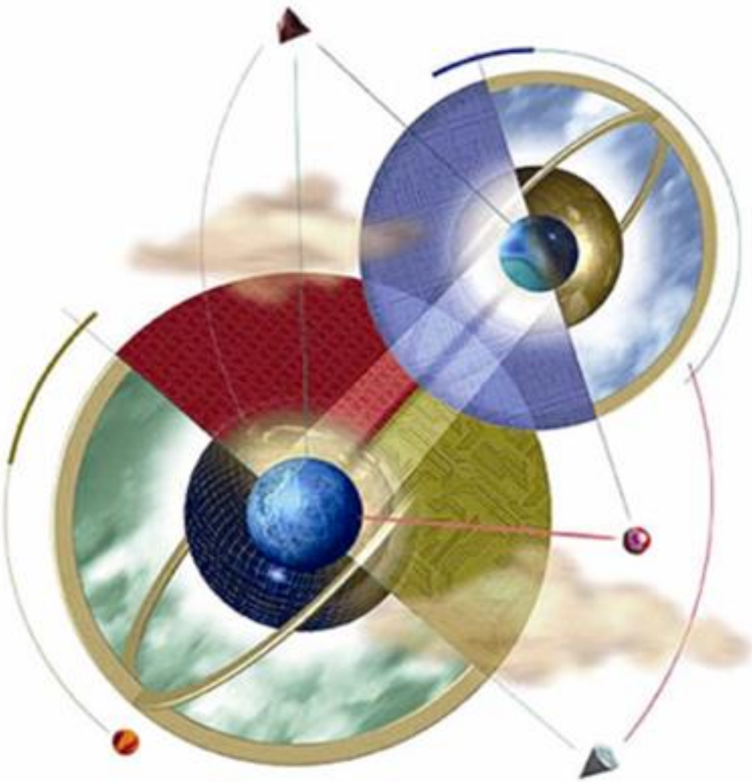


Chapter 2: The Representation of Knowledge

Expert Systems: Principles and Programming, Fourth Edition

Objectives

- Introduce the study of logic
- Learn the difference between formal logic and informal logic
- Learn the meaning of knowledge and how it can be represented
- Learn about semantic nets
- Learn about object-attribute-value triples

Objectives Continued

- See how semantic nets can be translated into Prolog
- Explore the limitations of semantic nets
- Learn about schemas
- Learn about frames and their limitations
- Learn how to use logic and set symbols to represent knowledge

Objectives Continued

- Learn about propositional and first order predicate logic
- Learn about quantifiers
- Explore the limitations of propositional and predicate logic

What is the study of logic?

- Logic is the study of making inferences – given a set of facts, we attempt to reach a true conclusion.
- An example of <u>informal</u> logic is a courtroom setting where lawyers make a series of inferences hoping to convince a jury / judge .
- Formal logic (symbolic logic) is a more rigorous approach to proving a conclusion to be true / false.

Why is Logic Important

- We use logic in our everyday lives – "should I buy this car", "should I seek medical attention".
- People are not very good at reasoning because they often fail to separate word meanings with the reasoning process itself.
- Semantics refers to the meanings we give to symbols.

The Goal of Expert Systems

- We need to be able to separate the actual meanings of words with the reasoning process itself.
- We need to make inferences w/o relying on semantics.
- We need to reach valid conclusions based on facts only.

Knowledge vs. Expert Systems

- Knowledge representation is key to the success of expert systems.

- Expert systems are designed for knowledge representation based on rules of logic called inferences.

- Knowledge affects the development, efficiency, speed, and maintenance of the system.

Arguments in Logic

- An argument refers to the formal way facts and rules of inferences are used to reach valid conclusions.
- The process of reaching valid conclusions is referred to as logical reasoning.

How is Knowledge Used?

- Knowledge has many meanings – data, facts, information.
- How do we use knowledge to reach conclusions or solve problems?
- Heuristics refers to using experience to solve problems – using precedents.
- Expert systems may have hundreds / thousands of micro-precedents to refer to.

Epistemology

- Epistemology is the formal study of knowledge .
- Concerned with nature, structure, and origins of knowledge.

Categories of Epistemology

- Philosophy
- A priori
- A posteriori
- Procedural
- Declarative
- Tacit

A Priori Knowledge

- "That which precedes"
- Independent of the senses
- Universally true
- Cannot be denied without contradiction

A Posteriori Knowledge

- "That which follows"
- Derived from the senses
- Now always reliable
- Deniable on the basis of new knowledge w/o the necessity of contradiction

Procedural Knowledge

Knowing how to do something:

- Fix a watch
- Install a window
- Brush your teeth
- Ride a bicycle

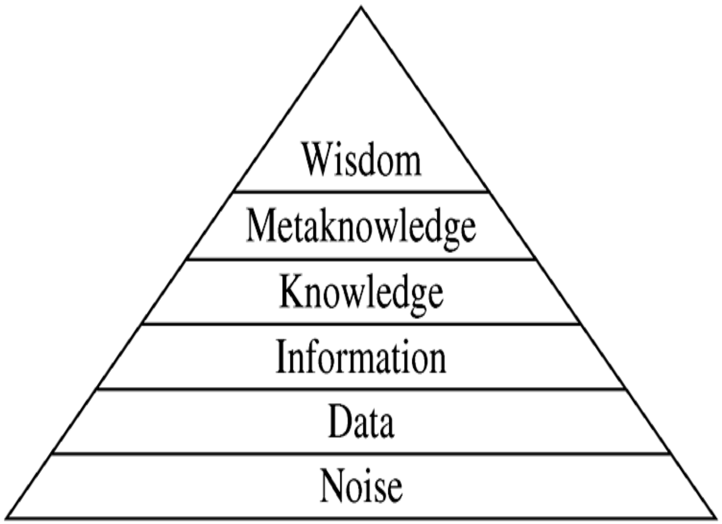
Declarative Knowledge

- Knowledge that something is true or false
- Usually associated with declarative statements

Tacit Knowledge

- Unconscious knowledge
- Cannot be expressed by language
- E.g., knowing how to walk, breath, etc.

The Pyramid of Knowledge



Wisdom: Using knowledge in a beneficial way
Metaknowledge: Rules about knowledge
Knowledge: Rules about using information
Information: Potentially useful for knowledge
Data: Potentially useful information
Noise: No apparent information.

Knowledge Types Example

- 46543218751321768732
- Group numbers by twos. Ignore any two-digit number less than 32. Substitute the rest by ASCII equivalent
- GOLD 438+
- If price less than 500 and rising, buy.

Metaknowledge

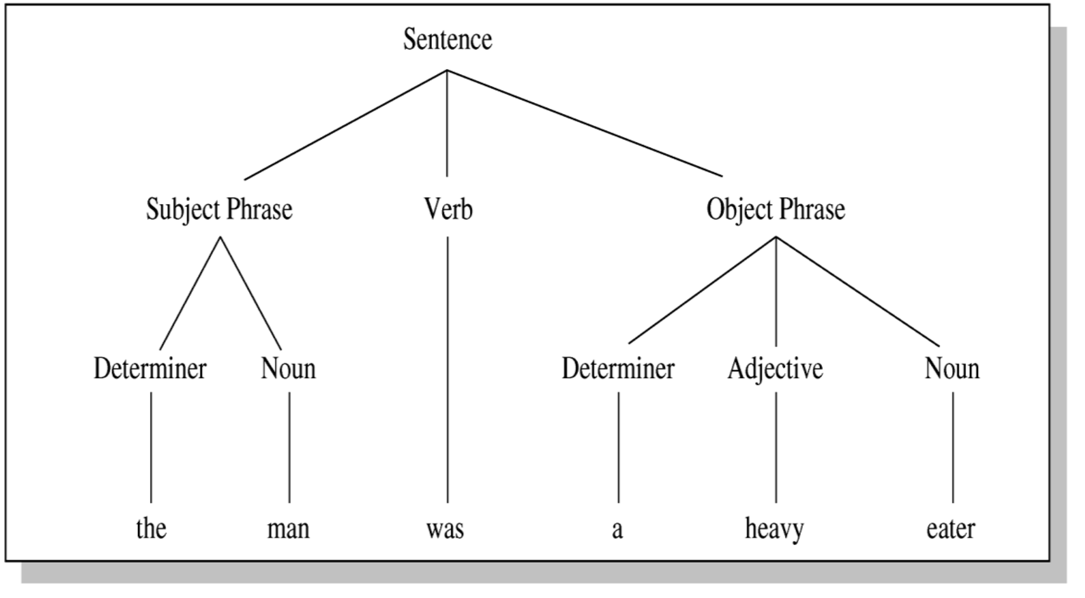
- Metaknowledge is knowledge about knowledge and expertise.
  - Ex. Emotions
- In an expert system, an ontology is the metaknowledge that describes everything known about the problem domain.
- Wisdom is the metaknowledge of determining the best goals of life and how to obtain them.

Knowledge Representation Techniques

- Rules
- Semantic nets
- Frames
- Scripts
- Logic
- Conceptual graphs

Productions (Rules)

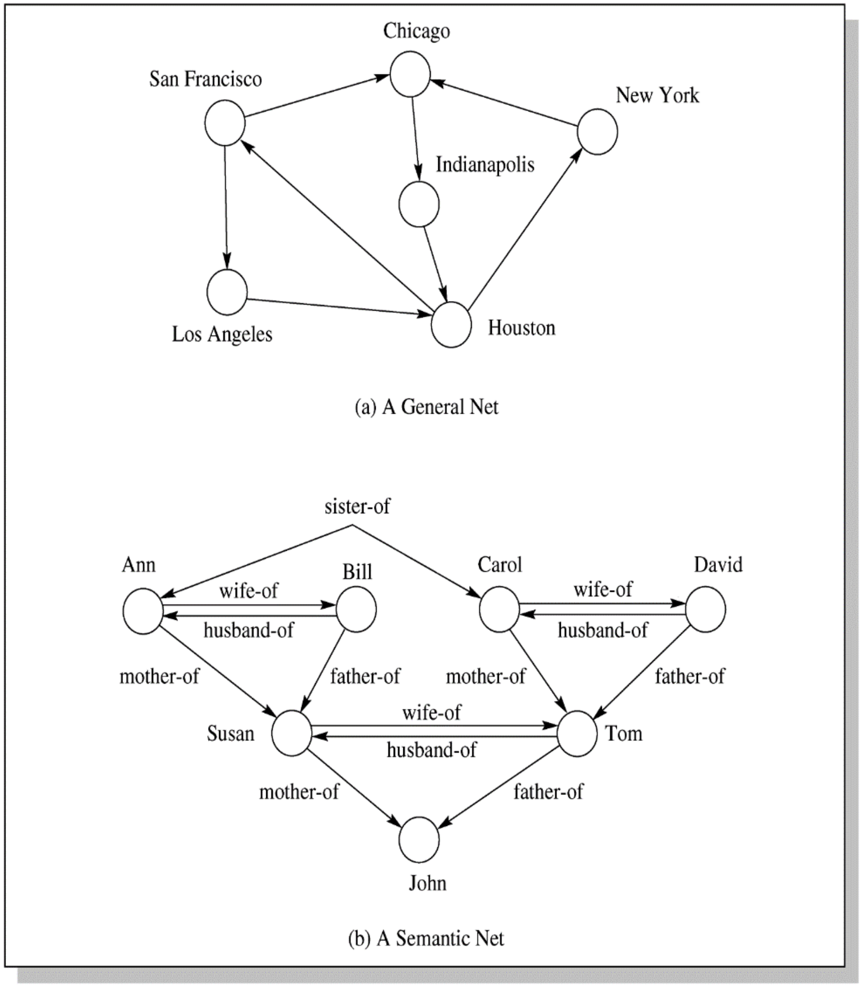
- Meta Language, BNF, Pars Tree, …
- Finite State Machines
- Hidden Markov Models



Semantic Nets

- Rooted from Human Associative Memory
- A classic representation technique for propositional information
- Propositions – a form of declarative knowledge, stating facts (true/false)
- Propositions are called “atoms” – cannot be further subdivided.
- Semantic nets consist of nodes (objects, concepts, situations) and arcs (relationships between them).

Two Types of Nets



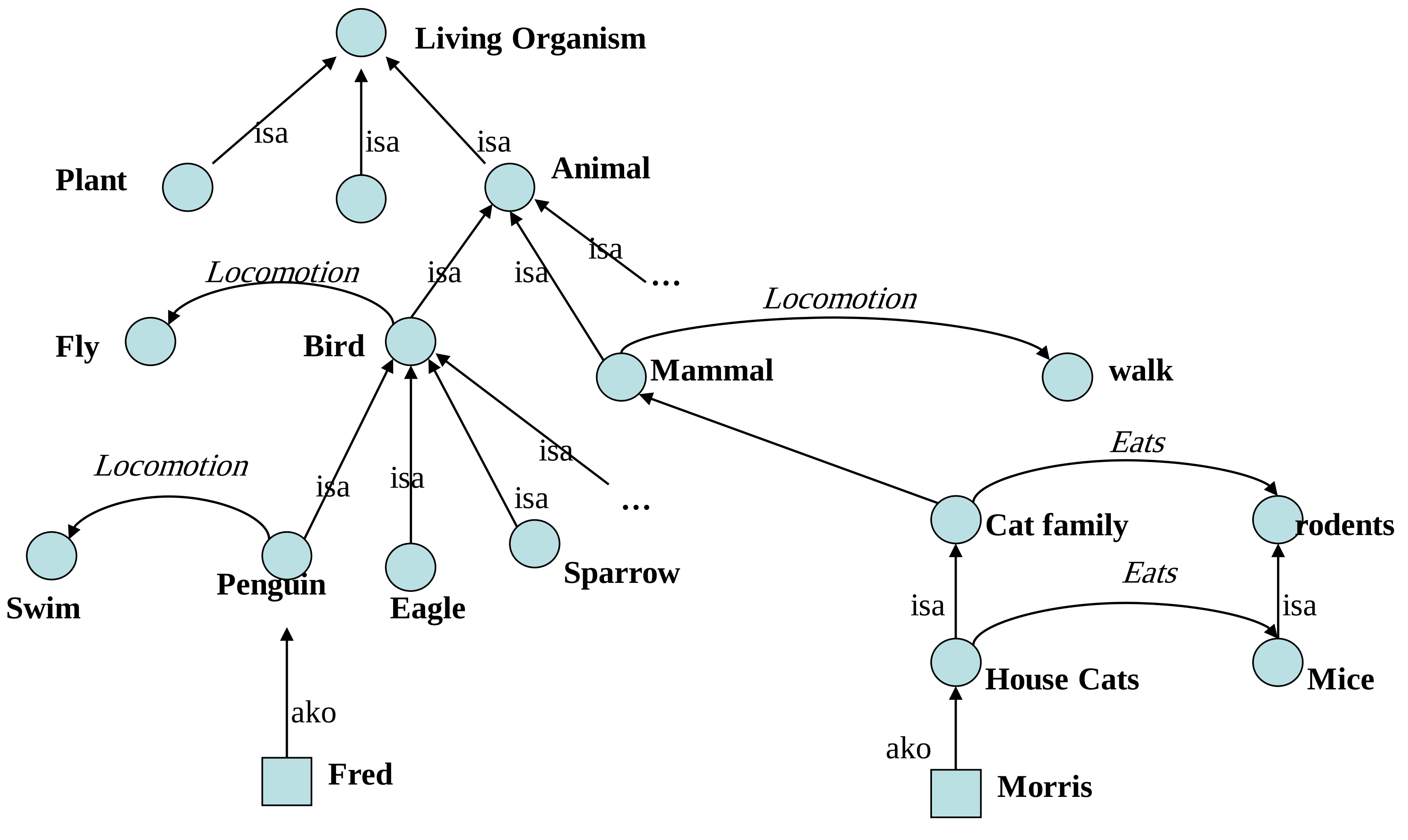
(a) A General Net

(b) A Semantic Net

Common Types of Links

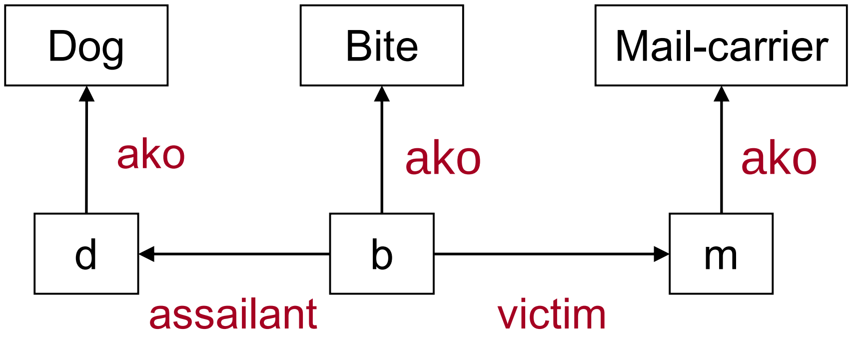
- IS-A – relates an instance or individual to a generic class
- A-KIND-OF – relates generic nodes to generic nodes

Semantic Net Example



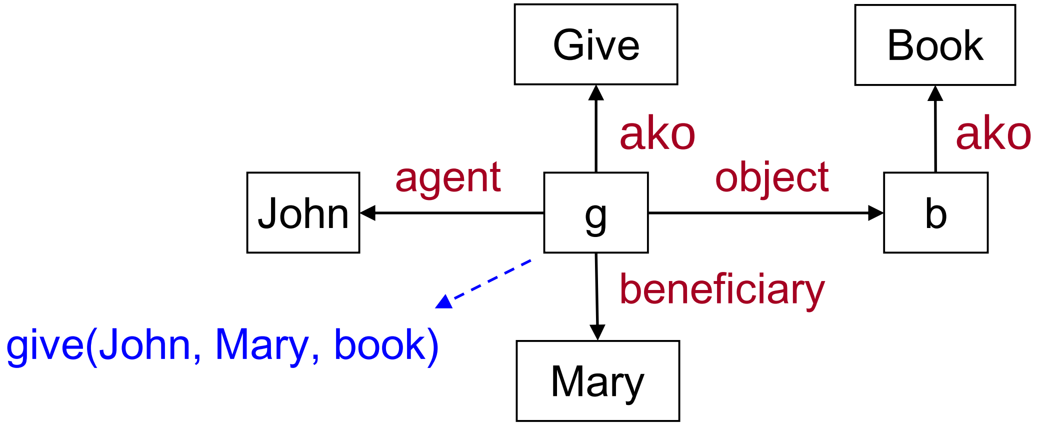
Semantic Net Example

"The dog bit the mail carrier"

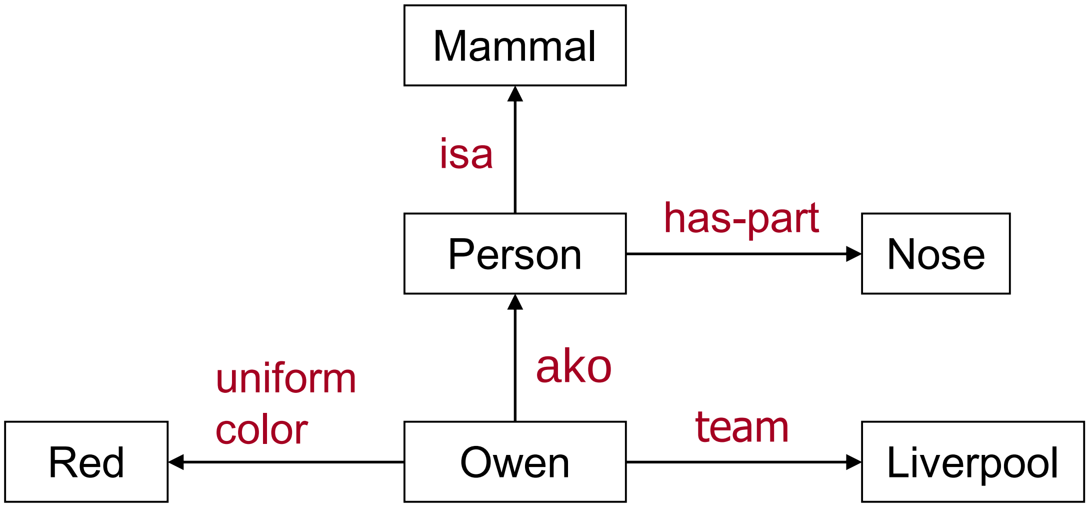


Semantic Net Example

"John gives Mary a book"

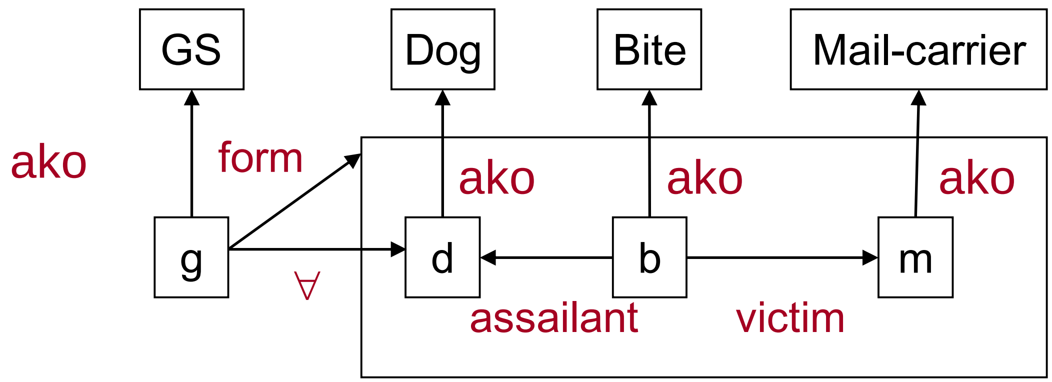


Semantic Net Example



Semantic Net Example

"Every dog has bitten a mail-carrier"



Object-Attribute-Value Triple

- One problem with semantic nets is lack of standard definitions for link names (IS-A, AKO, etc.).

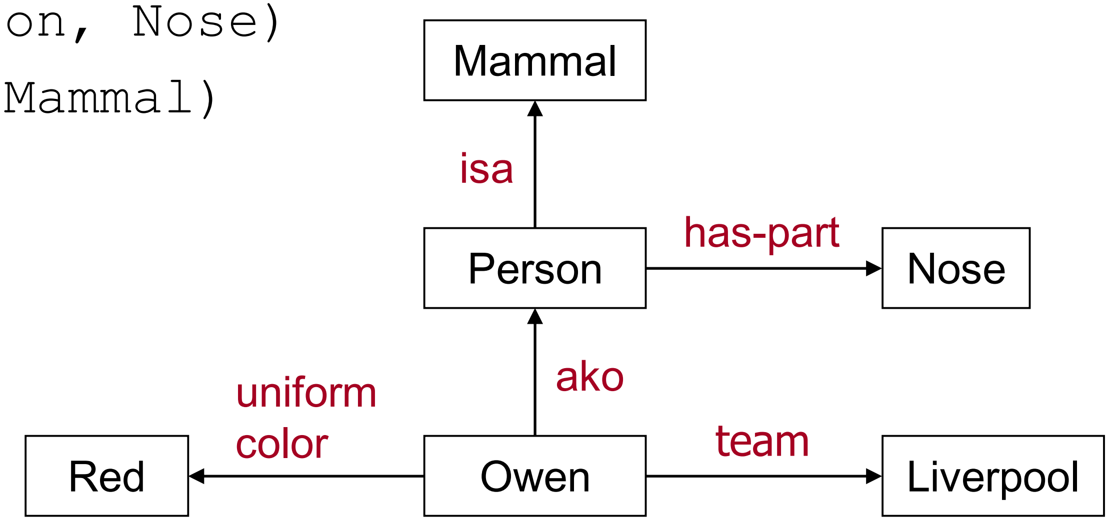
- The OAV triplet can be used to characterize all the knowledge in a semantic net.

Table 2.1 An OAV Table

Object	Attribute	Value
apple	color	red
apple	type	mcintosh
apple	quantity	100
grapes	color	red
grapes	type	seedless
grapes	quantity	500

PROLOG and Semantic Nets

- `UniformColor(Owen,Red).`
- `Team(Owen, Liverpool)`
- `AKO(Owen, Person).`
- `HasPart(Person, Nose)`
- `ISA(Person, Mammal)`



Problems with Semantic Nets

- To represent definitive knowledge, the link and node names must be rigorously defined.
- A solution to this is extensible markup language (XML) and ontologies.
- Problems also include combinatorial explosion of searching nodes.
  - Ex. What's the name of Pluto planet's football team?
- Inability to define knowledge the way logic can, and heuristic inadequacy.

Schemata

- Knowledge Structure – an ordered collection of knowledge – not just data.
- Semantic Nets – are shallow knowledge structures – all knowledge is contained in nodes and links.
- Schema is a more complex knowledge structure than a semantic net.
- In a schema, a node is like a record which may contain data, records, and/or pointers to nodes.

Frames

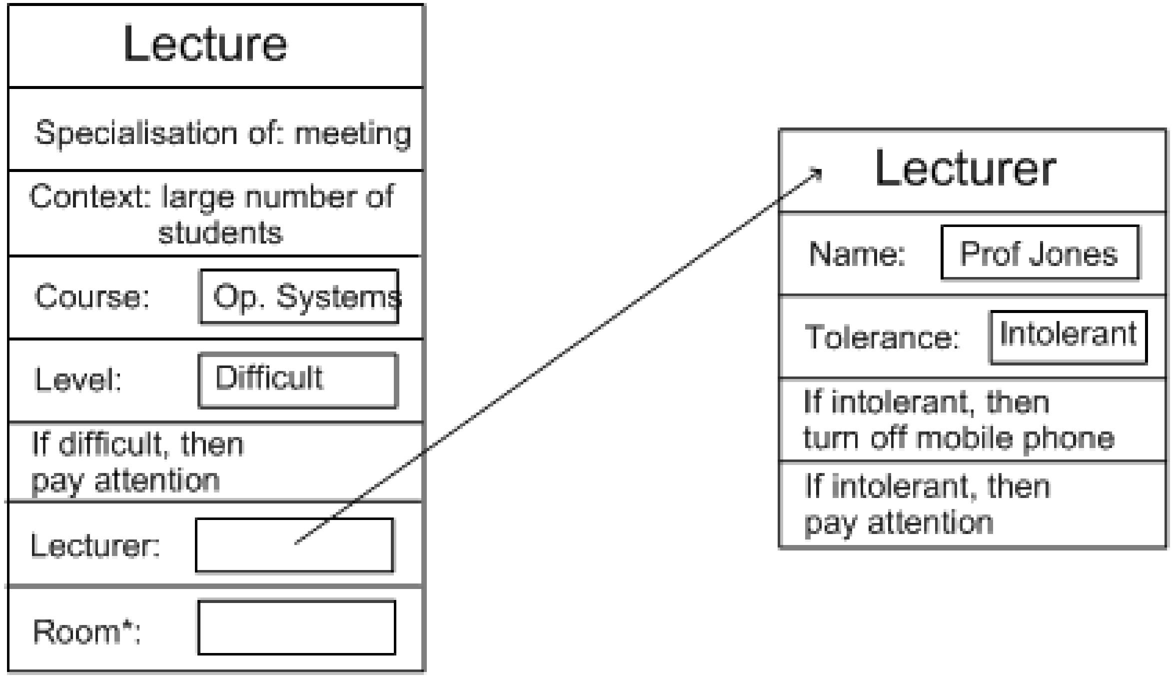
- One type of schema is a frame (or script – time-ordered sequence of frames).
- Frames are useful for simulating commonsense knowledge.
- Semantic nets provide 2-dimensional knowledge; frames provide 3-dimensional.
- Frames represent related knowledge about narrow subjects having much default knowledge.

Figure 2.8 A Car Frame

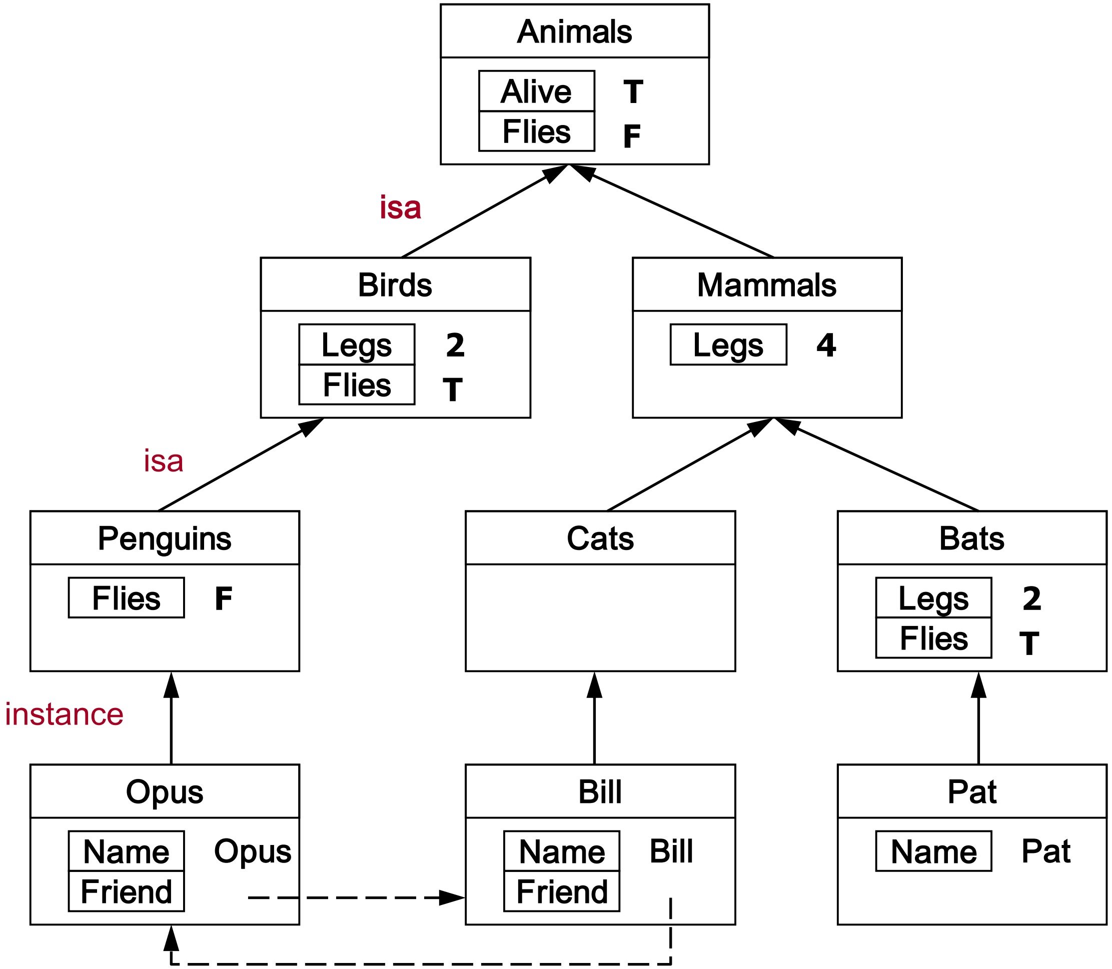
Slots	Fillers
manufacturer	General Motors
model	Chevrolet Caprice
year	1979
transmission	automatic
engine	gasoline
tires	4
color	blue

Frame Examples

- ONE/MORE GOOD FRAME SAMPLES



Frame Examples



Frames Continued

- A frame is a group of slots and fillers that defines a stereotypical object that is used to represent generic / specific knowledge.
- Commonsense knowledge is knowledge that is generally known.
- Prototypes are objects possessing all typical characteristics of whatever is being modeled.
- Problems with frames include allowing unrestrained alteration / cancellation of slots.

Logic and Sets

- Knowledge can also be represented by symbols of logic.
- Logic is the study of rules of exact reasoning – inferring conclusions from premises.
- Automated reasoning – logic programming in the context of expert systems.

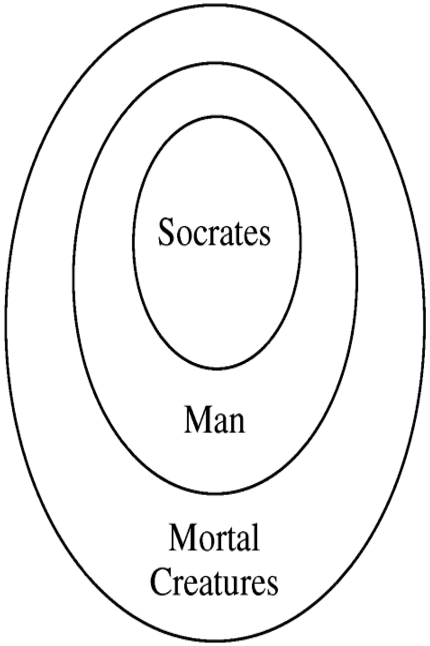
Forms of Logic

- Earliest form of logic was based on the syllogism – developed by Aristotle.
- Syllogisms – have two premises that provide evidence to support a conclusion.
- Example:
  - Premise: *All cats are climbers.*
  - Premise: *Garfield is a cat.*
  - Conclusion: *Garfield is a climber.*

Venn Diagrams

- Venn diagrams can be used to represent knowledge.
- Universal set is the topic of discussion.
- Subsets, proper subsets, intersection, union , contained in, and complement are all familiar terms related to sets.
- An empty set (null set) has no elements.

Figure 2.13 Venn Diagrams



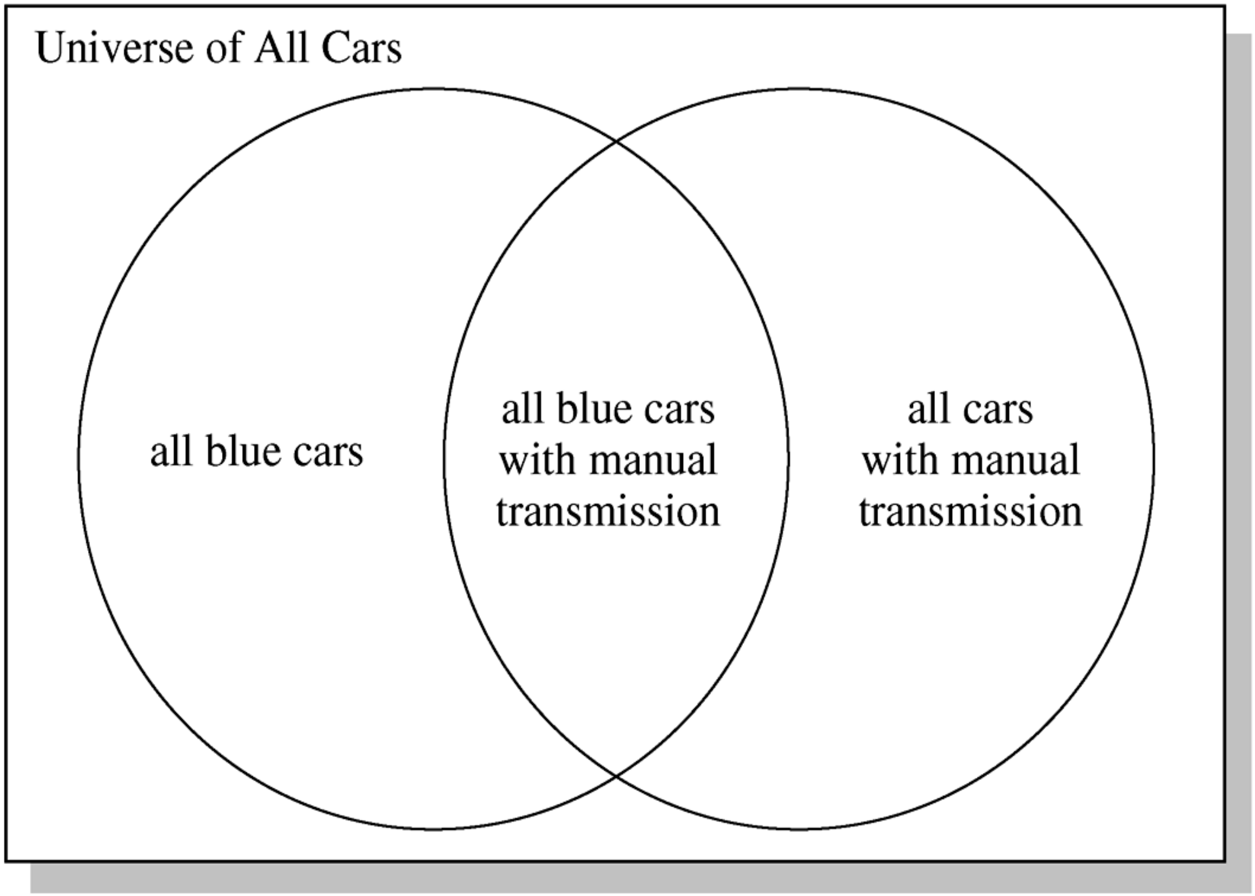
Propositional Logic

- Formal logic is concerned with syntax of statements, not semantics.
- Syllogism:
  - All goons are loons.
  - Zadok is a goon.
  - Zadok is a loon.
- The words may be nonsense, but the form is correct – this is a "valid argument."

Boolean vs. Aristotelian Logic

- Existential import – states that the subject of the argument must have existence.
- “All elves wear pointed shoes.” – not allowed under Aristotelian view since there are no elves.
- Boolean view relaxes this by permitting reasoning about empty sets.

Figure 2.14 Intersecting Sets



Boolean Logic

- Defines a set of axioms consisting of symbols to represent objects / classes.
- Defines a set of algebraic expressions to manipulate those symbols.
- Using axioms, theorems can be constructed.
- A theorem can be proved by showing how it is derived from a set of axioms.

Other Pioneers of Formal Logic

- Whitehead and Russell published ***Principia Mathematica***, which showed a formal logic as the basis of mathematics.

- **Gödel** proved that formal systems based on axioms could not always be proved internally consistent and free from contradictions.

Features of Propositional Logic

- Concerned with the subset of declarative sentences that can be classified as true or false.
- We call these sentences "statements" or "propositions".
- Paradoxes – statements that cannot be classified as true or false.
- Open sentences – statements that cannot be answered absolutely.

Features Continued

- Compound statements – formed by using logical connectives (e.g., AND, OR, NOT, conditional, and biconditional) on individual statements.

$\rightarrow$

- Material implication – $p \rightarrow q$ states that if p is true, it must follow that q is true.

- Biconditional – $p \leftrightarrow q$ states that p implies q and q implies p.

Features Continued

- Tautology – a statement that is true for all possible cases.
- Contradiction – a statement that is false for all possible cases.
- Contingent statement – a statement that is neither a tautology nor a contradiction.

Truth Tables

Table 2.4 Truth Table of the Binary Logical Connectives

p	q	$p \wedge q$	$p \vee q$	$p \rightarrow q$	$p \leftrightarrow q$
T	T	T	T	T	T
T	F	F	T	F	F
F	T	F	T	T	F
F	F	F	F	T	T

Table 2.5 Truth Table of Negation Connectives

p	~p
T	F
F	T

Universal Quantifier

- The universal quantifier, represented by the symbol $\forall$ means “for every” or “for all”.

$$(\forall x)\ (x \text{ is a rectangle} \rightarrow x \text{ has four sides})$$

- The existential quantifier, represented by the symbol $\exists$ means “there exists”.

$$(\exists x)\ (x - 3 = 5)$$

- Limitations of predicate logic – *most* quantifier.

Summary

- We have discussed:
  - Elements of knowledge
  - Knowledge representation
  - Some methods of representing knowledge
- Fallacies may result from confusion between form of knowledge and semantics.
- It is necessary to specify formal rules for expert systems to be able to reach valid conclusions.
- Different problems require different tools.