CHAPTER 1

Introduction to Knowledge-based Systems

1. Introduction

In the last decade or so, expert systems also called knowledge-based systems have made their way from research laboratories into the real world. Applications have been, and are continuing to be, developed in areas as diverse as business, medicine, manufacturing, defence, astronomy, science and engineering. Such applications perform tasks that include interpretation, prediction, diagnosis, design, planning, monitoring, debugging, repairing, instruction and control.

The expert systems are the offshoots of artificial intelligence which is concerned with using computers to simulate human intelligence in a limited way. Some researchers define artificial intelligence (AI) as the science of making machines do things that would require intelligence if done by men. In the last few decades, AI has spread into major subfields including expert systems, artificial neural networks, fuzzy systems, evolutionary computation and chaos theory. Some researchers do not differentiate between expert systems and knowledge-based systems. The key issue behind all these developments is the knowledge acquisition, knowledge representation and knowledge processing.

2. Expert (Knowledge-based) Systems

Knowledge-based system is a software system which can mimic the performance of a human expert in a limited sense. Figure 1 illustrates a simplified block diagram of a typical expert system.

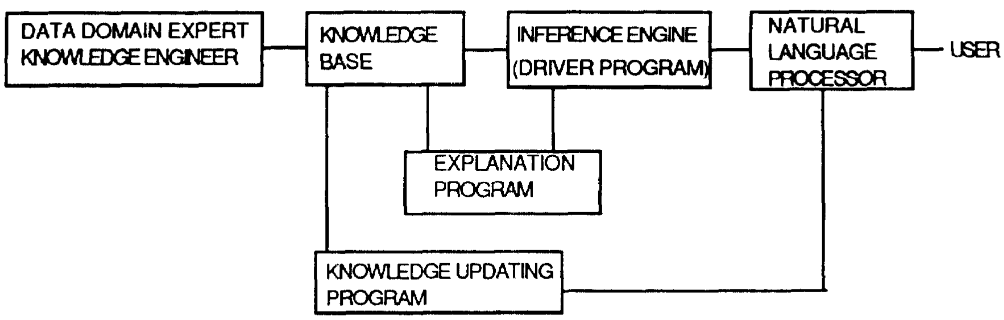

Figure 1 Simplified Block Diagram of a Typical Expert System

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The major logical components of an expert system are a Knowledge Base, an Inference Engine, an Interface between the system and the external environment, an Explanation facility, and a Knowledge Acquisition facility.

A "knowledge engineer" gathers the expertise about a particular domain from one or more experts, and organises that knowledge into the form required by the particular expert system tool that is to be used. Barr & Fiegenbaum list seven different forms of knowledge representation: logic, procedure, semantic network, production systems (rules), direct (analogical), semantic primitives, and frames and scripts. A typical expert system uses a data structure as the basis of the particular representation technique it implements. Consequently, the knowledge engineer needs to know the general form in which the knowledge is to be represented and the particular form of that representation required by the expert system itself. The "engineered" knowledge is the Knowledge Base.

The Inference Engine is the "driver" program. It traverses the Knowledge Base, in response to the observations and answers provided to it from the external world, in order to identify one or more possible outcomes or conclusions. The data structure selected for the specific form of knowledge representation determines the nature of the program created as the Inference Engine.

The Interface between the expert system and the external world is generally provided by a user sitting at a keyboard and screen display. However, there is increasing use of input from other sources. Sensors and transducers of many different kinds are being used to monitor the environment; these are regularly interrogated, and their output used by the expert system. Output from other computer programs, including expert systems, is often used. Extensive use is being made of vast quantities of information stored in databases to which the expert system has access. The story is similar with respect to output, which may be directed to actuators, machine controllers, other computer programs, speech synthesisers, and external data stores.

The Explanation facility is often quite simple, merely being a listing of the inputs, the appropriate parts of the Knowledge Domain, and the outcome or conclusion. Very rarely is there any facility provided to explain the reasoning process involved. In some cases, there are facilities provided to enable the knowledge engineer to provide special stores of text which may be accessed by users who need further information, either about the questions being asked or about the conclusions that are provided. These suffer from the disadvantage that they must be fully created in advance by the knowledge engineer, who must anticipate the kinds of things about which explanations might be required.

In the case of production (rule) based systems, the Knowledge Base consists of a number of rules written to an ASCII file. Therefore the Knowledge Acquisition facility required for these systems is often merely an external text editor. In systems based on other forms of representation, the Knowledge Acquisition facility will generally be an integral part of the expert system and can only be used with that system. The initial Knowledge Base is created using the appropriate facility, and modifications are made in a similar way. In very few systems does the Knowledge Acquisition facility possess any capability to "learn for itself"; the knowledge engineer is responsible for the maintenance of the Knowledge Base. The exceptions include those rule-based expert systems which have an "Induction" facility, often based on the ID3 algorithm developed by Quinlan. A series of examples is provided to the system. Each example, which is generally the result of a specific observation, consists of a set of attribute values associated with a particular outcome. Provided that enough examples are provided, a decision tree can be "induced", and this can be converted into the rule format required by the expert system being used.

Most expert systems available for use are "shells". They consist of the software programs required, but do not contain any Knowledge Bases. It is the responsibility of users to organise the creation of the required Knowledge Bases, any of which may be used by the expert system shell provided that they all satisfy the system's requirements with respect to the form of knowledge representation used and the particular structure required for the Knowledge Base. This has the advantage that the shell is usable for a large variety of applications, avoiding the necessity of creating a specific software system for each.

Figure 2 illustrates a second generation expert system. The system incorporates:

- Knowledge acquisition module for acquiring and editing the knowledge base.
- Knowledge explanation module.
- Knowledge utilization module which use the knowledge base to find solutions to a problem.

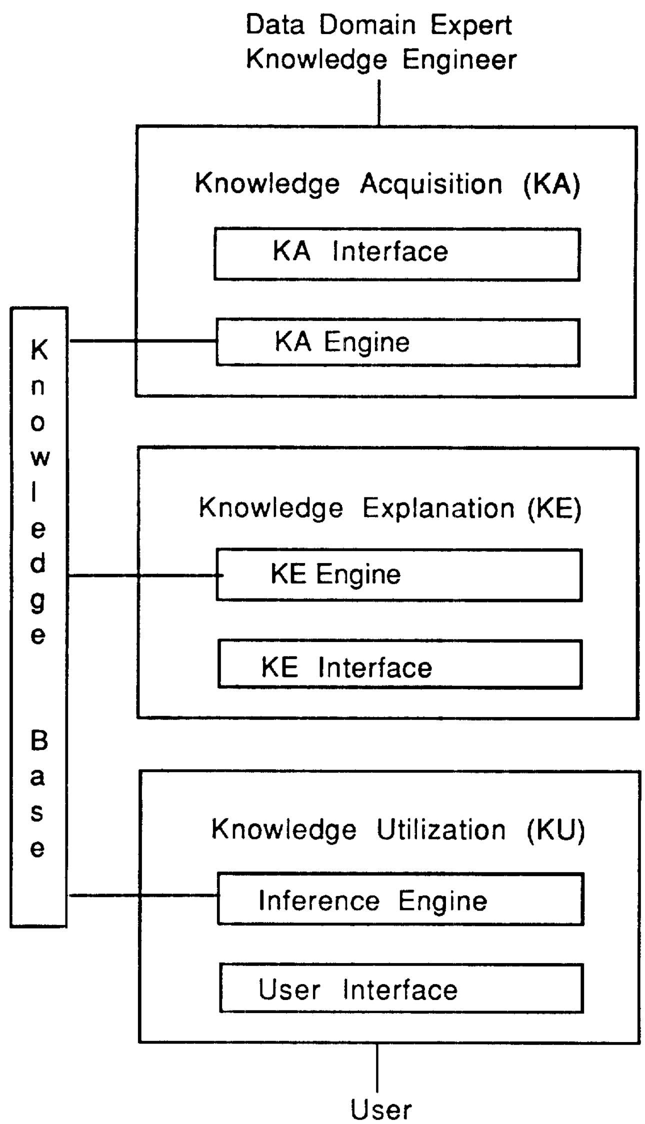

Figure 2 A Second Generation Expert System

3. Comparison of Conventional Computer Program an Expert System

Parameter	Conventional Traditional Computer Program	Expert System
Modification	Knowledge pertinent to the problem and the methods for using this knowledge are inter-wined, so it is difficult to change the program	There is usually a clear separation of the knowledge about the problem (Knowledge Base) and the methods (Inference Engine) for applying the knowledge to the problem. With this seperation the program can be changed by simple modification of the knowledge base. This is particularly true of rule-based systems where the system can be changed by the simple addition of rules in the knowledge base
Knowledge	Conventional algorithms are generally used in computer programs (knowledge is buried in algorithms)	Heuristic knowledge as well as conventional algorithms are used to solve problems.

Architecture	**Program** **DATA**	**Inference Engine** • Rules Interpretation • Explanation • Search control **Knowledge Base** • Heuristics **DATA** • Domain Expert • Knowledge Engineer
Reasoning Process	No mechanism is provided about the reasoning process about the conclusion	Expert system structure provides a mechanism of reasoning process about the conclusion
Explanation Facility	Explanation facility does not exist to show the pieces of knowledge which were used to reach a conclusion.	Explanation facility exists to show the rules which were used to reach a conclusion
Certainty Factor (CF)	No provision for certainty factor is incorporated in these systems.	In the real life situation, all the conclusions may not be reached with a 100 percent certainty. For this reason, the knowledge base in an expert system contains an indication of the degree of certainty like CF = 0 to 1 or, 0 to 10 or, 0 to 100 percent

4. Knowledge Representation

Various methods of representing knowledge within an expert system are reported in the literature. Some of the widely used methods are production rules, logic representation, semantic networks and frames.

PRODUCTION RULES

The production rules also called situation-action rules are widely used in the majority of the expert system. The rules are the IF - THEN - ACTION rules; that is if clause is true, then some action is performed. These rules may contain certainty factors (CF). In the absence of certainty factor, the decision is taken as 100% true.

Some of the advantages of the production rules are:

- It is easy to incorporate additional knowledge, modify knowledge and delete knowledge as the rules are independent on each other.
- Rules are generally crystal clear in the sense that they look like in natural language.
- There is a provision to incorporate heuristic knowledge and inexact information using uncertainty factors.
- It is easy to incorporate the explanation facility in the expert system by simply restating the rules.

Some of the disadvantages of the production rules are:

- As the knowledge base grows it becomes difficult to keep track of the rules.
- Structural knowledge (knowledge about cause and effect) is not handled easily using production rules.

SEMANTIC NETWORKS

A semantic network has the structure of a graph where node represents concept and arc connecting the nodes represent the relationship between the concepts. Figure 1.5 illustrates a simple semantic network.

Some of the advantages of the semantic networks are:

- Semantic networks permit the statement of important associations explicitly and succinctly.
- The search time in the semantic networks is less because the nodes are directly connected to related nodes.

Some of the disadvantages of the semantic networks are:

- No standard interpretation exists for knowledge representation within semantic network.
- There is a possibility of wrong inferences drawn using semantic networks.

FRAMES

Frame is one of the knowledge representation schemes which include knowledge about a concept. A frame structure may consist of various slots. Each slot may consist of properties of a single concept.

Some of the advantages of the frames are:

- The knowledge engineer can specify the actions that should take place when certain conditions arise during the knowledge processing.
- Inference process is speedy
- Frames can be made self driven

Some of the disadvantages of the frames are:

- Frame based systems can be complex
- It is not easy to accommodate the new situation in frame based systems.

5. Possible Advantages

The Knowledge-based systems offer advantages over the conventional programs. Some of these advantages are:

- Cost reduction in achieving a complex task
- Reduced downtime
- Capturing scarce expertise
- Flexibility in providing service
- Operation in hazardous environments
- Operation under incomplete and uncertain environment.

6. Limitations

In spite of the limited success, there are difficulties associated with the knowledge-based systems. These include:

- The lack of expertise
- Expertise is hard to extract from experts
- The lack of scientific techniques in knowledge engineering.

7. Applications

Knowledge-based systems have been applied successfully in a large number of applications. Some of these are:

- Aerospace applications
- Design

- Diagnosis
- Interpretation of data
- Monitoring
- Prediction.

8. Suitability of a problem for knowledge-based approach

It is very essential to choose a suitable technique for a given problem as the knowledge-based techniques are not suitable for all the problems in engineering, science and business. The suitability of a problem for a knowledge-based approach may incorporate the following ingredients.

- Task primarily requires symbolic reasoning
- Task requires use of heuristics, i.e. rules of thumb
- There exists an expert willing to work with the project
- Conventional programming approaches are not satisfactory.

9. Validation of the knowledge-based systems

It is not only the design of knowledge-based systems but their validation plays an important role in their ultimate usefulness. It is important to:

- Ascertain what the knowledge-based system knows or does not know or knows correctly
- Ascertain the level of expertise of the knowledge-based system
- Determine the reliability of the knowledge-based system.

10. Popular knowledge-based systems

The knowledge-based systems are successfully used in a large number of applications. Some of the widely reported classical knowledge-based systems are listed as under.

- ACE Diagnoses faults in telephone networks
- BLADES Knowledge-based analogue circuit designer
- DENDRAL Analyses information about chemical compounds
- MICON Knowledge-based single board computer design
- MYCIN Diagnoses blood and meningitis
- PSA Parts selection expert
- PALLADIO Helps design and test new VLSI circuits
- PROSPECTOR Assesses a given prospect site for its likelihood of containing an ore deposit of a certain type
- SOPHIE Teaches fault diagnosis in electrical circuits
- XCON Configures DEC VAX-11/780 systems.

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