Comparative Study of Three Declarative Knowledge Representation Techniques

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Abstract – **In artificial intelligence to solve the problem user require a knowledge base, consist all information related to problem domain and a method for manipulating the knowledge for finding the solution. For better result knowledge should be organized in better way. Hence, a structure for that knowledge is required. The knowledge representation techniques are divided in to two categories declarative and procedural. The main objective of this paper is to present the comparative study between three declarative knowledge representations techniques namely predicate logic, semantic net and frames.**

Keywords: Knowledge Representation, Semantic Network, Frame, Predicate Logic.

1. INTRODUCTION

A knowledge representation (KR) is an idea to enable an individual to determine consequences by thinking rather than acting, i.e., by reasoning about the world rather than taking action in it. There are two basic components of knowledge representation i.e. reasoning and inference. It is a way of efficient computation in which thinking is accomplished. In cognitive science it is concerned with how people store and process information and in AI the objective is to store knowledge so that programs can process it. Constructing an intelligent system, require large amount of knowledge and a method for representing large amounts of knowledge that permits their effective use and interaction. In fact KR is the fundamental issue in AI that attempt to understand intelligence. There are three wide perspectives of knowledge representation [3] [18].

1. KR as applied epistemology: All intelligent system presupposes knowledge which is represented in a knowledge base that consists of knowledge structures (normally symbolic) and programs.
2. KR as a tell-ask module: KR system should provide at least two operations:
   - For a given knowledge base K, with the facts f. It must be resulting in a new knowledge base, K'.
   - The knowledge base K is being queried about a fact f. Outcome depends upon KR paradigm used, may be yes, no, unknown, yes with a confidence factor of A ...etc.
3. KR as the embodiment of AI systems: There are identical interconnected units that are collectively responsible for representing various concepts. A concept is represented in a Distributed sense and is indicated by an evolving pattern of activity over a collection of units.

In conventional computing the data is stored in data base whereas in AI the knowledge base is used to store the knowledge required for solving the particular task. The difference between knowledge base and database is shown in Table 1.

1.1Knowledge representation techniques

Currently there are many techniques for representing the knowledge such as List and tree (graph) which is used to represent the hierarchical knowledge. Semantic networks in which nodes and links are used to store the propositions. Schemas are used to represent commonsense knowledge. Frames and scripts are the commonly used Schemas. Frame Describe the objects consist of a set of nodes and links Knowledge represented by frame is organized in slots. Frames are hierarchically organized. Scripts are used to describe the event rather than objects. Consist of stereotypically ordered causal or temporal chain of events. Rule-based knowledge representation basically used in problem-solving contexts that involve production rules containing if-then or situation-action pairs. Rule based or problem space representations contain:

- Initial state.
- Goal state.
- Legal operators which are the things allowed to do.
- Operator restrictions.

Logic-based representations may use deductive or inductive reasoning that contain:-

- Facts and premises.
- Rules of propositional logic and rules of predicate calculus that allows use of additional information about objects in the proposition, use of variables and functions of variables.
- Measures of certainty involve Certainty Factors. For e.g. If symptom then (CF) diagnosis) [20].

2. KNOWLEDGE REPRESENTATION USING LOGIC

Predicate logic/First order logic: Propositional logic works for the statement that are either true or false but in real

world there are many statement that cannot be treated in that way for e.g "all loves god". For these types of statement predicates logic works. First-order logic extends propositional logic in two directions first it provides an inner structure for sentences. They are viewed as expressing relations between objects or individuals. Second It provides a means to express, and reason with, generalizations [3]. It makes it possible to say that a certain property holds of all objects, of some objects, or of no object. In predicates logic there are three additional notations.

- Terms: in First-order logic are used to represent objects or individuals. Terms can be a constant (designate specific object) For e.g. A, B, Smith, Blue, etc, variable (designate unspecified object): x, y, z, etc, and Functions (designate a specific object related in a certain way to another object, or, objects):Father Of, Color Of.
- Predicates: Predicates is defined as a relation that binds two atoms have a value of true or false. A predicate can take arguments, which are terms. A predicate with one argument expresses a property of an object for e.g. Student(Bob).A predicate with two or more arguments expresses a relation between objects for e.g .likes(Bob, Mary). Predicate with no arguments is just a simple proposition logic.
- Universal Quantifier: are used to identify the scope of the variable in a logical expression. For e.g. ∀ x P(x) means "for all x, P of x is true". Example: ∀x Happy (x) If the universe of discourse is people, then this means that everyone is happy. Other examples: ∀x ∀y Knows(x, y) => Knows(y, x), ∀x∀y Knows(x, y) ^ Knows(y, x),
  ∀x ∀y Knows(x, y) => ¬ Likes(y, x).
- Existential Quantifier: if the statement is ∃x P(x) means "there exists at least one x for which P of x is true". Example: ∃x Happy(x),If the universe of discourse is people, then this means there is at least one happy person. Other examples: ∀x ∃y Knows(x,y), ∃x ∃y Knows(x, y) ^ Knows(y, x) . ∀x ∃y Knows(x, y) => ¬ Likes(y, x).

3. KNOWLEDGE REPRESENTATION USING SEMANTIC NET

A semantic network is widely used knowledge representation technique. As the name semantic network, it represents the connection between objects or class of objects. It is a directed graph in which nodes / vertices are used to represent the objects/ class of objects and edges or link (unidirectional) is used to represent the semantic relations between the objects. Semantic network are generally used to represent the inheritable knowledge. Inheritance is most useful form of inference. Inheritance is the property in which element of some class inherit the attribute and values from some other class as shown in Fig.1. To support inheritance object must be organized into classes and classes must be arranged in a generalization hierarchy.

Sometimes Semantic nets are also called as associative nets because nodes are associated or related to others node as there is an activation spreading form one concept node to other nodes This types of relationships have proven particularly useful in a wide variety of knowledge representations. Commonly used links in semantic nets are i.e. IS-A, and A-KIND-OF. IS-A means is an instance of or refers to a member of some class whereas A-KIND-OF represents the link from one class to other class as shown in Fig 2.

Semantic networks are a declarative graphic representation that can be used either to represent knowledge or to support automated systems for reasoning about knowledge. Following are six of the most common kinds of semantic networks.

1. Definitional networks
2. Assertional networks
3. Implicational networks
4. Executable networks
5. Learning networks
6. Hybrid networks

3.1 Partitioned semantic net.

The semantic net can be divided in to one or more net. The semantic net is to be partitioned to separate the various nodes and arcs in to units and each unit is known as spaces. One space is assigned to every node and arc and all nodes and arcs lying in the same space are distinguishable from those of other spaces. Nodes and arcs of different spaces may be linked, but the linkage must pass through the boundaries which separate one space from another.

Partitioning semantic nets can be used to delimit the scopes of quantified variables. While working with quantified statements, it will be help full to represent the pieces of information consist some event .For ex "Poonam believes that earth is round " is represented by the [figure 3]. Nodes<POONAM>' is an agent of Event node.<EARTH>' and <ROUND> represent the objects of space1.

Partitioning semantic net can also be used to represent Universal and existential quantifier. For ex, "Every sister knots the rakhee to her brother" in predicate logic. In predicate logic the sister S and rakhee R are represented as objects while the knot event is expressed by a predicate where as in case of semantic net the event is represented as an object of some complex object, i.e., the bite event is a situation which could be the object of some more complex event. Partitioning semantic net can also be used to represent universal quantifier. For ex "Every sister knots the rakhee to her brother" is represented in figure

4.Partitioning semantic net can also be used for complex quantifleations which involve nested scopes by using nesting space.

4. KNOWLEDGE REPRESENTATION USING FRAMES

Frame can be considered as an extension to the semantic net. Semantic net are used to labeled connections between objects. But when the task becomes complex the representation becomes more complex for such task the frame representation will be more beneficial. A frame is a collection of attributes or slots and their associated values which describe the real world entity. An example of a hotel frame is given in Fig 5. The frame is used to represent the following:

- a class (set),
- an instance (an element of a class).
- Frame has three main components
- frame name
- attributes (slots)
- values (fillers: list of values, range, string, etc.)

There are two different naming system for frame first is its true name that uniquely describe the frame and second it can have any number of public names. Public names are values stored in the name slot of the frame. For instance, Frame frame-30 will look as:

name: ("women")
sex: (frame-3)
spouse: (frame-31)
child: (frame-29 frame-31) here frame 30 is the true name that refer it uniquely. True names are the pointers from one frame to another that actually represent the structure of the knowledge base. Public names are for communication with other agents[8]. The advantage of a frame based knowledge representation is that there is no need to search the entire knowledge-base because the objects related to a frame can be easily accessed directly looking in a slot of the frame. The comparison between predicate logic, semantic net, Frame is shown in annexure 1, table 2 according to various parameters.

5. CONCLUSION

In AI for specific domain there is a knowledge base supported by various techniques for representing the knowledge. There are various knowledge representation schemes in AI. All have different semantics, structure and different level of power. This paper has presented the comparison between three representation schemes shown in annexure 1 and the objective is to analyses the power and expressiveness of a system. Each knowledge representation scheme has advantages and disadvantages. Combination of two or more representation scheme may be used to for making the system more efficient and improving the knowledge representation.

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Table 1 Difference between data base and knowledge base.

S. No	Data Base	Knowledge Base
1	Collection of data in database represents the facts.	It consist information at higher level of abstraction.
2	Operates on a single object.	Operates on a class of objects.
3	Updates are performed by clerical persons.	Updates are performed by domain experts.
4	All information needed to be explicitly stated.	Knowledge base has the power of inference.
5	Data base are maintained for operational purpose.	Used for planning and data analysis.
6	Represented by relational, network or hierarchical model.	KR is by logic or rules or frames or semantic nets
7	Interaction with the data base is by transaction programs and report generator.	Knowledge base has a consultation with the system and provides needed data to obtain the solution.

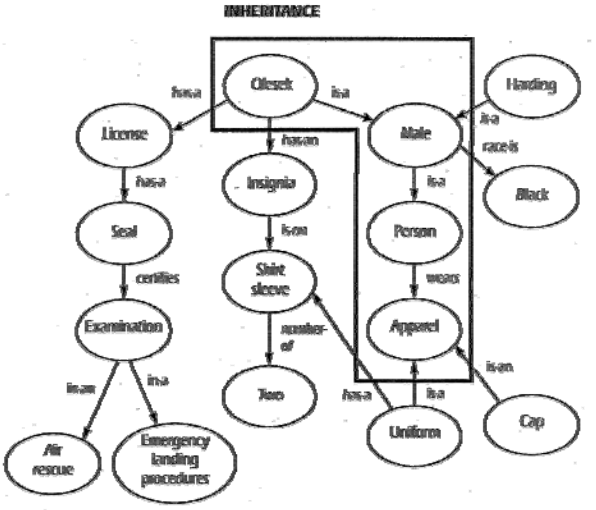


Fig.1 Property of inheritance [35]

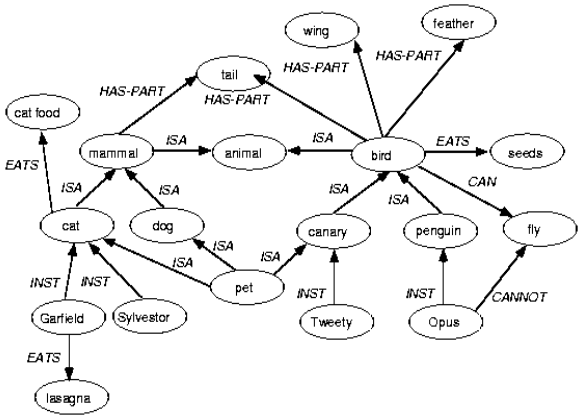


Fig **2** Representation of IS-A, HAS, INSTANCE [17].

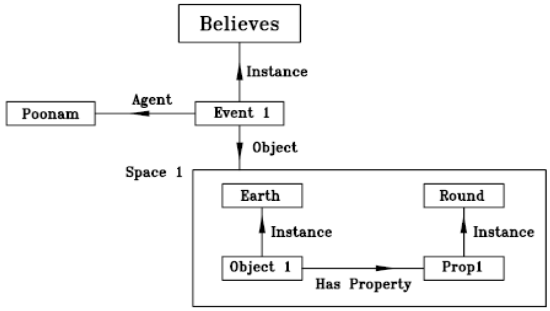


Fig.3 Partitioned Semantic Net

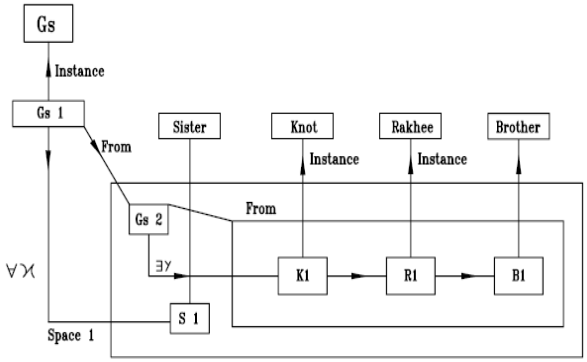


Fig.4 Represents Partitioned Semantic Net for Quantifiers

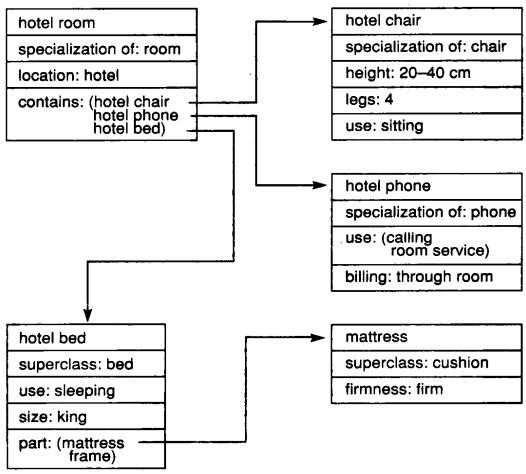
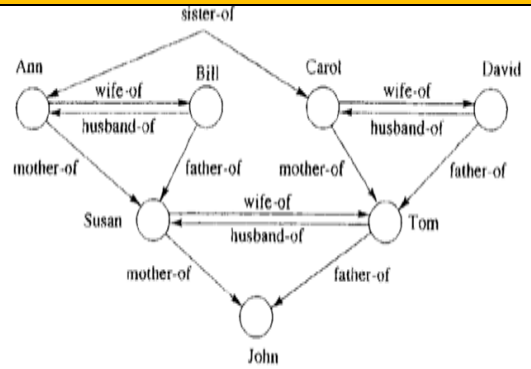
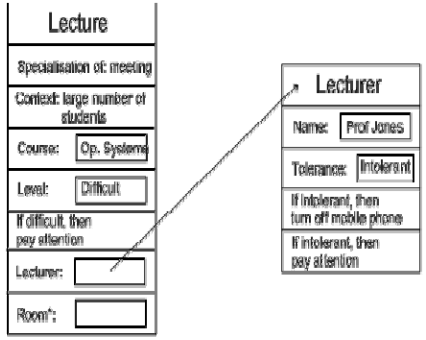
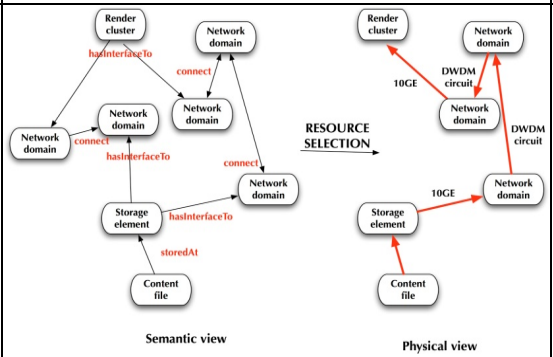
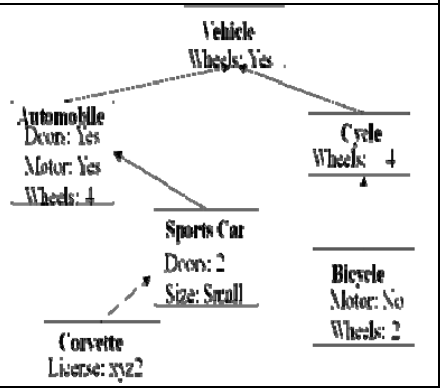
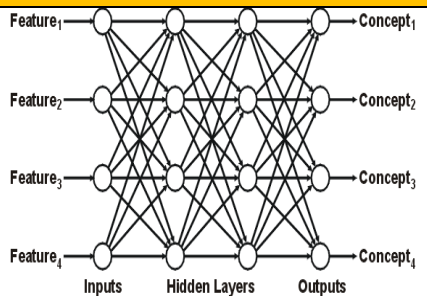


Fig.5 Represents Frame Hotel [36]

Annexure 1

Table 2: Comparison between Predicate Logic, Semantic Net and Frame

S no	Knowledge Structure/	Predicate Logic	Semantic Net	Frame
1	Example 1	¬ ∀xP(x)↔∃ x¬P(x)This ex shows that if P(x) represents x is happy and the universe is the set of people, then "There does not exist a person who is happy" is equivalent to "Everyone is not happy"		
2	Example 2	$\forall X.(rose(X) \rightarrow \exists Y.(has(X,Y) \wedge thorn(Y)))$ Predicate logic for statement "Every rose has a thorn" i.e For all X if (X is a rose) then there exists Y (X has Y) and (Y is a thorn)	 UML diagram for semantic reasoning as Semantic net	

S no	Knowledge Structure/	Predicate Logic	Semantic Net	Frame
3	Example 3	$\forall X.((is\_mon(X) \vee is\_wed(X)) \rightarrow eat\_meal(me, houseOf(john), X))$ Predicate logic for" On Mondays and Wednesdays I go to John's house for dinner".	 **A neural network as Semantic net**	Frame Name: Bus Subclass of: thing Slots: Name: Value: Restrictions wheels 4 moved by engine fuel ? petrol or diesel "a bus has 4 wheels, is moved by an engine, and runs on petrol or diesel."
4	Nearest Data Structure	Rule Based System	Graph	Class in Object Oriented Programming
5	Searching Algorithms	1Breadth First. 2Depth First. 3Chaining • Top to bottom • Bottom to top	1. Intersection Search. 2 Inheritance. 3Breadth First. 4 Depth First. 5 Heuristic search.	1 Inheritance. 2 Frame Matching (i.e. unification)
6	Merits	1 Its provide a better way to do reasoning by providing a way of deducing new from old one. 2 It can be used for proving the statements. 3 Quantified and Existential statements are easily represented.	1 Easy to visualize & understand. 2Knowledge engineers can easily define the relationship. 3 Related knowledge can be easily Categorized. 4 node objects represented only once. 5 Efficient in space requirements • Objects represented only once • Relationships handled by pointers	1 Easy to set up slots for new properties and relations. 2 Easy to include default Information and detection of missing values is also easy.. 3 Domain knowledge model reflected directly. 4 Efficient 5Support procedural knowledge
7	Demerits	1 Less expressive. 2Used for representing statics Facts only. 3 Predicate logic is not useful for representing facts like degree of hearts/ certainty, heuristic information like "Poonam believe that Mandeep might have not attended the class.	1Binary relation are easy to represent. But some time it is difficult. For Ex for the sentence "John cause trouble to the party". 2 Quantified statements are very hard to represent by Semantic net. 3 the lack of link name standard. 4 If a node is labeled "Table," for example, does it represent: • a specific Table • the class of all Table • the concept of a Table	1 No associated reasoning/inference mechanisms. 2 Lack of semantics. 3Expressive limitations.
8	Applications	1 inductive reasoning (For drawing conclusion) 2 deductive reasoning (For drawing logical conclusion 3 Machine Learning. 4 Natural language processing.	1 Practical knowledge representation for the Web. 2 Semantic modeling and knowledge representation in Multimedia Database. 3 To Model Trouble shooting's knowledge. 4 In Pattern-recognition semantic net can be used to help the computer to identify how objects to be analyzed are related to one another. 5 In Natural language processing. 6 Bootstrapping knowledge representation using semantic nets to	1For discrete event system.(DES) 2 For an Intelligent Environment. 3 Human resource management problem domains including planning, selection, placement, performance, evaluation etc 4 CORBA based distributed environment. 5 In Natural language processing. 6 Machine learning

S no	Knowledge Structure/	Predicate Logic	Semantic Net	Frame
			make the web more intelligent. 7 Reasoning.	
9	Variants	1 First order predicate logic 2 Second order predicate logic 3 many-sorted logic 4 infinitary logic 5 Annotated predicate logic 2 Monadic predicate calculus	1 Partitioned Semantic net 2 Neural Networks 3 Data flow diagram.	1 KRON (Knowledge representation Oriented Net 2 Frame with Fuzzy logic 3 Frame with well form formula (wff)
10	Type	Declarative	Declarative	Declarative/Procedural
11	Invented by	David Hilbert and Wilhelm Ackermann	Richard H. Richens	Marvin Minsky
12	Year	1928	1956	1975
13	Software	1 Prolog 2 Lisp	1Universal Semantic Code 2 OWL(Ontology Web Language)	1 KM (Knowledge Machine) 2 Frame Talk 3 Loom
14	References	[1][2][3][21][23][24]	[1][2][3][22][23][25][26][27][30]	[20][23][[27][28][30][31][33][34]