Expert systems

Objectives

By the end of this module, you'll be able to:

- Understand the concept of expert systems
- Explain components of expert system
- Explain the role in expert system implementation
- Understand process of building expert systems
- Define characteristics of expert systems
- Know applications, advantages and limitations of expert systems

Introduction

An expert system is an artificially intelligent program that implements the knowledge and reasoning processes of a human expert of a certain field. An expert system obtains the knowledge and set of rules about that domain from human experts in the attempt of making a system that's really 'expert' in that field. Expert systems (ES) are highly knowledge based. The ES designers explore all the information about a problem and then implement the ES in a way that evaluates possible solutions. Mostly, the ES can even explain how exactly it processed the data to come to conclusions.

Expert systems are special AI programs that are acting as very knowledgeable resourceful wizards. In reality, it's a bit difficult to get these many smart and genius human beings who will perform the same high-quality complex tasks as Expert Systems do for us. Even if it is possible to get such people, they would turn out to be very expensive to run the business. ES has contributed n performance and efficiency in the field of businesses, science, government and other sectors too. The expert systems are very interactive and reliable, too.

Definition:

The researchers have many definitions for Expert Systems. All of these definitions talk about the ability of an ES as decision-maker in complex situations, problem-solving capability, ability to reason through various rules and being at par with a human expert in the given domain.

Dr. Edward Feigenbaum- often called the "father of expert systems"- defines the expert systems as "an intelligent computer program that employs knowledge and inference procedures to solve problems that are considered difficult enough to require significant human expertise for their solutions."

Component diagram

Fig: Expert systems

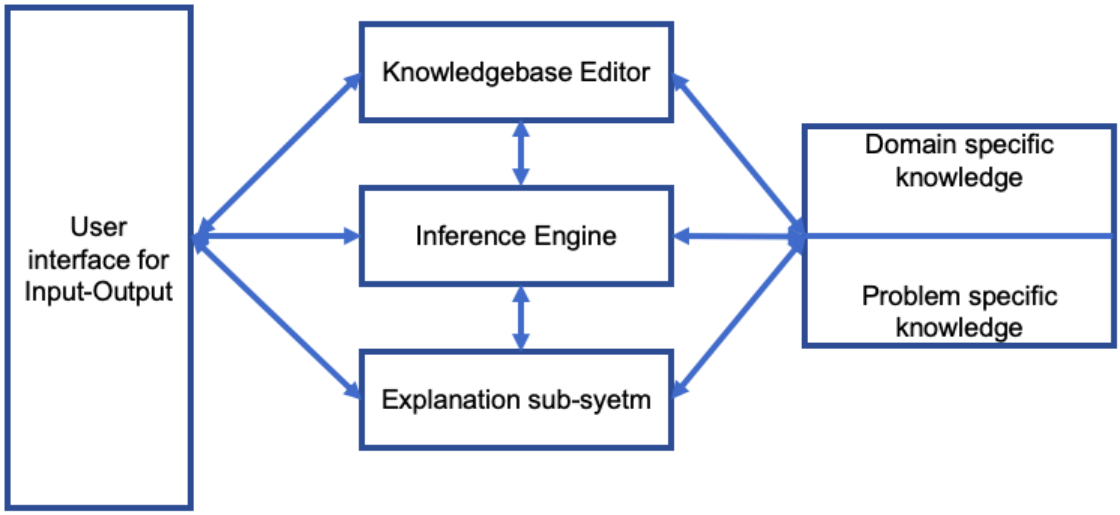

Fig: Expert systems component diagram

The major ES components are:

User Interface

The simplest form of an ES is a question-and-answer based system while the most complex one may have a GUI to interact with ES. Users interact with ES through this user interface to give input and to receive output.

Various ES in the world use different interfaces to communicate with the user. Some of the examples are-

- Input- speech input through a microphone, forms, questionnaire, dialogue boxes, various sensors, dialog boxes, command prompts, etc.
- Output- speech through speakers, graphs, actions such as modem dialing a phone number, graphical output, textual results, etc.

Inference Engine

The inference engine is the brain of the ES. The inference engine contains customized algorithms, rules, reasoning methods, etc. to solve a specific problem.

The inference engine interacts with the Knowledge Base to receive appropriate background and current information, facts-rules/ algorithms to apply to answer the user's

query. The inference engine uses various options to compute solution. Some of the algorithm families used by inference engine are-

1. Forward/backward chaining with if-then-else rules
2. Machine learning algorithms
3. Neural networks
4. Bayesian network
5. Decision trees
6. Customized algorithms

Knowledge base

The Expert Systems are highly knowledge-based systems. The knowledge base is nothing but a collection of facts and the rules. The knowledge is hard to characterize, very voluminous and constantly changing. That's why we can't have an in general ES, but they are implemented to give solutions about one particular problem domain. The success of the Expert System mainly depends on the highly accurate and precise knowledge. The knowledge is generally a domain-specific one. The knowledge is typically divided in two parts- domain specific knowledge and problem specific knowledge.

Explanation subsystem

The explanation subsystem is something unique to ES. When asked, the ES can explain its reasoning process of starting with the given information to all the intermediate states during the computation process. This can help in debugging where one can pinpoint missing a fact or a rule. It is also helpful in case of difference of opinion and it can be very well bounded by having access to the customers.

Roles in building expert systems

Expert systems are complex software which needs to be carefully designed, validated refined and tested for its performance. The stakeholders in development of an expert systems are-

Domain expert-

There could be one or more domain experts involved in the project. The domain expert is a person who beholds hefty proficiency in the domain for which the expert system is under development. It's not compulsory for the domain expert to have knowledge about AI, expert systems or computer programming

Knowledge engineer-

Given the complexity of the expert systems, generally more than one knowledge engineers work on project. A knowledge engineer is a person specialized in the field of AI. The knowledge engineer possess knowledge on computer programming and is perhaps a computer scientist or programmer, who is expert in the field of building expert systems. Typically, the system designers, programmers, testers, analysts, i.e., all of those who have worked on technical aspect of expert system development are believed to be knowledge engineers.

Knowledge engineers work on expert systems in various domains and they may not be familiar with those domains beforehand. To do so, the knowledge engineer should be well acquainted with-

i. various of knowledge representation techniques
ii. intelligent searching strategies
iii. expert system tools
iv. software engineering methodologies those formalize the process and can also speedup the development.
v. Other expert systems working on similar problems or domains so as to understand their strengths-weaknesses and thus adapt the best practices, avoid mistakes in the expert system being developed.

User –

These are the end users who are supposed to use the expert systems. These could be technical or nontechnical people who are supposed to operate the developed software and may assume different roles. E.g. In Mycin the physician entering symptoms is one user while the one who is trying to understand the diagnosis and prescription possesses different role in the ES.

The process of Building An Expert System

Problem and goal identification

The first and foremost thing to do in development of process is problem and goal identification.

This is analogues to requirements analysis step followed in traditional software development life cycle. It identifies the external requirements, input/output forms, identification of problem environment and the user. Formulating Problem helps in limiting scope and boundaries while goal formulation is focusing the expected goals and outputs of the expert systems. In this phase, the knowledge engineer gathers information about the expert system domain from books, manuals, training guides and human expert. The human (domain) expert explains various cases in the task environment to help the knowledge engineer understand better his problem The meetings between domain expert(s) and knowledge engineers help them penning down precise problem description and they iteratively go on refining the problem description until it gets accepted.

The iterative refining process is evaluated at every stage and the results are checked after every evaluation. Output of this phase is finalization of the objectives, technical team size, the actual technical personnel, domain expert(s), manuals, reference books, cost, time frame etc gets finalized in the identification phase.

During problem identification the domain expert(s) and knowledge engineer(s) together need to seek essential answers to following points:

i. Complexity class of the problem?
ii. How to characterize or define the problem?
iii. Key subproblems and partitions of the subtasks?
iv. The data and datasources?
v. Taxonomy and key terms of the problem and their association with each other?
vi. What is the expected solution?
vii. Human skill qualities and proficiencies that are important in the problem solving?
viii. Role of knowledge, its characteristics and volume required for a human expert to give the solution?
ix. Tricky and complex circumstances that would need special treatment in problem solving?
x. Any uncertainties involved in problem and solution domain?

Conceptualization

The second phase in building expert systems involves problem analysis and finalizing requirement specification. It confirms that specific interfaces and associations in the problem domain are fathomed well and clearly stated. This can be termed as primary phase of knowledge acquisition.

At this stage, the knowledge engineer(s) divide the problem into subproblems, and represent relationships amongst processes & objects diagrammatically. The domain expert validates those diagrams or suggests changes in the same. Like in identification, conceptualization also involves iterative refinement process until domain expert(s) and knowledge engineer(s) aren't on same page. Thus the first two stages of building the expert system are devoted to understanding the problem.
The key concepts to be answered in this phase are-

- Availability of various types of data?
- What will be contained in knowledgebase, what will be assumptions and what needs to be inferred?
- Relationships of objects in problem domain?
- problem solution process(s) and constraints on the processes?
- Data flow in system?
- Nature of the human expert decisions?
- Nature of decision outcomes? Number of outcomes?
- Which one the outputs are more complex to process?
- resources or inputs required to reach a decision?
- Elements those introduce uncertainty in outcome and how those are to be treated?
- To what extent output of the expert system is expected to be consistent with recommendation of human expert?

Formalisation (Designing):

This stage connected the problem with AI technology which is set to solve the problem. It begins with knowledge engineer identifying the appropriate technologies and ends with encoding rules of the domain specific knowledge.

As the knowledge engineer supposed to have expertise with knowledge representation, knowledge engineering processes, intelligent searching strategies for various problem characteristics, tools in expert systems, software engineering methodologies and existing expert systems in the same and other domain areas, he/she can come up with the best suitable technical approach of designing the solution. The suggested approach may use single technology or combined approach based on nature of the subproblems.

Further, the knowledge engineer(s) encodes the domain specific rules which are later reviewed by domain expert. This process continues in multiple iterations until all the required domain expert(s)' knowledge is not currently encoded in the system. This can be taken as the most time-consuming and important process in the design and implementation of an expert system.

The output of this stage is formal specification And approved encoded knowledge base of the expert system.

Implementation

The finalized formalization from earlier step gets actually implemented in this phase. The output is first version or prototype version of the project at hand.

Most of the times, the first version is considered a throw away one by the knowledge engineer(s) as it is hardly usable as an expert system. Although, the entire technical teams learn which technologies aren't or are compatible, and which one of the selected ones don't work at all for the undertaken project. Sometimes it calls for re-formalization before proceeding with implementation all over again.

After the implementation process settles down and the final prototype is refined enough, the developed software goes through the further process of testing.

Testing

This phase in development of expert system ensures real expertise of the developed expert system. As the expert systems are highly based on knowledge and knowledge being very voluminous, hard to characterise and constantly changing, chances are very low that the expert system will turn out to be complete during implementation of prototype version. Rather, this phase points out the missing knowledge, errors in formulization and weaknesses in design & implementation process. Based on outcomes of this phase, the team can go back to earlier phases to fix the problem areas and refine the system in iterations until it doesn't give results of desired accuracy and precision.

Once the system works well for simple problems, its tested against complex situations in the problem domain. This process exposes more critical shortcomings and helps in performance tuning the system. This process requires lot of human intervention. Finally, the systems passes the testing phase only when it can perform at par with human expert(s). The system can be deemed complete only when it gives consistently correct solutions for the real-life problems in the chosen domain area.

Characteristic of Expert System

Here are a few Important characteristics of the Expert System:

- The expert systems are efficient, accurate and solve complex problems like any other human expert.
- Provided that ES are well equipped with the knowledge to make decisions, they are highly reliable and error-free.
- The knowledge base editor keeps the ES Flexible and open to adopting new knowledge.
- The ES have the ability to handle complex and challenging decision-making problems.
- Performance of the expert systems is characterized by quantity and quality of the knowledge integrated in the ES program.

Applications of expert systems

The basic purpose of Expert systems is to help people during the decision making the process by making them available an imitation of human expert bundled in a software package.

1. Helping investors with Financial investments and risks' management
2. Helping doctors for medical diagnosis, especially in remote medicine facilities
3. Exploration of oil fields in oil industry.
4. Maintenance and repairs of equipment in manufacturing industry.
5. Management of complex production processes.
6. Help desk management
7. Malicious software detection
8. Anomaly detection
9. Cargo and airline scheduling
10. Stock market analysis
11. Profile analysis for loan approvals etc

Advantages of Expert Systems

1. Schooling and educating human workforce for an expert's position is quite an expensive affair. The human experts may change job, may retire or may get tired with age. On the contrary, a computerised system is comparatively easy to build, can take input from multiple human experts, can be relocated, modified, copied at many places, can be put to work for extensive hours.
2. The ES software has high availability and will not need vacation or fall ill etc.
3. Accumulated knowledge of multiple human experts may help in improvement of decision quality

4. The consultation from human experts is also a costly affair; their availability is another issue altogether. Investment into a good ES might be just one time cost than paying per session fees.
5. If implemented properly, ES is quite Fast and accurate and has less chances of human errors
6. ES are free from human virtues such as emotions, tensions, anxiety and fatigue.
7. ES holds tremendous amount of information and doesn't forget to consider even tiniest bit of information while suggesting output(s), provided they have all the knowledge needed to make decisions.
8. Human experts aren't immortal, but expert systems last longer, they can be modified as the knowledge and technology changes.
9. Human experts sometimes act unpredictably to human nature, comparatively, expert systems are quite consistent.

Limitations of the expert system

Though there are various advantages of expert systems, they aren't free from limitations. Here are a few lacunas of expert systems.

- ES typically cannot give a reasonably accurate and reliable response in an unforeseen situation
- The knowledge is very vast and voluminous. Missing facts and rules in KB, uncertainty can make the ES give incorrect suggestions/decisions.
- Building and maintenance cost of an expert system is very expensive
- An expert system can combine knowledge of multiple human experts and give decisions accordingly, but it cannot be creative in similar situations. Rather, it would give almost same answer every time in those similar situations.
- A human expert can logically give decisions in other domains, but an ES will work only for specific domain and will fail tragically when faced with problem that is out of the scope of the chosen field.
- The ES cannot be flexible and adopt new learnings unless its programmed to do so.
- The initial setup cost and time taken by ES is expensive than using a human expert.

Differences between Neural Networks and Expert Systems

Both expert systems and neural networks help users in decision making process. But the difference lies in their processes.

An expert system gets the input through user interface. The inference engine then combines domain-specific and case-specific knowledge with the algorithmic processes contained in itself. The result is thus computed by inference engine and given to user through user interface to view.

Neural networks use layers of neurons and non-linear in structure. They use previous patterns, samples, and inputs and outputs to make decisions.
Example- a crime related expert system will analyse crime to give suspect, culprits and motives while neural network evaluation will be to figure out crime patterns and growth etc.

Examples of Expert Systems

- ***MYCIN:*** *Mycin is one of the earliest expert system built in 1960's for medical diagnosis purpose. It took answers to series of questions in yes or no forms, used more than 600 simple inference rules and used backward chaining to give output. It could also give drug prescription to the patients.*
- ***DENDRAL:*** *This was another expert systems from 1960s and many expert systems, including Mycin, were derived from it. Its purpose was to identify unknown organic molecules. It used some graph theory algorithms for the same.*

Case Studies

Here are some examples of the existing expert system in the light of basic architecture of the same. The examples are referred from the published journal papers.

"Web Based Fuzzy Expert System for Lung Cancer Diagnosis"

Problem: the problem of detecting the lung cancer based on patients medical history.

COMPONENTS OF ES FROM CHOSEN CASE :

- User Interface:

The UI consists of a form on a website. In order to access the system, the user must log in with their credentials, which include Medical Record Number. The user then enters the essentials details via a form on the website, and the output is generated on screen with the diagnosis and the treatment suggestion.

- General Knowledgebase:

The KB is stored in a MySQL database. It consists of variables like anamnesis, doubling, time of the tumour, degree of smoking, age and performance status. Anamnesis in turn consists of several other variables like fever, genetics, chest pain etc. The general knowledgebase consists of 243 combinations of rules obtained from doctors via interview. They consist of the 5 input variables; anamnesis, degree of smoking etc. and the corresponding output.

- Inference Engine:

The inference engine uses fuzzy logic in order to perform a diagnosis. The input variables are classified into fuzzy sets, and the weighted average of the fuzzy inputs

is taken in order to the compute the final step. Based on the weighted average, after de-fuzzification is performed, the tumour is either diagnosed as absent, benign or malignant.

- Features of the expert system
  - *The given expert system is able to diagnose lung cancer using fuzzy logic with rules based on interviews from doctors and supporting data.*
  - *The patients receive their diagnosis as well as a suggestion of the type of treatment required.*
  - *The patient is either classified as healthy, having a benign tumour or having a malignant tumour.*

Expert System for Financial Decision Making"

Problem- The Problem of deciding on the part of a consumer or a novice individual investor when to invest in the stock market and how to select what company's share to buy in order to be able to get a good portfolio growth in the highly volatile stock market demands the development of expert systems for the novice investors.

COMPONENTS OF ES FROM CHOSEN CASE :

- User Interface:

ES provides Graphical User Interface like menus and graphics in the Windows Environment. It enables the user to query the system, input the relevant information and then receive advice in the user's language.

- Knowledge base editor

The knowledge base editor is a simple editor that enables a subject matter expert to compose and rules to the expert system. They can also convert the rules from one form to another.

- Knowledge Base

It Consists of Facts, Rules or heuristic rules – specific rule of thumb. The Prolog suite is widely used to formulate the knowledge into rules and store them in the knowledge base.

  - Examples
    - *falls (investment):- rises (interest rate).*
    - *rises (Investment):- falls (interest rate).*
    - *rises (interest rate):- rise (stock price).*
    - *falls (interest rate):- falls (stock price).*

Knowledge acquisition captures the knowledge from a financial expert with adequate knowledge and experience in this field. Source of knowledge are online journals, databases, reports, etc.

The Case Specific data contains facts of problem that happen during the consultation process when the user in interacting with the expert system. It

compares this information with the one found in the knowledge base and also stores the reasoning in the working memory.

- Inference engine

An inference rule is a statement that has two parts- an if-clause and a then-clause. An expert system's rule base is made up of many such inference rules which resemble human reasoning.
The system uses Forward chaining and backward chaining for reasoning.

What we learnt?

Let's have a quick recap of what we learnt.

- Expert systems are type of AI programs
- Expert systems combine knowledge of multiple human experts and help the user in decision making.
- Expert systems are highly knowledge-based systems.
- User interface, knowledge base, inference engine, explanation subsystem and knowledgebase editor are main components of any expert systems.
- Inference engine is brain of expert systems and has algorithms from various algorithmic strategy families to give output to the user.
- Explanation subsystems is a unique feature of ES.
- Expert systems have applications in various areas in real life.
- The expert systems are efficient, accurate, highly reliable, error-free, Flexible and open to adopting new knowledge
- One can compare the human expert and expert systems for their performance to see ES are better than having just one human expert.
- Neural networks and expert systems both help in decision making, but their working styles and outputs expected are different.
- Though it comes with many positive points, the expert systems cannot handle unforeseen events properly. It simply cannot think out of the box.

What you have to do!

Multiple choice questions

1. Which of the following statements is not true for expert systems?
    a. Expert systems have has pool of knowledge from various domain experts.
    b. Expert systems are very expensive to design and implement.
    c. Expert systems does not require very high end computing machines to run.
    d. **Maintenance of expert systems is very difficult burdensome affair.**

2. Identify component of expert system from the below list.
    a. User interface in natural language for I/O
    b. Knowledge base
    c. Explanation subsystem
    d. **All of the above**

3. **State true or false-** The expert system is an artificially Intelligence program
    a. **True**
    b. False
4. Which of the following algorithm family is generally not part of inference engine-
    a. Forward or backward chaining
    b. Machine learning algorithms
    c. Bayesian network
    d. Decision trees
    e. Customized algorithms
    f. **Branch and bound**

5. State true or false- Domain experts need not necessarily have any technical programming knowledge.
    a. **True**
    b. False

6. Which of the following is true about knowledge engineer-
    a. Needs expertise on various knowledge representation techniques
    b. Should have knowledge on various expert system tools
    c. Should possess expertise on software engineering methodologies
    d. Experience o working on various kinds of expert systems
    e. **All of the above**
7. Expert system implementation has which one of the following stapes-
    a. A problem and goal identification
    b. Conceptualization
    c. Formalization
    d. Implementation
    e. Testing
    f. **all of the above**
8. state true or false-expert systems are not very useful in giving correct and reliable suggestion in unforeseen situation.
    a. **True**
    b. False

9. state true or false- Like a human expert, an expert system can give its expert advice in every domain.
    a. True
    b. **False**

10. The expert system is built by interviewing and taking feedback from ------ domain expert(s) in the field.
    a. One
    b. **Many**
    c. None
    d. At least three in number

Theoretical questions

1. **Explain the concept of expert system.**
2. **What is the difference between human expert and an expert system?**
3. **What are the difference and similarities between artificial intelligence and an expert system?**
4. **Give some examples of the expert systems.**
5. **Discuss various phases of expert system development.**
6. **Map 7 step process of knowledge engineering to expert system development.**
7. **Discuss merits and demerits of expert systems.**
8. **Justify why the problem and goal formulation step of ES implementation has to be done before the conceptualization.**
9. **Consider a problem of protection and restoration of ancient monuments. If you would be appointed as the knowledge engineer to implement an expert systems to solve this problem, what would be the contents of various components of expert systems?**
10. **Consider a problem of implementing expert systems for some crop disease. If you would be appointed as the knowledge engineer to solve this problem, what would be the contents of various components of expert systems? (Assume necessary data)**