Expert Systems in Education – A Case Study

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Abstract: **In education field, many of the expert system's applications are embedded inside the Intelligent Tutoring System (ITS) by using techniques from adaptive hypertext and hypermedia. Most of the system usually will assist student in their learning by using adaptation techniques to personalize with the environment, prior knowledge of student and student's ability to learn. In terms of technology used, expert system in education has expanded very consistently from microcomputer to web-based and agent-based expert system. Besides technology used, expert system also had a tremendous changes in the applying of methods and techniques. Starting from a simple rule based system; currently expert system techniques had adapted a fuzzy logic and hybrid based technique. This paper would present the application of expert system in teaching introductory data structure; followed by application in engineering, technology and earth science.**

Index Terms: Expert **System and Artificial Intelligence, ITS, Knowledge Engineering, AI, Decision Support System.**

I. INTRODUCTION

Expert systems are computer programs that are derived from a branch of computer science research called *Artificial Intelligence* (AI). AI is concerned with the concepts and methods of symbolic inference, or reasoning, by a computer, and how the knowledge used to make those inferences will be represented inside the machine. Often, the term expert systems is reserved for programs whose knowledge base contains the knowledge used by human experts, in contrast to knowledge gathered from textbooks or non-experts. Building an expert system is known as *knowledge engineering* and its practitioners are called *knowledge engineers*. The knowledge engineer must make sure that the computer has all the knowledge needed to solve a problem. The knowledge engineer must choose one or more forms in which to represent the required knowledge as symbol patterns in the memory of the computer – that is, he (or she) must choose a *knowledge representation*. He must also ensure that the computer can use the knowledge efficiently by selecting from a handful of *reasoning methods*.

II. HOW DO PEOPLE REASON?

Here, we can identify several specific reasoning processes used by humans, which are easily translated into the realm of expert systems and artificially intelligent computers:

1. Categorization –

When we identify a piece of information as important enough to remember, we categorize it according to one or more categorization or criteria. Our memories store these categories as a loose set of hierarchies where lower-level pieces of information can "inherit" characteristics from a higher-level category. Categorization allows for rules to be derived from the relationships among the categories.

2. Specific Rules –

If a particular rule, or set of rules, is known to exist and be true, then we can use that knowledge to reason our way through a problem context associated with the rules. Humans make use of rules by cascading them into a reasoning process that allows them to reach reliable conclusions.

3. Heuristics –

Heuristics are rules of thumb that can be translated or captured for use. Despite the lack of formality associated with a heuristic we know that searches and decisions using well-formed heuristics can often reduce the time necessary to reach a solution.

4. Past Experience –

This method can be thought of as a meta-categorization whereby humans look at the whole of a situation and attempt to compare it to situations they experienced in the past. If enough characteristics or sequences of events can be matched up, the necessary actions can be reasoned based on what was done in the past. Reasoning by this method makes some rather large assumptions – such as history will repeat itself and the present situation really is similar in most respects to the past situation.

5. Expectations –

Once we experience a particular situation or phenomenon a number of times, we begin to expect it to appear in a certain manner or under a predictable set of conditions. If it occurs as we expect, then we can reason that all is well or that nothing is out of order. If, however, the situation fails to meet our expectations, we can reason that something occurred to change the expected set of conditions. Reasoning by expectation is simply a form of pattern recognition.

III. HOW DO COMPUTERS REASON?

The methods employed by AI system designers to create a reasoning system using a computer are based on the same processes and mechanisms used by humans.

1. Rule-Based Reasoning –

The rule composition takes the form of an IF-THEN statement as shown here:

IF condition THEN operator

If a condition is found to be logically true, then the operator becomes an acceptable action to be taken and the rule is said to have fired or instantiated. If the condition is logically false, then the operator is ignored and the next rule is accessed. This process continues until either the problem space reaches the desired condition or the rules in the knowledge base are Exhausted. Using a formal set of rules, several types of knowledge can be encoded:

(a) **Inferential Knowledge**: - This type of knowledge is one whereby a conclusion is reached as a result of one or more premises (facts) being established.

Ex – IF premise(s)
THEN conclusion

(b) **Procedural Knowledge**: - Here the conditions take the form of a stated situation and the operator becomes an action to take when the stated situation is logically true.

Ex – IF situation
THEN action

(c) **Declarative Knowledge**: - If the antecedent is found to be logically true, then the consequent must also be true.

Ex – IF antecedent
THEN consequent

2. Frames –

A frame is a logical extension of a knowledge encoding formalism known as a semantic net. In a semantic net, concepts or entities are represented as nodes and the arcs connecting the nodes represent their relationships. These discrete structures called slots can be thought of as similar to fields in a database. Within each slot is contained one or more facets. These facets describe any data or specific procedures associated with the slot. Another important type of facet is called the daemon. A daemon is a short procedure that can be triggered whenever a slot is created, modified or even accessed. The frame concept allows for two types of objects to be represented: classes and instances. The objects represented by frames contain slot values that can be inherited down the frame hierarchy. The frame hierarchy is organized by two constructs: subclass links (IS-A) and membership links (INSTANCE-OF). The membership links serve as a classification mechanism and the subclass links serve as a taxonomic mechanism.

3. Case-Based Reasoning –

The idea is to adapt solutions of similar problems to the problem at hand. The process of case-based reasoning involves two primary steps: (a) finding those cases in storage that have solved problems similar to the current problem, and (b) adapt the previous solution(s) to fit the current problem context.

Each potential case is compared to the present problem using a set of similarity metrics that measures the degree of similarity between the selected case and the current one. Once this process takes place, the contained solutions are analyzed and adapted to the new situation. The process of adaptation consists of a series of modifications to the parameters of the old solutions to fit the new problem context. Finally, the new solution is tested and, if successful, added to the case library. If, however, the test fails, then the adaptation process must be revised or a new set of cases must be retrieved.

4. Pattern Recognition –

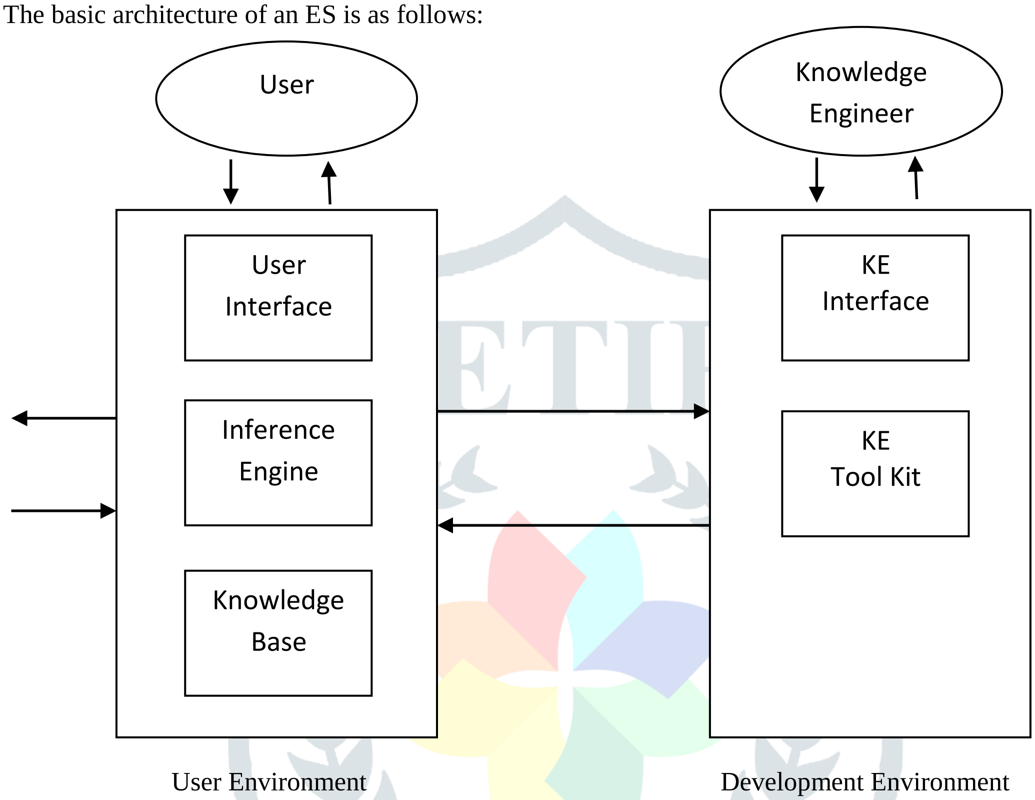
Pattern recognition includes both visual and audio patterns. As with humans, the degree to which a computer can exhibit intelligent behavior through a pattern recognition system is a function of its ability to perceive its environment and surroundings. If the computer is limited to key strokes and mouse or trackball movements then its perceptual abilities are also limited to those realms. If, however, additional hardware and software allow the computer to detect sounds and to sense patterns or shapes, then entirely new possibilities for simulating intelligent behavior open up. Advanced pattern recognition systems can detect a specific human voice, a fingerprint or even identify a person by his or her photographic or video image.

5. Rete Algorithm –

Rete algorithm makes use of the fact that the contents of the working memory do not change drastically after each rule application but rather exhibit only minor changes from the previous pass. Specifically, the Rete algorithm figures out which rules from the prior cycle did not fire, which rules from the prior cycle will not fire in the next cycle, and which rules from the prior cycle that did not fire will most likely fire in the next. Using this method, the algorithm avoids performing a pattern recognition cycle from scratch each time it must cycle through the rules. By maintaining an internal representation of the state of each rule in working memory, it uses that representation as the basis for repeating the cycle during each subsequent pass until the pattern is matched.

IV. THE CONCEPTS AND STRUCTURE OF EXPERT SYSTEMS

The basic architecture of an ES is as follows:



Common Expert System Architecture

The Component elements that define an expert system are:

1. The User Interface –

The issues associated with better ES interface design are:

(a) Users should be equal or dominant partners in the design of the UI.
(b) ES dialogs should be flexible enough to allow users to volunteer information and allow for smooth changes of initiative.
(c) Explanation facilities must be of high quality and detail.
(d) A natural language interface may not be appropriate for an expert system.
(e) ES dialogs should emphasize graphics over text wherever appropriate.

2. Knowledge Base –

The knowledge base of an ES contains the domain-specific knowledge collected from the sample of domain experts during the design stage. This knowledge consists of all types of knowledge used by the domain expert during the course of solving domain-related problems, object descriptions and relationships, problem-solving behaviors, constraints, heuristics and uncertainties. The success of an ES relies to a great extent on the completeness and accuracy of its knowledge base.

3. The Inference Engine –

Here, the processing in an ES occurs, and the knowledge is put to work to produce solutions. The inference engine (IE) performs deductions or inferences based on rules or facts. The basic process of the IE is called a control cycle. Three steps categorize an inference control cycle:

(a) match rules with given facts
(b) select the rule that is to be executed.
(c) execute the rule by adding the deducted fact to the working memory.

An ES uses two basic procedures for applying the two rules of deductive reasoning i.e. modus ponens and modus tollens for drawing appropriate conclusions: chaining and resolution.

Chaining –

In this method, the set of rules is organized in a recursive manner so that a fact concluded by one rule is used as the premise for the next. Two types of chaining based upon the direction of the search process are possible in an ES: forward and backward. In forward chaining, the inference engine begins with the initial content of the workspace and proceeds towards a final conclusion through a series of inference control cycles. This method of reasoning is also referred to as data driven because the process involves a movement from data to goals. The backward chaining causes the IE to work backward from the goal to be proven to the necessary data within the workspace to prove it. Backward chaining can be thought of as a form of hypothesis testing in which the conclusion is proposed and then the data are collected to determine support for the hypothesis.

The Blackboard Workspace –

The blackboard can be thought of as an electronic scratchpad or notebook where calculations are performed and intermediate hypothesis and decisions are stored during the problem-solving process. Once the system completes its work, the blackboard area is erased and is ready for the next problem-solving session.

V. DESIGNING AND BUILDING AN EXPERT SYSTEM

Knowledge Engineering

Knowledge Engineering is the art of designing and building expert systems, and knowledge engineers are its practitioners. A knowledge engineer interviews and observes a human expert or a group of experts and learns what the experts know, and how they reason with their knowledge. The engineer then translates the knowledge into a computer-usable language, and designs an inference engine, a reasoning structure, that uses the knowledge appropriately. Next, the inference engine and facilities for representing knowledge and for explaining are programmed, and the domain knowledge is entered into the program piece by piece.

Tools, Shells, and Skeletons

Compared to the wide variation in domain knowledge, only a small number of AI methods are known that are useful in expert systems. That is, currently there are only a handful of ways in which to represent knowledge, or to make inferences, or to generate explanations. Thus, systems can be built that contain these useful methods without any domain-specific knowledge. Such systems are known as *skeletal systems*, *shells*, or simply *AI tools*.

Building an Expert System

Several activities unique to expert system development must be performed prior to formal design:

1. **Finding the Experts –**

   It is important that the expert be clearly informed of the time commitment associated with the ES development effort. He or she must be willing to participate in the project from start to finish and to expend a significant amount of time and energy in its early stages. It is also important that the expert fully understands the value of the proposed system to the organization in terms of productivity, performance, and quality.

2. **The Development Team –**

   Quite often, the team is divided early in the process into smaller groups that focus on specific aspects of the system. Some members of the development team will be assigned to the construction of the rule set, others will be focused on the user interface, while still others will play a unique role in the ES design process by serving as knowledge engineers (KEs).

3. **The Application Development Tool –**

   The iterative nature of prototyping, reviewing, and refining the ES during development makes the selection of the development tool an important predesign decision. The tool must complement the skills of the development team and must provide the appropriate functionality for the problem domain being modeled. The ideal development tool enhances the productivity of the development team while remaining both flexible and versatile.

4. **Hardware Selection –**

   The selected ES hardware platform must not only support the final ES product and allow for its growth but ideally it should support the selected ES development tool as well. In this way, the prototypes generated during the development process will perform in exactly the same manner in the final product, and no changes in functionality or performance will be incurred due to a change in hardware platform after development.

Stages in the Development of an Expert System

Expert system design and development must be carefully programmed if success is desired. Some of the main steps to be followed are given below:

1. Outline Statement –

The expert and the knowledge engineer work out the concepts, boundaries, relationships, control mechanisms to be included in the system. Development strategies and constraints as well as user expectations are explored. The results of this stage of assessing the potential performance and benefits of the system should be encapsulated in an outline specification. This specification holds for the initial prototype development.

2. Knowledge Acquisition –

In this stage, there is intensive interaction between the expert and the knowledge engineer. The expert is specific in articulating his knowledge in line with the constraints imposed and tries to highlight the essential issues that set the information apart as being knowledge. The knowledge engineer on the other hand tries to comprehend the essence of the knowledge, its limits, and the complexities.

3. Knowledge Representation –

A successful system will meet the user's requirements only if the knowledge of the expert is conveyed in a manner understandable to users and in a mode equivalent to what is normally used by a human expert to solve the problem. It is the knowledge engineer's ability to enter into the frame of reference of both the expert and the potential users and to suitably structure the acquired knowledge that sets him apart as a good or bad engineer.

4. Prototype Development –

The advantage of building a prototype system first is that the expert and the knowledge engineer can establish whether the system is feasible. Further, users get an opportunity to test out the system and to see whether it is likely to meet their requirements. It also provides the expert and the knowledge engineer with an opportunity to evaluate the cost and the performance of the chosen system.

5. Testing –

Testing involves evaluating the performance and utility of the prototype program and revising it as necessary. This evaluation may uncover problems such as missing concepts and relations in the representational scheme, knowledge represented at the wrong level **of** detail, or unwieldy control mechanisms. Such problems may force the developers to recycle through the various development phases, reformulating the concepts, refining the inference rules, and re-testing the control flow.

6. Main Knowledge Acquisition –

In the development of the actual system, the first stage is to assess the extent of the knowledge that is required in order to meet the user's needs. During this stage, it may be decided to involve multiple experts in the acquisition process. The experts check whether the system can or should be integrated with other systems existent within the organization.

7. Specification with Detailed Information –

The knowledge and the expert provide a detailed system specification during this phase. The detailed specification covers the objectives of the expanded system, the resources required, the projected time required for implementation, planned costs, system testing, and implementation planning.

8. System Development –

During this stage, it is very important for the users to know exactly how the system is progressing, any problems encountered, and the evidence of new limitations and new opportunities. Their support during this phase is very useful to the expert and the knowledge engineer. Since this phase requires greater investments of both cost and time, it requires careful monitoring.

9. Implementation –

Implementation procedures should be carried out by the user and supported by the expert. The implementation plan should have been documented during the 'specification with detailed information' stage.

10. Maintenance –

It requires continuous revision and updating to ensure that the knowledge it contains is always up to date and in accordance with the changing environment in which organizations operate. Maintenance procedures should be formally documented and the responsibility of carrying them out should be assigned in advance.

VI EXPERT SYSTEMS IN EDUCATION

In education field, many of the expert system's application are embedded inside the Intelligent Tutoring System (ITS) by using techniques from adaptive hypertext and hypermedia. Most of the system usually will assist student in their learning by using adaptation techniques to personalize with the environment, prior knowledge of student and student's ability to learn. In terms of technology used, expert system in education has expanded very consistently from microcomputer to web-based (Woodin D. E., 2001) and agent-based expert system (Vivacqua A., and Lieberman H., 2000). By using web-based expert system, it can provide an excellent alternative to private tutoring at anytime from any place (Markham H. C., 2001) where Internet is provided. Also, agent-based expert system surely will help users by finding materials from web based on the user's profile.

Needs for Expert Systems in Education

According to Markham H. C. (2001), expert systems are beneficial as teaching tools because it has equipped with the unique features which allow users to ask question on how, why and what format. When it is used in the class environment, surely it will give many benefits to students as it prepares the answer without referring the teacher. Besides this, expert system is able to give reasons towards the given answer. This feature is really great as it can make students more understand and confident with the answer. Ability of expert system to adaptively adjust the training for each particular student on the bases of his/her own pace of learning is another feature that makes expert system more demanding for students. This feature is used in (Zorica Nedic, Vladimir Nedic and Jan Machotka, 2002) for teaching engineering students. It should be able to monitor student's progress and make a decision about the next step in training.

Application of Expert System in Education

Expert system had been used in several fields of study including computer animation (Victor Yec, 1995), computer science (Heather Christine Markham, 2001), engineering (Zorica Nedic, Vladimir Nedic and Jan Machotka, 2002), language (Expert System in Language Teaching), and business study. For Computer Animation Production, expert system had been used as a guide to developer to design 2D and 3D modeling package. Other than that expert system also had been used as a tool in teaching mathematic related subject (Kristopeit). This paper would present the application of expert system in teaching introductory data structure; followed by application in engineering, technology and earth science.

Expert System for Teaching Introductory Data Structure

This expert system had used Internet technology as a medium to access the information. This expert system had been developed by using CLIP (C Language Integrated Production System) as an inference engine, and HTML program as a front page for the system. According to (Markham, 2001), this expert system had provided the excellent alternative to the private tutorial. Since this expert system is developed using Java technology, thus make this system interoperable and independent platform.

Expert System for Engineering

This expert system, using fuzzy logic method as an engine to enable this system, operates adaptively. This expert system was developed to help first year engineering students gain deep understanding of fundamentals to be able to follow the more advanced topics in the engineering fields. This ITS will help adaptively adjust the training for each particular student on the bases of his/her pace of learning. ITS will monitor the student's progress and have the ability to make decision about the next step in training. Figure I below shows the architecture of ITS for teaching engineering student which had embedded expert system inside. This expert system uses fuzzy rule based decision making system that would guide the ITS's behavior. For each student, this expert system will draw the information regarding student's performance against the membership function for each topic, difficulty and importance level.

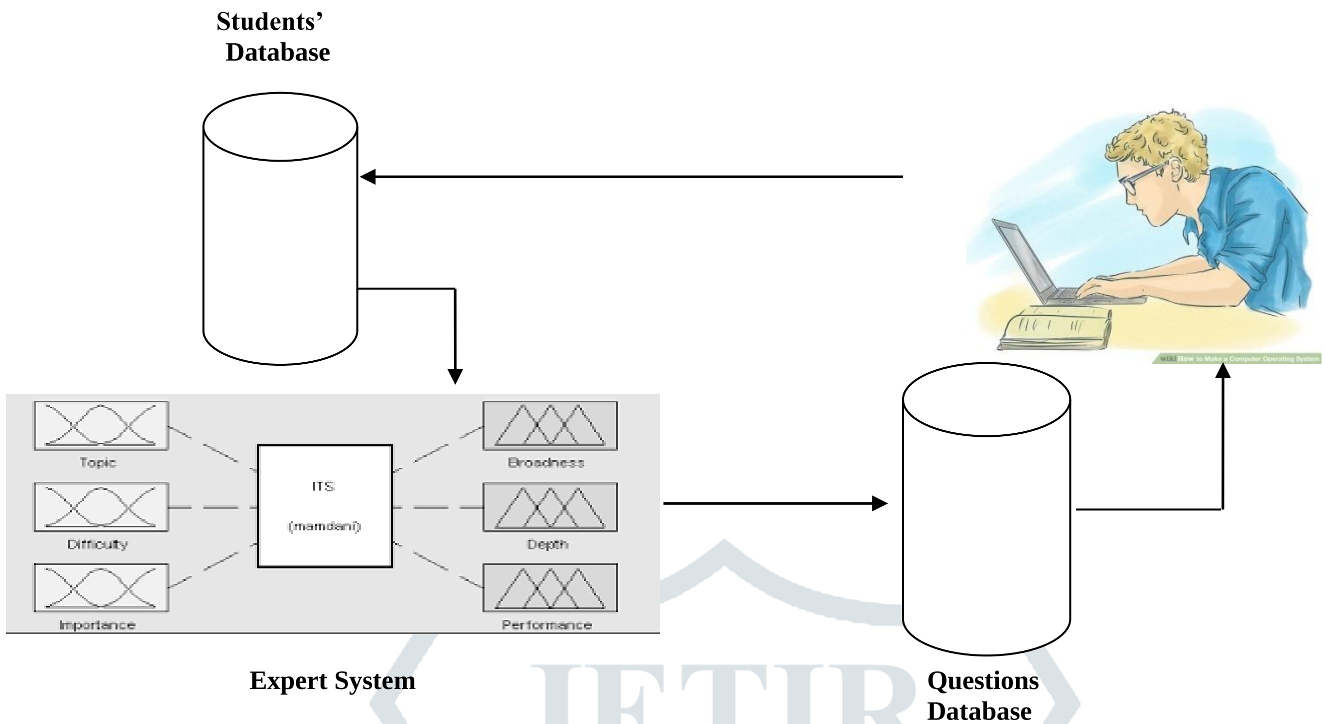


Figure1: Structure of ITS to teach engineering student. Adapted from Zorica Nedic, Vladimir Nedic and Jan Machotka (2002)

Expert System for Learning Internet

According to (Jim Prentzas, Loannis Hatzilygeroudis, C. Koutsojannis, 2001), hybrid expert system had been developed to assist teacher in learning new technologies such as Internet. They had build web based Intelligent Tutoring System (ITS) for teaching new technologies to high school teacher. Figure 2 below is example of architecture that had been developed in this ITS.

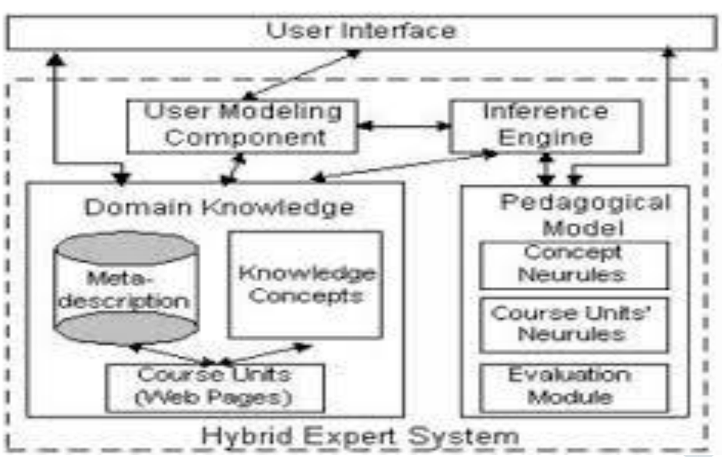


Figure 2: Architecture of ITS. Adapted from Jim Prentzas, Loannis Hatzilygeroudis, C. Koutsojannis (2001)

This architecture had made use of expert system's knowledge representation formalism based on neurules, a type of hybrid rules integrating symbolic rules with neurocomputing. This neurules will improve the performance of symbolic rules and simultaneously retain naturalness and modularity.

Expert System for Teaching Fault Analysis

Application of expert system also been used by lecturer to teach student on subject relating fault analysis. By using this expert system, lecturer aim to make learning more productive and efficient without increasing the staff number. This ITS was developed by using Leonardo expert system shell, object oriented tool for developing expert system application.

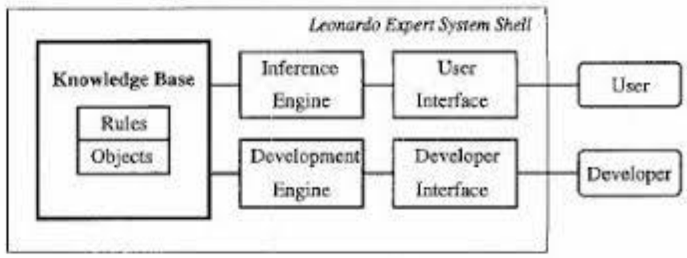


Figure 3: Basic components of Leonardo expert system shell. Adapted from Negnevitsky, M. (1998)

Figure 3 above had shown the architecture of Leonardo expert system shell. This architecture was used by Negnevitsky, M. (1998) to develop expert system for teaching fault analysis. According to Negnevitsky, M. (1998) this Leonardo tutoring system is a very useful tool for teaching fault analysis in power system. In October 1994, the system was installed in a computer network and it can now be accessed from any computer in the Department of Electrical and Electronic Engineering. It has been found that network delivery of computer-based tutorials is the most cost effective (Negnevitsky, M., 1998).

Expert System For Mineral Identification

This expert system is developed to be used for supporting the teaching of mineral properties at college level and hence to promote effective and meaningful learning of scientific observation in earth science. This system is used by the college students, who may or may not have n-depth computer skills. An expert system building tool which can be easily maintained by people from non-computer science background EXSYS (EXSYS inc. 1994) was used to build this expert system. EXSYS is a commercial expert system building tool that has been in the market for several years. It is easy to use, easy to learn and easy to maintain. EXSYS can explain why and how it reaches a conclusion.

VII CONCLUSION

Expert system in education had been through tremendous phases from simple expert system to complex multipurpose systems. Hybrid expert system together with fuzzy expert system can be seen as a new technique that was used by researchers lately. Implementation of expert system in such fields is greatly influenced by techniques and methods from adaptive hypertext and hypermedia. Features of personalization, user modeling and ability of adaptive towards environment will become great challenges to settle. It can be used as a guideline to promote an expert system in various functions. In recent years, ES's have been used together with artificial neural networks, fuzzy logic, genetic algorithms and other methods of Artificial Intelligence. These methods allow taking into account their advantages in the designed system and, therefore, now designed systems are more powerful instruments to facilitate various tasks that require instant, accurate and reliable results.

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