

Artificial Intelligence

Expert Systems

Rule-based expert systems and CLIPS

Other approaches to knowledge representation:

Semantic networks and frames

Common sense reasoning: CYC

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What is an expert system?

- An expert system is computer software that embodies a significant portion of the specialized knowledge of a human **expert** in a specific, narrow **domain**, and emulates the decision-making ability of the human expert
- The technology is based on the premise that what makes a person an expert is years of experience that enables him to recognize certain patterns in a problem as being similar to patterns he has seen previously
- It is one of the early (large-scale) successes of artificial intelligence

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Many applications

- control (air traffic)
- debugging
- design (computer configuration)
- medical diagnosis
- instruction/training
- interpretation (speech)
- monitoring (nuclear plant)
- planning (mission planning)
- Factory scheduling
- prediction (weather)
- repair (telephone)

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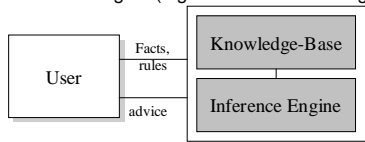
Advantages and disadvantages

	Human Expert	Expert System
Pro Expert System	perishable unpredictable slow reproduction expensive slow processing	permanent consistent quick replication affordable fast processing
Pro Human	creative adaptive broad focus common sense	lacks inspiration needs instruction narrow focus machine knowledge

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Expert system technology

- Consists of:
 - Knowledge-base (+ language for encoding knowledge)
 - Inference engine (algorithms for reasoning)



Expert System

Expert Systems – Knowledge Based Systems – Knowledge Based Expert Systems

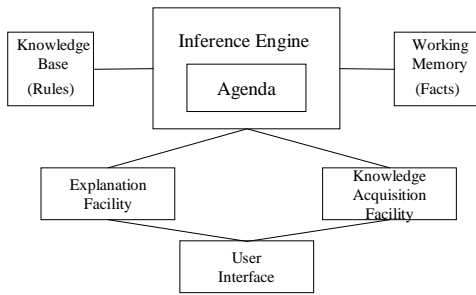
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Rule-based knowledge representation

- A rule consists of two parts: condition (antecedent) part and conclusion (action, consequent) part, i.e:
IF (conditions) THEN (actions)
- Antecedent part of the rule describes the facts or conditions that must exist for the rule to fire
- Consequent describes
 - the facts that will be established, or
 - the action that will be taken or conclusion that will be made

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Structure of Rule-Based Expert System



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Components of rule-based system

- Working memory (Fact memory)
 - data structures representing the current state of the system (Facts = positive literals with no variables)
- Knowledge base (Rule memory)
 - set of condition action rules
 - <WM pattern> \longrightarrow <WM changes>
 - Rules can add and delete facts from working memory
- Inference engine (Rule interpreter)
 - applies production rules to the working memory.

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Pattern Matching

- Find all rules that are eligible to be “fired” by matching left-hand side of rules to facts in working memory
- If rules have variables, matching requires unification (the RETE algorithm can do this efficiently)

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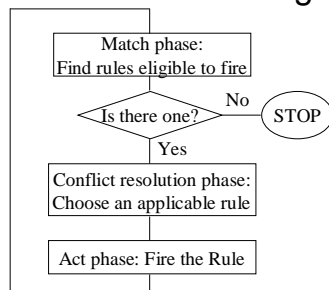
Conflict resolution

When several rules are eligible to fire, there are different criteria for selecting which to fire next:

- Fire rule with the highest priority
- Fire rule with the most specific condition
- Fire the most recently used rule
- Fire rule with the most recently used variable
- Fire the most recently added rule

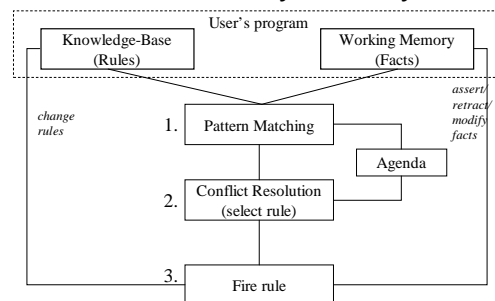
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Forward Chaining



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Rule-based system cycle



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Advantages of rule-based expert systems

- Good for complex problems where humans have expert knowledge
- Expressiveness and intuitiveness
 - Rules can be understood by a non-programmer
- Simplicity (uniform KR)
- Modularity and modifiability
 - Individual rules can be changed and added
 - But it is hard to analyze the effect of each new rule on performance.

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Difficulties

- “Knowledge acquisition bottleneck”
 - Difficulty in acquiring expert knowledge and putting it in system
- Not good at common-sense reasoning
- Traditional systems not good at handling uncertainty
 - Recent techniques have overcome this

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Expert system shell

- A tool for building an expert system
- A software package that includes an inference engine, knowledge representation language, user interface, and all the code used by an expert system – regardless of the domain
- All you have to add is the knowledge, i.e., the rules and facts used by an expert to solve problems in a certain domain
- CLIPS is an example of an expert system shell

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CLIPS: basic elements

- **Fact-list:** global memory for data that contains the facts
- **Knowledge-base:** contains all the rules.
- **Inference engine:** forward chaining

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Syntax for facts

- (single-field)
- (two fields)
- (speed 38 mph)
- (cost 78 dollars 23 cents)
- (name “John Doe”)
- **Adding facts:**
(assert <facts>)
- **Removing facts:**
(retract <fact-index>)

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Syntax for rules

- (defrule <rule name> [<optional comment>]
 <<patterns>>
 =>
 <<actions>>)
- (defrule fire-emergency “An example rule”
 (emergency fire)
 =>
 (assert (action activate-sprinkler-system)))

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Syntax for variables

- ?speed
 - ?sensor
 - ?value
- ```
(defrule grandfather
 (is-a-grandfather ?name)
 =>
 (assert (is-a-man ?name)))
```
- E.g: (is-a-grandfather John) → ?name = John  
 (is-a-grandfather Joe) → ?name = Joe

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## Wildcards

```
(person <name> <eye-color> <hair-color>)
(person John brown black)
(person Joe blue brown)

(defrule find-brown-haired-people
 (person ?name ? brown)
 =>
 (printout t ?name " has brown hair"))
```

**States that eye color doesn't matter.**

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## Expert Systems vs Conventional Programs

| Characteristic | Conventional Program             | Expert System                   |
|----------------|----------------------------------|---------------------------------|
| Control by...  | Information & control integrated | Knowledge separate from control |
| Solution by... | Algorithm                        | Rules & inference               |
| Representation | Numeric                          | Symbolic                        |
| Execution      | Generally sequential             | Opportunistic rules             |

Important difference:

- Expert system is developed by considering how a human expert would perform a task.
- Conventional program is developed by considering how a computer would perform a task.

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## Knowledge Representation

- There are other ways of representing declarative knowledge besides first-order logic and rule-based systems
- Semantic networks and frames are closely related formalisms that graphically represent taxonomies of objects and their properties
- They often provide a clearer view of represented knowledge, and allow more efficient inference, than an equivalent logical representation

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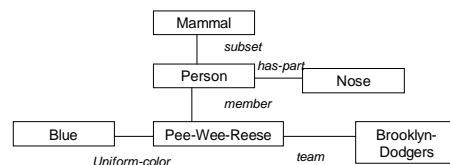
## Semantic networks

- Graph structures that encode taxonomic knowledge of objects and their properties
  - objects represented as nodes
  - relations represented as labeled edges
- Inheritance = form of inference in which subclasses inherit properties of superclasses

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## Semantic Network Example

Adapted from Figure 9.1 Page 252 of Rich and Knight

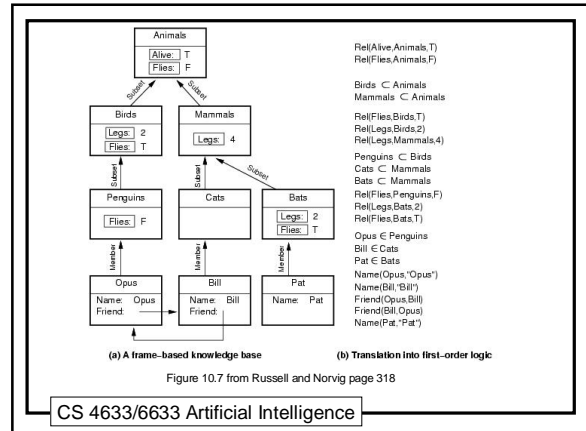


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## Frames

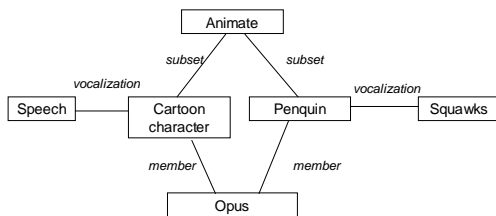
- A limitation of semantic networks is that additional structure is often necessary to distinguish
  - statements about an object's relationships
  - properties of the object
- A frame is a node with additional structure that facilitates differentiating relationships between objects and properties of objects.
- Sometimes called a "slot-and-filler" representation

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## Multiple inheritance



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## CYC (from enCYClopedia) Project

- Began at MCC (Microelectronics and Computer Technology Corporation) in Austin, TX, in 1984, as a ten-year project with a \$35 million grant
- Since 1995 has been continued by a private company, CYCORP
- A massive knowledge base and inference engine designed to overcome the limitations of expert system technology by formalizing common sense knowledge

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## Cycl

- CYC originally used a frame-based system to represent knowledge, but has since developed its own knowledge representation language, Cycl, which is an extension of first-order logic
- All the knowledge in CYC is represented declaratively, as facts and rules
- CYC presently has close to a million facts and rules from which its inference engine can derive new conclusions using deductive reasoning
- The present estimate (which keeps being revised upwards) is that it needs ten to twenty million facts and rules to have common sense

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## Examples of common-sense knowledge

- "Cars in motion generally have a driver"
- "Police in most countries are armed"
- "If you drop a glass, it will break"

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## Natural language interface

- Development of a natural language interface for CYC is ongoing
- The goal is for CYC to learn by reading books and articles, or by having people tell it things in English
- Current natural language interface is useful but very primitive (this is a *hard* problem)

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## Applications of CYC

- Although CYC is far from having common sense, the techniques developed in the course of this project for knowledge representation and inference have a number of applications, including:
- Heterogenous database browsing and integration
- captioned image retrieval
- natural language processing

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