose actions are justified by sensing the environment and using knowledge.

But, if we remove the knowledge part here, it will not be able to display any intelligent behavior.

Now that you know the relationship between knowledge and intelligence, let's move on to the techniques of Knowledge Representation in AI.

Knowledge Representation in AI

Logical Representation

- Logical representation is a language with some definite rules which deal with propositions and has no ambiguity in representation.

It represents a conclusion based on various conditions and lays down some important communication rules.

Also, it consists of precisely defined syntax and semantics which supports the sound inference.

Each sentence can be translated into logics using syntax and semantics.

Logical Representation

Syntax	Semantics
• It decides how we can construct legal sentences in logic. • It determines which symbol we can use in knowledge representation. • Also, how to write those symbols.	• Semantics are the rules by which we can interpret the sentence in the logic. • It assigns a meaning to each sentence.

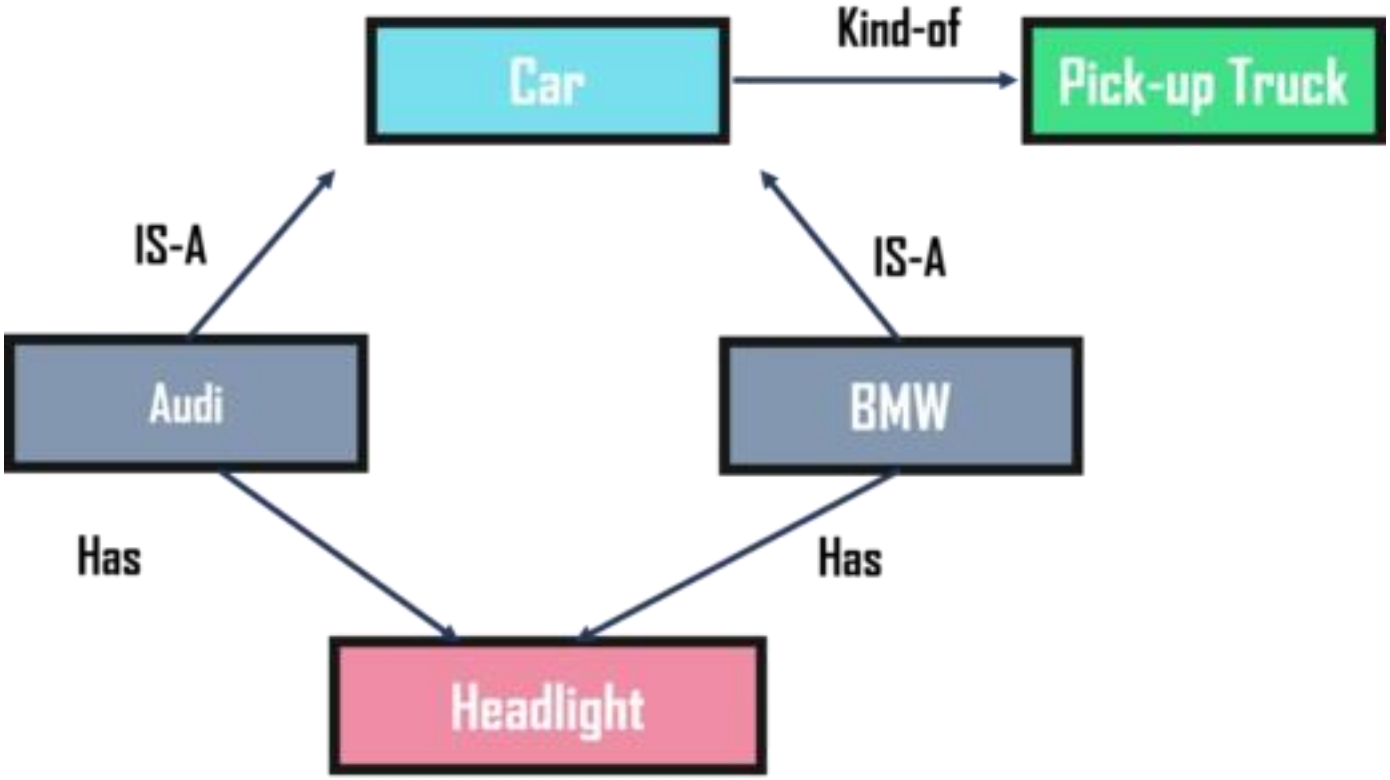
Logical Representation

- Advantages:
  - Logical representation helps to perform logical reasoning.
  - This representation is the basis for the programming languages.
- Disadvantages:
  - Logical representations have some restrictions and are challenging to work with.
  - This technique may not be very natural, and inference may not be very efficient.

Semantic Network Representation

- Semantic networks work as an alternative of predicate logic for knowledge representation. In Semantic networks, you can represent your knowledge in the form of graphical networks.
- This network consists of nodes representing objects and arcs which describe the relationship between those objects. Also, it categorizes the object in different forms and links those objects.
- This representation consist of two types of relations:
  - IS-A relation (Inheritance)
  - Kind-of-relation

Semantic Network Representation



Semantic Network Representation

- Advantages:
  - Semantic networks are a natural representation of knowledge.
  - Also, it conveys meaning in a transparent manner.
  - These networks are simple and easy to understand.
- Disadvantages:
  - Semantic networks take more computational time at runtime.
  - Also, these are inadequate as they do not have any equivalent quantifiers.
  - These networks are not intelligent and depend on the creator of the system.

Frame Representation

- A frame is a record like structure that consists of a collection of attributes and values to describe an entity in the world.
- These are the AI data structure that divides knowledge into substructures by representing stereotypes situations.
- Basically, it consists of a collection of slots and slot values of any type and size.
- Slots have names and values which are called facets.

Frame Representation

- Advantages:
  - It makes the programming easier by grouping the related data.
  - Frame representation is easy to understand and visualize.
  - It is very easy to add slots for new attributes and relations.
  - Also, it is easy to include default data and search for missing values.
- Disadvantages:
  - In frame system inference, the mechanism cannot be easily processed.
  - The inference mechanism cannot be smoothly proceeded by frame representation.
  - It has a very generalized approach.

Production Rules

- 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. Whereas, the action part carries out the associated problem-solving steps. This complete process is called a recognize-act cycle.
- The production rules system consists of three main parts:
  - The set of production rules
  - Working Memory
  - The recognize-act-cycle

Production Rules

- Advantages:
  - The production rules are expressed in natural language.
  - The production rules are highly modular and can be easily removed or modified.
- Disadvantages:
  - It does not exhibit any learning capabilities and does not store the result of the problem for future uses.
  - During the execution of the program, many rules may be active. Thus, rule-based production systems are inefficient.

Representation Requirements

- A good knowledge representation system must have properties such as:
  - Representational Accuracy: It should represent all kinds of required knowledge.
  - Inferential Adequacy: It should be able to manipulate the representational structures to produce new knowledge corresponding to the existing structure.
  - Inferential Efficiency: The ability to direct the inferential knowledge mechanism into the most productive directions by storing appropriate guides.
  - Acquisitional efficiency: The ability to acquire new knowledge easily using automatic methods.

Approaches to Knowledge Representation in AI

- Simple Relational Knowledge
  - It is the simplest way of storing facts which uses the relational method. Here, all the facts about a set of the object are set out systematically in columns.
  - Also, this approach of knowledge representation is famous in database systems where the relationship between different entities is represented.
  - Thus, there is little opportunity for inference.

Approaches to Knowledge Representation in AI

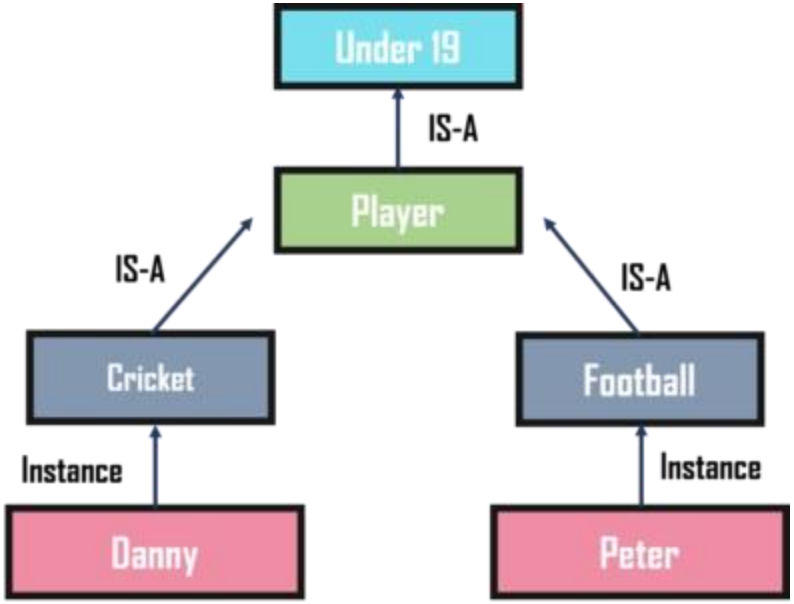
Name	Age	Emp ID
John	25	100071
Amanda	23	100056
Sam	27	100042

Approaches to Knowledge Representation in AI

- Inheritable Knowledge
  - In the inheritable knowledge approach, all data must be stored into a hierarchy of classes and should be arranged in a generalized form or a hierarchal manner.
  - Also, this approach contains inheritable knowledge which shows a relation between instance and class, and it is called instance relation.
  - In this approach, objects and values are represented in Boxed nodes.

Approaches to Knowledge Representation in AI

- Inheritable Knowledge



Approaches to Knowledge Representation in AI

- Inferential Knowledge
- The inferential knowledge approach represents knowledge in the form of formal logic. Thus, it can be used to derive more facts. Also, it guarantees correctness.
- Example:

Statement 1: John is a cricketer. Statement 2: All cricketers are athletes. Then it can be represented as;

  - Cricketer(John)
  - ∀x = Cricketer (x) ——–> Athelete (x)s

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 explained below.
- Important Attributed:
  - Any attribute of objects so basic that they occur in almost every problem domain?
  - There are two attributed “instance” and “isa”, that are general significance. These attributes are important because they support property inheritance.

Issues in Knowledge Representation

- Relationship among attributes:
  - Any important relationship that exists among object attributed?
  - The attributes we use to describe objects are themselves entities that we represent.
  - The relationship between the attributes of an object, independent of specific knowledge they encode, may hold properties like:
- Inverse – This is about consistency check, while a value is added to one attribute. The entities are related to each other in many different ways.

Issues in Knowledge Representation

- Existence in an isa hierarchy –
  - This is about generalization-specification, like, classes of objects and specialized subsets of those classes, there are attributes and specialization of attributes.
  - For example, the attribute height is a specialization of general attribute physical-size which is, in turn, a specialization of physical-attribute.
  - These generalization-specialization relationships are important for attributes because they support inheritance.

Issues in Knowledge Representation

- Technique for reasoning about values –
  - This is about reasoning values of attributes not given explicitly.
  - Several kinds of information are used in reasoning, like, height: must be in a unit of length, Age: of a person cannot be greater than the age of person's parents.
  - The values are often specified when a knowledge base is created.

Issues in Knowledge Representation

- Single valued attributes –
  - This is about a specific attribute that is guaranteed to take a unique value.
  - For example, a baseball player can at time have only a single height and be a member of only one team.
  - KR systems take different approaches to provide support for single valued attributes.

Issues in Knowledge Representation

- Choosing Granularity:
  - At what level of detail should the knowledge be represented?
  - Regardless of the KR formalism, it is necessary to know:
    - At what level should the knowledge be represented and what are the primitives?
    - Should there be a small number or should there be a large number of low-level primitives or High-level facts.
    - High-level facts may not be adequate for inference while Low-level primitives may require a lot of storage.

Issues in Knowledge Representation

- Example of Granularity:

Suppose we are interested in following facts:

John spotted Sue.

This could be represented as Spotted (agent(John),object (Sue))

- Such a representation would make it easy to answer questions such are: Who spotted Sue?
- Suppose we want to know: Did John see Sue?
- Given only one fact, we cannot discover that answer.
- We can add other facts, such as Spotted(x, y) -> saw(x, y)
- We can now infer the answer to the question.

Issues in Knowledge Representation

- Set of objects:
- How should sets of objects be represented?
- There are certain properties of objects that are true as member of a set but not as individual;
- Example: Consider the assertion made in the sentences: “there are more sheep than people in Australia”, and “English speakers can be found all over the world.”
- To describe these facts, the only way is to attach assertion to the sets representing people, sheep, and English.

Issues in Knowledge Representation

- The reason to represent sets of objects is: if a property is true for all or most elements of a set, then it is more efficient to associate it once with the set rather than to associate it explicitly with every elements of the set.
- This is done,
  - in logical representation through the use of universal quantifier, and
  - in hierarchical structure where node represent sets and inheritance propagate set level assertion down to individual.

Issues in Knowledge Representation

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Issues in Knowledge Representation

- Finding Right structure:
  - Given a large amount of knowledge stored in a database, how can relevant parts are accessed when they are needed?
  - This is about access to right structure for describing a particular situation.
  - This requires, selecting an initial structure and then revising the choice.

Issues in Knowledge Representation

- While doing so, it is necessary to solve following problems:
  - How to perform an initial selection of the most appropriate structure.
  - How to fill in appropriate details from the current situations.
  - How to find a better structure if the one chosen initially turns out not to be appropriate.
  - What to do if none of the available structures is appropriate.
  - When to create and remember a new structure.