Knowledge Representation & Production Rule Systems

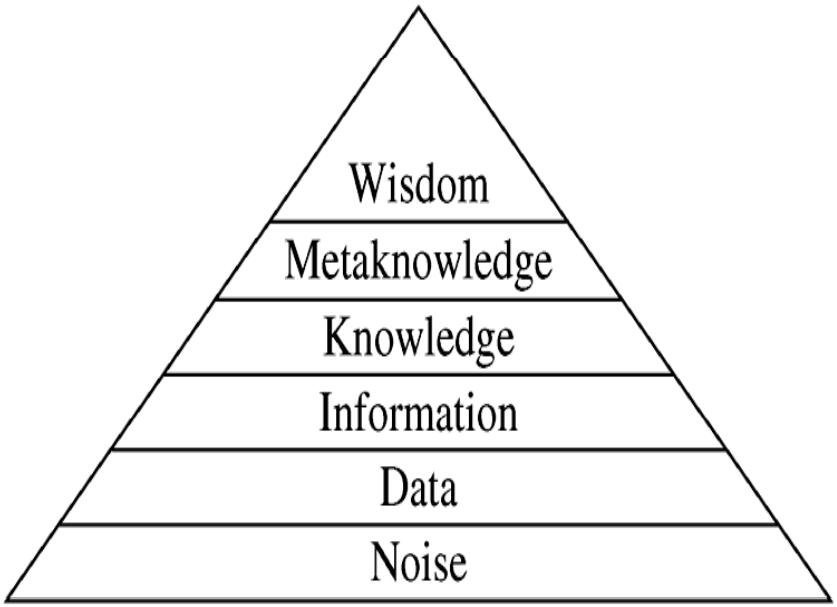
Introduction

- Knowledge representation (KR) is as significant a factor in determining the success of a system as the software that uses the knowledge
- KR is of major importance in expert systems for two reasons:
  - Expert systems are designed for a certain type of knowledge representation based on rules of logic called inferences
  - KR is important as it affects the development, efficiency, speed, and maintenance of the system

The meaning of knowledge

- Two special types of knowledge
  - a priori
  - a posteriori
- *A priori* knowledge
  - comes before and is independent of knowledge from the senses
  - is considered to be universally true and cannot be denied without contradiction
  - examples of a priori knowledge: logic statements, mathematical laws, and the knowledge possessed by teenagers
- The opposite of a priori knowledge is knowledge derived from the senses: *a posteriori* knowledge
  - since sensory experience may not always be reliable, a posteriori knowledge can be denied on the basis of new knowledge without the necessity of contradictions

The meaning 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.

The meaning of knowledge

- As an example:

  137178766832525156430015

  - Without knowledge, this entire sequence appears to be noise
  - if it is known that this sequence is meaningful, then the sequence is data
- Certain knowledge may transform data into information
  - For example, the following algorithm processes the data to yield information:

    Group the numbers by twos.

    Ignore any two-digit numbers less than 32.

    Substitute the ASCII characters for the two-digit numbers.
- Application of this algorithm to the previous 24 numbers yields the information:

  GOLD 438+

The meaning of knowledge

- Now knowledge can be applied to this information:

  IF gold is less than 500

  and the price is rising (+)

  THEN

  buy gold

Knowledge Acquisition

- **Knowledge engineer**

  An AI specialist responsible for the technical side of developing an expert system. The knowledge engineer works closely with the domain expert to capture the expert's knowledge in a knowledge base

- **Knowledge engineering (KE)**

  The engineering discipline in which knowledge is integrated into computer systems to solve complex problems normally requiring a high level of human expertise

Production Systems

- Represent knowledge in terms of multiple rules that specify what should be or should not be concluded in different situations.
- A rule-based system consists of IF-THEN *rules, facts,* and an *interpreter*
- Rules are popular for a number of reasons:
  - *Modular nature*
    - easy to encapsulate knowledge and expand the expert system by incremental development
  - *Explanation facilities*
    - By keeping track of which rules have fired, an explanation facility can present the chain of reasoning that led to a certain conclusion.
  - *Similarity to the human cognitive process*

Post production systems

- Production systems were first used in symbolic logic by Post who originated the name.
- The basic idea of Post was that any mathematical or logic system is simply a set of rules specifying how to change one string of symbols into another set of symbols.
- Given an input string, the antecedent, a production rule could produce a new string, the consequent.

Post production systems

- A production rule could be:

  Antecedent → *Consequent*

  person has fever → take aspirin

- In terms of the IF-THEN notation as:

  IF person has fever THEN take aspirin

- The production rules can also have multiple antecedents

  person has fever AND

  fever is greater than 102 → see doctor

Post production systems

- A Post production system consists of a group of production rules

  (1) car won't start → check battery

  (2) car won't start → check gas

  (3) check battery AND battery bad →replace battery

  (4) check gas AND no gas → fill gas tank

Post production systems

- The rules could have been written in any order

  (4) check gas AND no gas → fill gas tank

  (2) car won't start → check gas

  (1) car won't start → check battery

  (3) check battery AND battery bad →replace battery

- The basic limitation is lack of a control strategy to guide the application of the rules
- Therefore, although they were useful in laying part of the foundation of expert systems, they are not adequate.

Markov Algorithms

- A Markov algorithm is an ordered group of productions that are applied in order of priority to an input string
- It terminates if either,
  - (I) the last production is not applicable to a string or,
  - (2) a production that ends with a period is applied,
- For example, suppose the system consists of the single rule:

  $AB \rightarrow HIJ$
  - input string GABKAB produces the new string GHIJKAB
  - the production now applies to the new string, the final result is GHIJKHIJ

Markov Algorithms

- ^ represents the null string

  A→^

  - deletes all occurrences of the character A
- Lowercase letters a, b, c, …x, y, z represent single-character variables

  AxB→ BxA

  - Reverse the characters A and B, where x is any single character
- An example of a Markov algorithm that moves the first letter of an input string to the end
  - The rules are ordered in terms of highest priority (I), next highest (2), and so forth

Markov Algorithms

- The following rules can move the first letter to the end.
- The rules are prioritized in the order that they are entered:
  (x and y are single-character variable; α is a special punctuation)

  (1) αxy → yαx
  (2) αx → xα
  (3) α● → ^ ●
  (4) ^ → α

Input string:
ABC

Execution Trace

Rule	Success / Failure	String
1	F	ABC ●
2	F	ABC ●
3	F	ABC ●
4	S	αABC ●
1	S	BαAC ●
1	S	BCαA ●
1	F	BCαA ●
2	S	BCAα ●
1	F	BCAα ●
2	F	BCAα ●
3	S	BCA ●

The Rete Algorithm

- Markov algorithm is very inefficient for systems with many rules
- A solution is the Rete Algorithm
- The Rete Algorithm functions like a net in holding a lot of information
  - much faster response times and rule firings can occur compared to a large group of IF-THEN rules which must be checked one by one in a conventional program
- The Rete Algorithm is a very fast pattern-matcher that obtains its speed by storing information about the rules in a network in memory

Rule-based Systems

- Consider the problem of deciding to cross a street
- The productions for the two rules are

  the light is red -> stop

  the light is green -> go
- An equivalent pseudo code IF-THEN format as:

```
Rule: Red_light IF
IF
    the light is red
THEN
    stop

Rule: Green_light IF
IF
      The light is green
THEN
      go
```

Rule-based Systems

- Each rule is identified by a name. Following the name is the IF part of the rule
- Between the IF and THEN part of the rule is called by various names such as the **antecedent, conditional part, pattern part, or left-hand-side** (LHS)
- The individual condition:

  the light is green

  is called a **conditional element** or a **pattern**

Rule-based Systems

- The following are some examples of rules from the classic systems:

  MYCIN system for diagnosis of meningitis and bacteremia (bacterial infections)

  IF

  The site of the culture is blood, and

  The identity of the organism is not known with certainty, and

  The stain of the organism is gramneg, and

  The morphology of the organism is rod, and The patient has been seriously burned

  THEN

  There is weakly suggestive evidence (.4) that

  the identity of the organism is pseudomonas

Rule-based Systems

XCON/Rl for configuring DEC VAX computer systems

IF

The current context is assigning devices to Unibus modules and

There is an unassigned dual-port disk drive and

The type of controller it requires is known and

There are two such controllers, neither of which has any devices assigned to it, and

The number of devices that these controllers can support is known

THEN

Assign the disk drive to each of the controllers, and

Note that the two controllers have been associated and each supports one drive

Rule Inference

- Two general methods of inferencing used
  - **forward chaining**
  - **backward chaining**
- Other methods used
  - means-ends analysis, problem reduction, backtracking, plan-generate-test, hierarchical planning and the least commitment principle, and constraint handling
- Forward chaining is reasoning from facts to the conclusions resulting from those facts
- Backward chaining involves reasoning in reverse from a hypothesis, a potential conclusion to be proved, to the facts that support the hypothesis

Rule Inference

- CLIPS is designed for forward chaining, PROLOG performs backward chaining
- The choice of inference engine depends on the type of problem
  - Diagnostic problems are better solved with backward chaining
  - Prognosis, monitoring, and control are better done by forward chaining
- A rule whose patterns are all satisfied is said to be activated or instantiated.
- Multiple activated rules may be on the agenda at the same time, the inference engine must then select one rule for firing

Rule Inference

- Following the THEN part of a rule is a list of actions to be executed when the rule fires
  - the consequent or right-hand side (RHS)
- The inference engine operates in **recognize-act cycles** will repeatedly execute a group of tasks until certain criteria cause execution to cease

Rule Inference

- Conflict resolution, act, match, and check for halt:

WHILE not done

Conflict Resolution: If there are activations, then select the one with highest priority, else done.

Act: Sequentially perform the actions on the RHS of the selected activation. Re-move the activation that has just fired from the agenda.

Match: Update the agenda by checking if the LHS of any rules are satisfied. If so, activate them. Remove activations if the LHS of their rules are no longer satisfied.

Check for Halt: If a halt action is performed or break command given, then done.

END-WHILE

Accept a new user command