Expert Systems

(Introduction)

Lecture 001

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What is an Expert System ?

- The first step in solving any problem is defining the problem area or domain the problem belongs to.
- "… an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution … " (Feigenbaum 82)
- In other words … an expert system is a computer system which emulates the decision-making ability of a human expert.
- General purpose problem solver !!! NO WAY but … expert systems function very well in their restricted domains like business, medicine, science and engineering.

What is an Expert System ? (cont.)

- Expert systems is ‘probably’ one of the most successful branches of AI, that makes extensive use of specialized knowledge to solve problems at the level of a human expert.

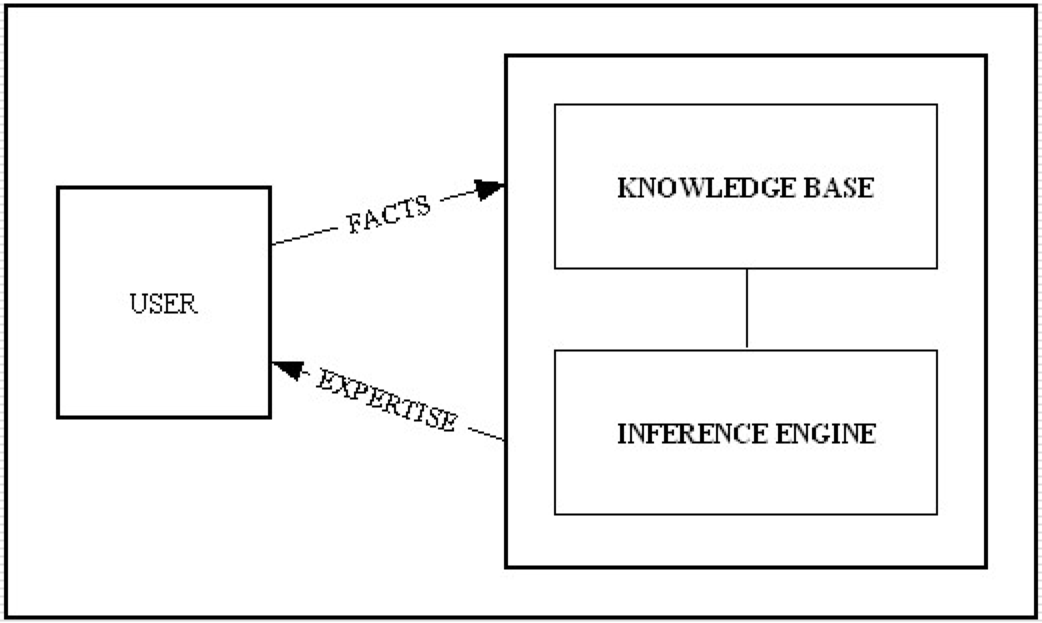
- An expert can solve problems that most people cannot solve at all or solve them much more efficiently (but not as cheaply!!)

- The basic components of an expert system include:
  - A knowledge-Base (facts) and
  - An Inference Engine

- The knowledge-base contains the knowledge with which the inference engine draws conclusions. These conclusions are the expert system’s response to the user’s queries for expertise.

A Basic Expert System

- Facts → Knowledge Base + IE → Expertise



Some Advantages of Expert Systems

- Increased Availability,
- Reduced Cost,
- Permanence (as opposed to humans it does not retire, quit or die),
- Increased Reliability (provide second opinion for a human expert),
- Explanation (explicit explanation of reasoning that led to conclusion),
- Fast Response,
- Knowledge base can be examined for correctness, consistency and completeness.

Knowledge Representation

- The knowledge of an expert system may be represented in a number of ways. One very common method of representing knowledge is in the form of the IF THEN type rules:

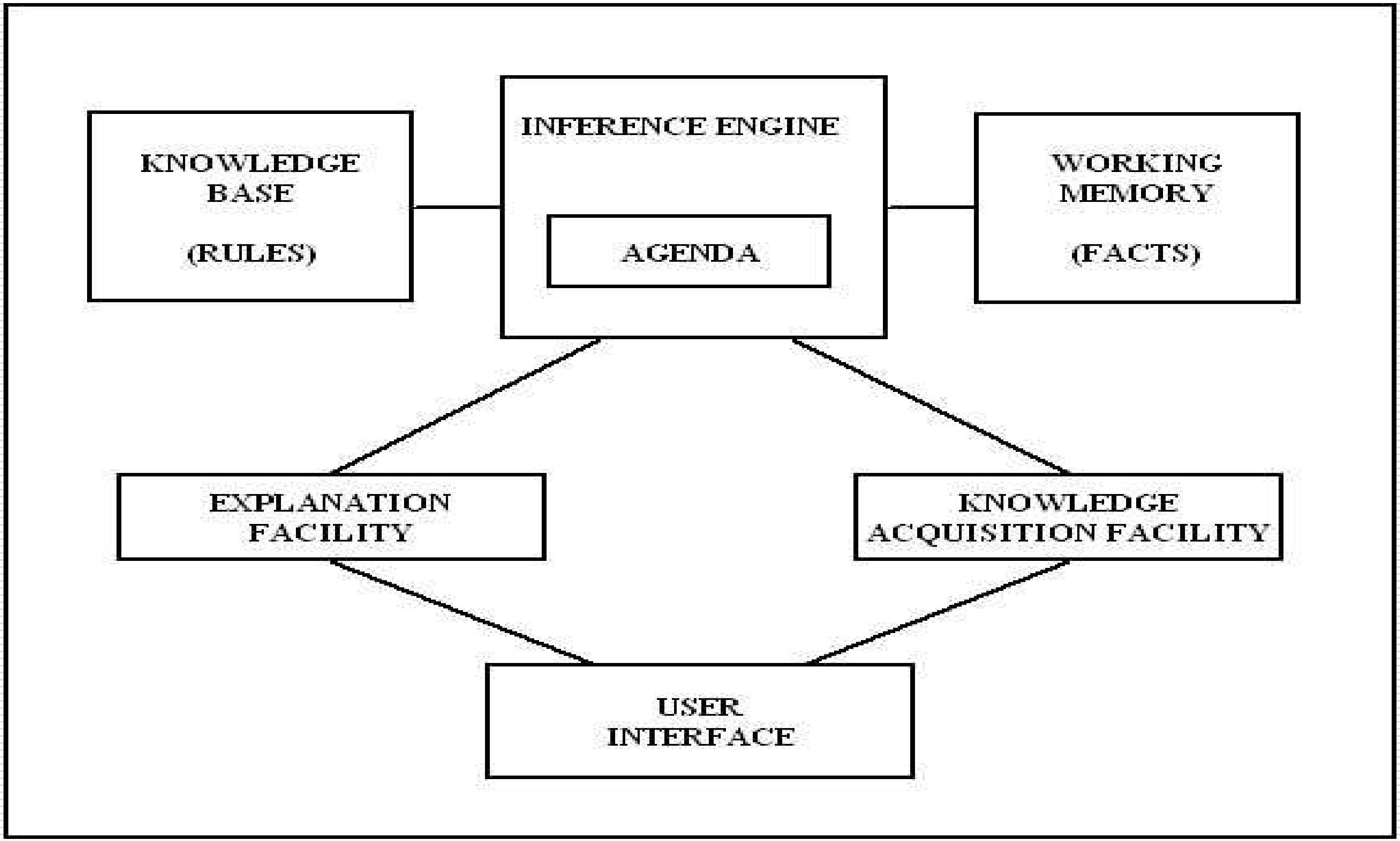
- Ex: IF the light is red THEN stop
- Or using propositional logic
  - LightRed → Stop
  - i.e. if LightRed is TRUE then Stop is TRUE

- LightRed is a fact
- What is the best granularity for facts and rules ???

Production Rules (cont.)

- Consider the following two production rules:
  - Fire → Run
  - Clothes Burning → Put out fire
- Clearly we need to put priorities on the rules.
- Moreover knowledge might not be expressed with complete certainty, for example:
  - IF there is smoke THEN there may be a fire
  - IF there is a siren THEN there may be a fire

Structure of a rule based expert system



Components

- *User Interface* – the mechanism by which the user and the expert system communicate
- *Explanation Facility* – explains the reasoning of the system to a user
- Working Memory – a global database of facts used by the rules
- Inference Engine – makes inferences by deciding which rules are satisfied by facts, prioritizes the satisfied rules, and executes the rule with the highest priority.
- Agenda – a prioritized list of rules created by the inference engine, whose patterns are satisfied by facts in working memory
- Knowledge Acquisition Facility – an automatic way for the user to enter knowledge in the system rather then by having the knowledge engineer explicitly code the knowledge

Inference through Forward Chaining

- Suppose the following 4 rules are available to the Inference Engine:
  - A & C → F
  - A & E → G
  - B → E
  - G → D
- … and we want to show that D is true whenever A and B are true.
  - Rule 3 fires in the first iteration. Thus E is true
  - Rule 2 fires in the second iteration. Thus G is true
  - Rule 4 fires in the third iteration. Thus D is true
- After three iterations the inference engine concludes that D is true whenever A and B are true.
- This way of inferring knowledge is referred to a forward chaining. Inference moves from a given situation to a desired goal, adding new assertions along the way.

Inference through Backward Chaining

- With Backward Chaining, one starts with the desired goal, and then attempts to find evidence for proving the goal.

- With respect to the previous example, then, the strategy to prove that D is true is as follows:

  - First, find a rule that proved D. Rule 4 does so.
  - This provides a sub-goal – to prove that G is true.
  - We can use Rule 2 since we already know that A is true. We know need to show that E is true (new sub goal)
  - Rule 3 provides the next sub-goal of proving that B is true. But we already know that B is true, since this was one of our assertions.
  - Therefore, E is true, which implies that G is true, which in turn implies that D is true !!

- Backward chaining is useful in situations where the quantity of data is potentially very large and where some specific characteristics of the system is of interest. Ex. Medical diagnosis.

A simple Rule-Based Inference Algorithm

- 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. Those which change working memory have immediate effect in the cycle. Remove the activation which 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 not satisfied any more.
  - Check for Halt: If a halt action is performed or break command given, then done.
- END WHILE

Markov Algorithm …

- … is an ordered group of productions which are applied in order of priority to an input string. If the highest priority rule is not applicable, then the next one if applied and so forth. The Markov algorithm terminates if either:
  - (1) the last production is not applicable to a string or
  - (2) a production that ends with a period is applied
- Markov algorithms are applied to substrings of strings, starting from the left. For example, the production system consisting of the single rule, *AB* → *HIJ* when applied to the input string GABKAB produces the new string GHIJKAB.
- Both null strings and variables are taken in consideration.

Markov Algorithm … an example

(1) $\alpha\ x\ y \rightarrow y\ \alpha\ x$

(2) $\alpha \rightarrow$ null

(3) null $\rightarrow \alpha$

Input string ABC

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

Some Applications

- MYCIN - expert system for medical diagnosis,
- BLUE BOX - expert system for diagnosis/ remedy of depression,
- PROSPECTOR – expert system used to interpret geological data for minerals.
- DENDRAL – expert system used to interpret molecular structure.