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ISSN 1012-277X S.Afr.j.ind.eng.

S A Tydskrif vir Bedryfsingenieurswese, Vol 3, No 1, Junie 1989 pp 10-29

EXPERT SYSTEMS
An Industrial Engineering Perspective

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ABSTRACT

The purpose and scope of this paper may be summarized as follows :

An attempt to make the Industrial Engineering community aware of the existence and potential benefits of Expert Systems technology,

providing a superficial introduction to the basic concepts and terminology of Expert Systems, and

exploring some of the interfaces between Industrial Engineering and Expert Systems as well as the possible worthwhile applications within the South African context.

OPSOMMING

Die doelwit en omvang van hierdie artikel kan soos volg opgesom word :

'n Poging om die Bedryfsingenieurswesegemeenskap bewus te maak van die bestaan en potensiële voordele van Ekspertstelseltegnologie,

die verskaffing van 'n oppervlakkige inleiding tot die beginsels, konsepte en terminologie van Ekspertstelsels, en

'n bespreking van sommige van die koppelvlakke tussen Bedryfsingenieurswese en Ekspertstelsels sowel as die moontlike toepassings wat binne die Suid-Afrikaanse konteks die moeite werd mag wees.

"Daar is drie maniere waarop 'n mens sy geld kan verloor : deur dit op vroue te verkwis, deur dit weg te dobbel, of deur deskundiges aan te stel. Hiervan is vroue die lekkerste, dobbel die opwindenste en deskundiges die sekerste".

Georges Pompidou

1. INTRODUCTION

"Time flies like an arrow, but fruit flies like bananas"

Mickey Williamson

The development of the science of Artificial Intelligence may be traced back for at least three or four decades when most of the fundamental concepts were formalized by researchers such as Norbert Wiener, Alan Turing, Marvin Minsky, John McCarthy, Donald Michie and Edward Feigenbaum. Since then extensive and widespread research were unable, in the majority of instances, to fulfill the original promises of, for example, building a "General Problem Solving Machine". The ease with which most humans will be able to interpret the quotation at the beginning of this introduction, relative to the severe difficulties a natural language processor will experience, is indicative of the problems inherent in Artificial Intelligence applications [18,29].

However, during the last few years some aspects of Artificial Intelligence research have emerged as commercially viable at least to some degree. Most important for Industrial Engineers are applications within the areas of robotics, natural language query systems, sensory systems, automatic programming, decision support systems and expert systems. Although Industrial Engineers will probably be involved in all of these and other areas of Artificial Intelligence, the major interaction will probably occur in the area of expert systems [26].

2. DEFINITION OF AN EXPERT SYSTEM

"Expert systems such as Mycin are like Potemkin villages. You move a little to the left, and you see it is all a facade".

Joseph Weizenbaum

A variety of definitions of what an expert system is or should be may be formalized and the Appendix provides a selection of some possible definitions from the literature. For the purpose of this paper it may suffice to define an expert system as a computer programme :

Capable of recording, storing and refining knowledge, expertise and experience about a specified domain, and

which may be used to consult, process, manipulate and distribute the stored knowledge for a very specific practical decision making purpose.

In this context it may be instructive to consider some of the more important differences between "normal" computer programmes and expert system programmes. These differences are summarized in table 1 and should be interpreted as differences in emphasis rather than hard and fast rules [27].

Expert System Programmes	"Normal" Computer Programmes
Manipulate knowledge	Manipulate data
Heuristic	Algorithmic
Inferential	Repetitive
Knowledge based	Data based
Data- or goal-driven	Algorithmic-driven
Perform symbolic reasoning	Perform arithmetic calculations
Have self-knowledge (explanation)	Have no self-knowledge
Flow of control not predetermined	Flow of control predetermined
Highly interactive	Not necessarily interactive
Potential to learn from errors	Limited learning potential

Table 1 Differences between expert system and "normal" programmes

A typical expert system may consist of at least three main subsystems :

A **Knowledge Base** for storing and organizing the domain knowledge,

an **Inference Engine** for manipulating the knowledge, and

a **User Interface** for facilitating the interaction between the user and the knowledge base.

3. KNOWLEDGE, KNOWLEDGE REPRESENTATION AND KNOWLEDGE BASE

"For in much wisdom is much grief : and he that increaseth knowledge increaseth sorrow".

Ecclesiastes I : 18

Knowledge

It is important to distinguish between information and knowledge. Information is raw data that has not been interpreted while knowledge implies understanding of the data, its implications and possible applications. Large amounts of information often exists but at the same time knowledge may be a scarce resource within the same problem environment. Expert Systems provide a way not only to capture and package existing knowledge but to transform information into useful knowledge [7].

Various types of knowledge may be recognized of which the following may be the most important [1,11] :

Declarative knowledge (facts, classes, relationships, etc.) describing the state of a system,

procedural knowledge (rules, control structures, algorithms, etc.) stating the steps needed to accomplish a task, and

reasoning knowledge used for reasoning about other knowledge.

In reality the boundaries between these types of knowledge are very flexible and the distinctions are often not very meaningful. For example, the definition of a production rule may be seen as declaring a procedure for purposes of reasoning.

From a different viewpoint knowledge may also be classified as :

Public domain or book knowledge since it has been well documented and is available to everyone, or

expert knowledge since it is based on experience which is not well documented and which exists as rule of thumb, gut feeling, heuristics, expertise, judgment and even common sense of a few human experts.

Knowledge representation

Many different and often complementary ways of representing knowledge exist. Well known traditional methods such as data bases, spreadsheets, text files and programme variables are well developed and appropriate for representing certain types of declarative knowledge. Similarly, traditional procedural programming languages (FORTRAN, C, PASCAL, etc.) are well suited for representing procedural knowledge such as some control structures and algorithms. More recently developed alternative approaches for representing declarative, procedural as well as reasoning knowledge may include production rules, semantic networks and frames. Programming languages based on list processing (LISP), predicate logic (PROLOG) or an object orientation (SMALLTALK) are also available and probably better suited to the manipulation of knowledge. The traditional approaches are best suited to the representation of public domain knowledge while the alternative approaches are appropriate for representing expert knowledge.

Production rules [7,13]

At present, the most often used approach for representing expert knowledge consists of so called facts and production rules.

A fact is a statement, such as "job is late". It may be build into the knowledge base, it may be solicited from the user or an external data base or it may be inferred from other existing facts through the application of relevant production rules.

Production rules may be written in various forms but are essentially IF...THEN... rules, for example "IF job is late AND customer is important THEN priority is high".

Every production rule consists of two parts, a premise (antecedent) and a conclusion (consequent). Several, possibly several thousand, production rules pertaining to a specific domain constitutes a knowledge or, in this instance, a rule base. A particular rule in a rule base represents possibly only a fraction of the total domain knowledge.

Production rules are easy to understand and use and are well suited to the representation of a variety of heuristic knowledge [7]. Furthermore, it is relatively easy to expand or modify a knowledge base consisting of a number of production rules.

Most of the expert system development shells presently available use a production rule approach for representing knowledge.

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Semantic Networks [7,13]

A Semantic Network is a graphical depiction of knowledge about objects and the relationships between the objects [7,8]. A semantic network consists of "nodes" representing objects such as people, places, things, events and concepts or attributes of related objects such as size, color, specifications, characteristics and configuration. The nodes are linked through "arcs" stating the relationships between the nodes. Since a semantic network may be used to represent hierarchical information, nodes that are lower in the hierarchy may inherit properties from nodes higher in the hierarchy. In this way the need to repeat information is eliminated, providing a very efficient way of representing knowledge. Semantic networks are an excellent visual, and probably the oldest and easiest way, to represent knowledge. A language based on predicate logic, such as Prolog, may be used to represent and manipulate the knowledge contained in a semantic network. Figure 1 shows a typical example of a simple semantic network.

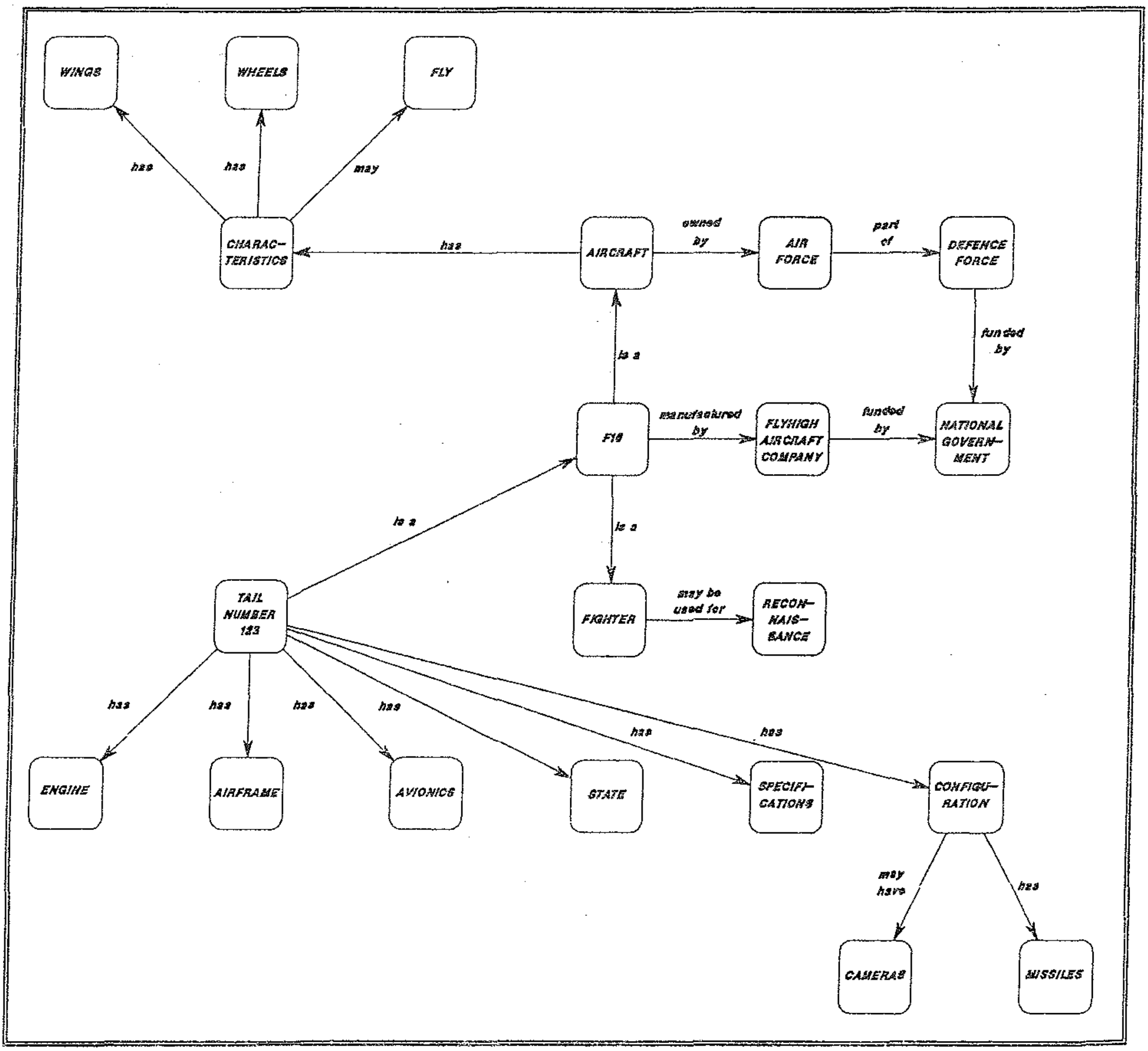

Figure 1 A simple semantic network

Frames [7,13,24]

Frames are primarily used to organize knowledge in relative large blocks of knowledge about a particular object, event, concept, class or component. Therefore, a frame may occupy one of the nodes of a sementic network. A frame, concerned with a specific object, may have several "slots" where each slot may describe a specific characteristic or attribute of the object. Every slot may have one or more "types" or "facets" of information each with a specific "value" or "filler". These fillers may be values in the normal sense of the word but may also contain restrictions on the allowable values of other facets of the same slot, such as units, a range of acceptable values or alternatives. Frames and slots may have names or labels for reference purposes. A slot may refer to another frame, contain a default value, refer to a set of production rules or contain a procedural attachment. A procedural attachment implies that a procedure or process outside the knowledge base may be executed depending on certain conditions such as "if-needed" or "if-modified". These processes are known as "daemons" or "methods". Frames may be linked together to form a hierarchy enabling inheritance similar to semantic networks. For example, every subframe may inherit the slots, and therefore all the facets and values, of its ancestors and also the rules of its decendants. All the frames in a knowledge base, possibly with the exception of the root frame, need to be "instantiated" or executed. This may take place automatically, requested by the user or performed under programme control. The resultant concept of multiple instantiation is very important in expert system technology but not very common in most other types of computer programmes.

Expert system development software, such as Personal Consultant Plus, employs an approach consisting of production rules organized into a frame hierarchy [31].

Figure 2 shows a typical frame hierarchy, which may be part of the semantic network shown in figure 1 while the frame shown in figure 3 may be one of the frames in this hierarchy.

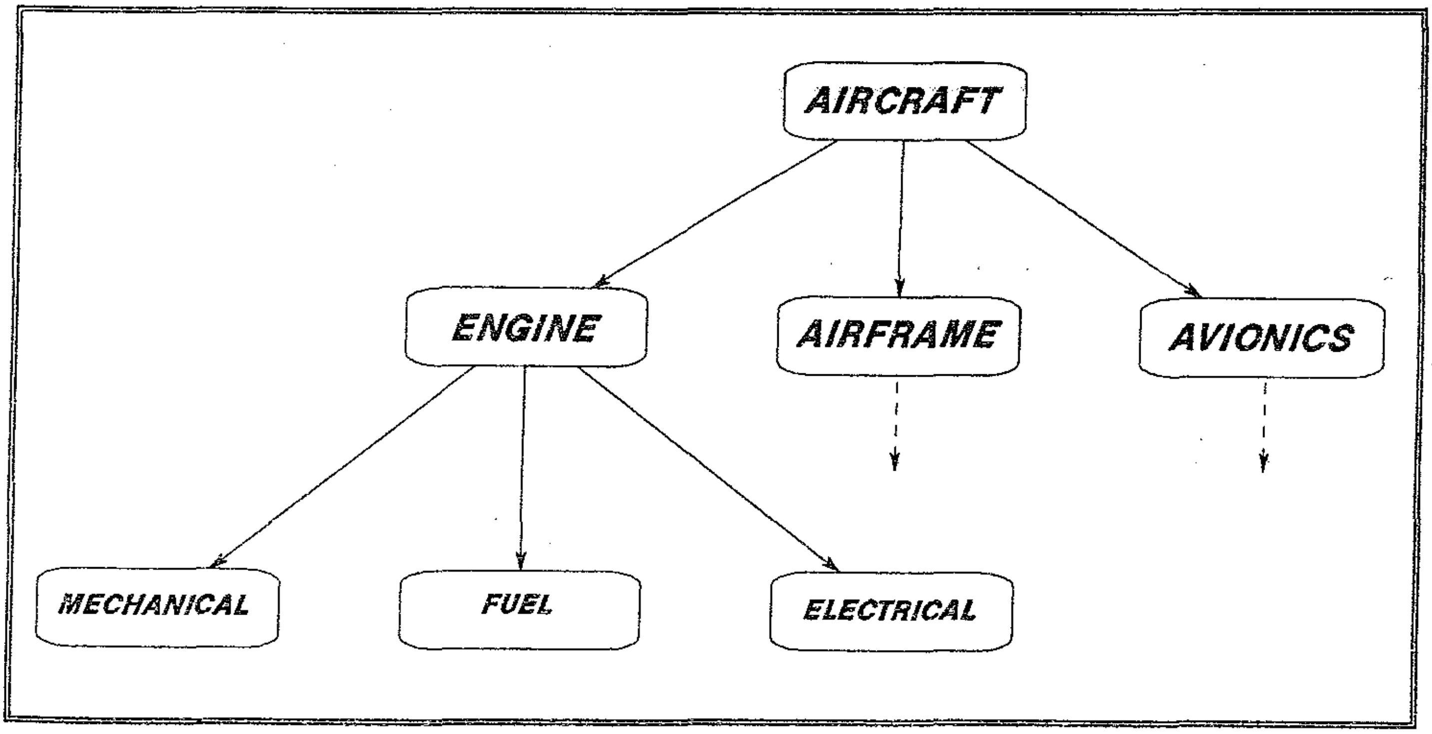

Figure 2 A typical frame hierarchy

Figure 3 shows a typical simple frame. The frame is only partly instantiated with the purpose of illustrating some of the characteristics of a frame. Therefore, some facets have values while others have specifications. Specific implementations of the frame concept, in a particular software product, may differ significantly from this example.

NAME : ENGINE	
SLOTS	FACETS
Parent frame	AIRCRAFT
Serial number	1234567/8
Manufacturer	Flyhigh Aircraft Company
Type	Range (F16, Puma, Sikorsky)
Last maintenance	Unit (hours) (default : 0) Unit (day, month, year)
Operating hours	1241
Installed in	F16 123
Part list	External data base
Engine replacement	Rule set
Maintenance schedule	Rule set (if needed)
Performance	Procedural attachment
Child frames	MECH FUEL AVION

Figure 3 A typical frame

Lists, Trees and Scripts [8]

Various other knowledge representation schemes exist. Lists and Trees are simple structures for representing hierarchical knowledge. A list of related items, products, activities, people, etc. may be organized in a hierarchical tree using a language such as LISP. Scripts are a knowledge representing scheme similar to frames. A frame is used to describe an object while a script is used to describe a "scene" or sequence of events which may occur given certain "entry conditions" and using the available "props" or resources. The entities or objects involved in the "scene" are known as "roles" while the different possible variations described by the script are known as "tracks". A script, implemented in a language such as LISP, may provide answers to questions such as : "What is done, when, to whom, by who, under which conditions and using which resources ?"

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Knowledge base

The necessary knowledge, experience and expertise about a specific and often very limited domain is stored and organized in a knowledge base using one or more of the available knowledge representation schemes. Therefore, a knowledge base may consist of a collection of facts and production rules, organized in a hierarchy of frames and representing, to some extend, the public and expert knowledge about the specific problem domain. The particular knowledge representation scheme used in a knowledge base may to some extent limit the possible inference techniques that may be used.

It is instructive, or at least interesting, to note the conceptual similarities between for example data base technology and semantic networks or simulation modelling and scripts. The data base concepts of records and fields may be seen as a subset of the concept of frames, slots and facets. These similarities may indicate the possibility of significant advances which may be made, in data base and simulation technology, using artificial intelligence concepts.

It also seems as if the terminology of expert system technology have not as yet reached a reasonable state of stability or maturity. For example, slots and facets may be called "parameters" and "properties" (even "flavours") respectively [24]. The resulting confusion, often propagated by software developers, is not only disconcerting to potential users of expert system technology, but may be considered as an indication that the underlying theory has not as yet been placed on a sound foundation.

4. INFERENCE ENGINE

"What we must look for here is, first, religious and moral principles; secondly, gentlemanly conduct; thirdly, intellectual ability".

Thomas Arnold

The knowledge in the knowledge base is in itself not very useful unless in may be manipulated in some way or another by what is known as an inference engine. In simple terms, the inference engine is responsible for making sense of the knowledge in the knowledge base by generating new facts as concequences from the existing knowledge, thereby infering a solution or reaching a goal. In this way it tries to mimic, but not replicate or copy, the human reasoning process. In general, humans probably use an approach based primarily on pattern recognition and matching to solve problems while expert systems use a variety of search techniques.

Problem solving

Problem solving approaches may be classified as either [7] :

> **Analysis by inductive reasoning** (reasoning from the specific to the general) or
>
> **synthesis by deductive reasoning** (reasoning from the general to the specific).

The first approach consists of starting with a proposed solution, goal or hypothesis and then trying to accumulate enough facts or evidence to prove or support the validity of the hypothesis. This approach is best suited to problems concerned with, for example, diagnostics, prediction and classification. The second approach starts with existing or known facts and attempts to deduce a solution or reach a goal. This approach is often used to solve problems in the areas of, for example, design, planning and configuration. In any practical problem solving situation a human will probably use a combination of at least these two approaches.

Search strategies

No simple general way exists for characterizing an inference engine since its structure depends on the problem domain and the way in which the knowledge is represented and organized. However some search or inference strategies have proved to be sufficient for handling a variety of problems efficiently for the purposes of expert systems. The two most often used search strategies for making inferences from a knowledge base, consisting of production rules, are backward chaining (goal-driven) and forward chaining (data- or knowledge-driven). Backward chaining uses in principle the analyis by inductive reasoning approach, while forward chaining uses the synthesis by deductive reasoning approach.

Various other search strategies may be employed in an attempt to increase the efficiency of the search. A combination of forward and backward chaining may be used while the search may be conducted in a depth-first or breadth-first fashion. Heuristic techniques may also be used such as placing an arbitrary bound on a depth-first search. Specific rules prescribing how the search of a knowledge base should be conducted may be included as an integral part of a rule base. These type of rules are known as meta-rules. Another way to minimize the search process is to subdivide the problem, and therefore the knowledge base, into a hierarchy possibly using frames. In this way the search may be restricted to an area most likely to provide a solution [7].

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Forward chaining [13]

In its simplest form an inference engine using the forward chaining approach, under the assumption that no facts are given as true, may start arbitrarily with the first rule in the knowledge base. It will try, by either asking the user or accessing a data base, to determine whether all the premises of the rule is true. If so, the rule will be executed (fired) and the conclusion(s) of the rule will be used as premises with the purpose of executing as many other rules as possible. This logical motion from one rule's conclusion to another rule's premise constitutes the forward chain. Forward chaining is most appropriate in situations where the user provides some data and is interested in finding a conclusion if any. Forward chaining is easy to understand and to implement but it may generate many facts or conclusions which may not necessarily be relevant to the particular problem. Furthermore, unless modified substantially, it may have to search the entire knowledge base before reaching a conclusion which is not very efficient.

Backward chaining [13]

The backward chaining approach differs from forward chaining mainly in that it starts by assuming some arbitrary or specified conclusion to be true and try to prove it. The truth of a conclusion depends on the truth of its premise(s) which in turn may be a possible conclusion of another rule. If such a rule is found the process chains backward to that rule and try to prove it by proving the truth of each of its premises in the same fashion or by soliciting information from the user. Backward chaining is appropriate for proving a specified hypothesis which implies that the user has at least some idea of the probable solution to the problem. If this is not true backward chaining is probably no more efficient than forward chaining.

Uncertainty [13,31]

Uncertainty is an unescapable characteristic of the real world primarily caused by the ever present problem of incomplete information. Expert systems are supposed to assist in finding solutions to practical problems and therefore should include some way of handling uncertainty. A variety of ways have been proposed for this purpose and have been inplemented in existing software, for example Bayesian statistics and "fuzzy" logic. However, the most often used approach providing a measure of confidence or uncertainty, is based on what is known as certainty factors.

A certainty factor (CF) with a value between 0 and 1, for example, may be attached to a fact provided by the user or may be assigned by the system developer to the conclusion of a rule. These certainty factors are not probabilities in the normal statistical sense of the word, mainly because of the way in which the effect of certainty factors are propagated through the knowledge base. Consider for example the following rule where the certainty factors of the premises were provided by the user, or may be the result of conclusions of other rules :

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IF A is true (CF 0,80) AND

B is true (CF 0,70) THEN

C is true (CF 0,90)

Several different ways exist for calculating the final certainty factor for the conclusion "C is true". One possible approach is to multiply the value of the smallest certainty factor allocated to all the premises (linked with the AND operator) with the certainty factor assigned to the conclusion (0,70 x 0.90 = 0.63). Similar ways exist for calculating final certainty factors in the case where the premises are linked with the OR operator.

The specific implementation of certainty factors may differ significantly in different expert system development software.

5. USER INTERFACE

"Remember that the most beautiful things in the world are the most useless; peacocks and lilies for instance"

John Ruskin

The user interface is a very important part of any expert system, since it provides the facilities for the user to interrogate and interact with the system during a consultation. The interface is the link between the expert system and the outside world which is often represented by a human user but also possibly other computer systems. The ability to handle a relative unstructured dialogue between the user and the expert system programme is one of the most important characteristics and advantages of a well designed expert system. Apart from various forms and formats of input and output the user interface may provide facilities such as explaining why specific information was requested, explaining how a specific conclusion was reached and provide interactive graphical input and output.

Some expert systems are dedicated toward providing intelligent user interfaces to other software systems. The most important example of such an expert system application may be a data base system based on natural language processing [8].

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6. EXPERT SYSTEM DEVELOPMENT TOOLS

"Give us the tools and we will finish the job".

Winston Leonard Spencer Churchill

An expert system is a computer programme and therefore some kind of computer programming tool is necessary for the development of an expert system. It may be possible to develop an expert system using a general purpose procedural language but a variety of programming tools specifically designed for this purpose is commercially available. These tools may be categorized as [13] :

Low level artificial intelligence languages such as LISP and PROLOG,

higher level development environments such as Arity and Goldworks,

expert system shells such as PC Plus, Synapse and VP Expert, and

integrated software such as Guru.

Deciding on an approach represented by one of these categories invariably results in a trade-off between flexibility and convenience. A shell may be easy to learn and convenient to use but may lack flexibility. On the other hand an artificial intelligence language may offer all the necessary flexibility but may be difficult to use and may require special programming skills. Other factors which should be taken into account are ease of development and maintenance, ease of learning, present programming skills available, integration capabilities and software performance [16].

Choosing a specific development tool within one of the categories mentioned and for a particular project represents an important but difficult decision where criteria such as functionality, representation of knowledge, control of knowledge, development capabilities and various other factors should be evaluated [5].

7. POTENTIAL BENEFITS AND PROBLEMS OF EXPERT SYSTEMS

"We have spend hundreds of billions of dollars developing computer power that has set us adrift in a sea of data".

Thomas P Kehler

Some of the relative advantages and disadvantages of an expert system computer programme relative to a human expert is summarized in Table 2 [22,28,31].

Human experts	Expert systems
Perishable (may leave the company)	Permanent
Knowledge difficult to transfer	Easy to transfer knowledge
Often irrational	Completely rational
Often unpredictable and inconsistent	Highly consistent
Sometimes unavailable	Always available
Expensive	Affordable
Knowledge often undocumented	Knowledge well documented
May be unable to explain reasoning	Able to explain reasoning in detail
Knowledge often unstructured	Knowledge well structured
Represent one-person knowledge	Represent multi-person knowledge
Understand knowledge	Do not understand knowledge
Have common sense knowledge	Do not have any common sense knowledge
Knowledge not domain dependent	Knowledge highly domain dependent
Realize it if problem is outside domain of expertise	Do not realize that problem is outside domain of expertise
Will check that conclusions are reasonable	Has no independent way to check that conclusions are reasonable

Table 2 Relative advantages and disadvantages of expert systems

Other potential benefits which may be realized from adopting expert system technology may include the following [7,20,22,28,31].

The process of designing an expert system may improve the general understanding of how information and knowledge is used to solve a problem in a specific domain.

The ability of an expert system to reproduce and explain knowledge makes it suitable as an effective teaching and training tool.

An expert system may enhance the productive utilization of existing specialized knowledge, experience and expertise and may be used to efficiently secure, preserve, duplicate and distribute such specialized knowledge.

An expert system may be capable of solving a problem fast and efficiently which otherwise may be difficult and time consuming to solve using traditional computing techniques.

Expert systems may relieve the burden on scarce human experts and support them in the creative aspects of their work.

Significant improvement in overall productivity may result from the use of expert systems.

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An expert system provides consistent, uniform, methodical and unbiased advise and decision support.

An expert system is a convenient way of not only capturing and storing expert knowledge, but over time may be used to tailor, revise, update, refine and expand the knowledge, allowing the system's expertise to evolve similar to the way in which human expertise evolves.

An expert system approach may be the preferred and possibly the only way to partially automate decision making and to handle the ever increasing information processing needs of modern society.

Some of the present problems in the application of expert systems may have a detrimental effect on the acceptance and general use of the technology. Similar to artificial intelligence, an inflated expectation and misconception of what expert systems can do may lead to unnecessary disappointment and unwarranted rejection of the technology. An extremely wide variety of development tools are available and a large body of seemingly disjointed theoretical concepts and terminology is in existence. Conversely, relatively few significant practical applications have been reported resulting in an understandable scepticism and reluctance to accept the technology on the part of potential users [22].

The severity of most of these problems will be reduced as the technology becomes more mature and the application base more extensive.

8. EXPERT SYSTEMS AND THE INDUSTRIAL ENGINEER

"While the first wave (of the information revolution) automated data processing, the second wave will automate decision making".

Herbert Schorr

Expert systems evolved as part of the science of artificial intelligence and as such may be seen as part of computer science. However, many Industrial Engineers are involved in the design as well as the day to day operation of a variety of computerized systems and there are indications that this involvement may increase dramatically, in both scope and intensity, in the future. If the present promises and potential benefits of expert systems are fulfilled to some degree, very little doubt exists about the significance of the opportunities and advantages inherent in this technology and its potential impact on the Industrial Engineering profession.

The following important areas of potential interaction between Industrial Engineering and Expert System Technology may be identified :

Expert systems as Industrial Engineering consultants or advisors,

expert systems as an integrated part of existing computerized systems,

expert systems as a tutor or training system,

expert systems as a supplement to operating manuals and procedures, and

management expert systems.

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Industrial Engineering consultants

Possible applications of expert systems in this area may include the following :

Scheduling and sequencing,
real time decision support,
fault detection and error diagnoses,
preventative maintenance planning,
resource and process planning,
facility location, planning and design,
configuration analysis,
financial analysis,
group technology,
maintenance management,
resource allocation,
evaluation of quality assurance systems,
productivity measurement and evaluation,
statistical analysis,
forecasting model development,
logistics management and control,
personnel training and retraining,
work measurement and standards,
requirements planning,
job costing analysis,
transport route selection,
equipment selection, and
plant layout and process design.

These problem areas are all characterized by their inherent complexity, ambiguity and fuzziness. Furthermore, it may be impossible to solve these problems effectively by relying only on public domain (book) knowledge since judgement, experience and expertise plays an important part.

Part of existing computerized systems

A second important area of application may be the use of expert system methodology to enhance the usefulness, power and specifically the user interface of existing computerized systems in the Industrial Engineering environment. This goal may be achieved through the design of intelligent front end processors, intelligent help systems, output analyzers, post processors and integrated intelligent system control procedures preventing, for example, inadvertent, but possible catastrophic, mis-use of the computerized system.

Typical examples of these applications may include intelligent front end processors, imbedded subsystems and report generators for :

Data base systems,
Material Requirements Planning systems,
simulation models and other decision support systems,
maintenance planning and control systems, and
inventory control systems,

Training systems

The inherent capability of an expert system approach to capture, store, refine and distribute both public domain knowledge and expert knowledge presents a powerful methodology for the design of efficient computerized training systems. This particular application area may prove to be capable of making significant contributions to some of the particular problems experienced by the South African industry. The South African society, and therefore industry, is often characterized as consisting of a mixture of first and third world economies and technologies and as suffering from a shortage of industrial and engineering skills while at the same time is burdened by an over supply of low level manpower. Expert system technology may be used to capture some of the knowledge and expertise of the few highly qualified engineers. The expert system may be used to distribute the expertise to semi-skilled engineering technicians and to effectively train and assist lesser qualified people. In this respect South Africa, and in particular the South African Industrial Engineering profession, has a very special opportunity to become world leaders in this particular expert system application area [17].

Supplement to operating manuals

Operating manuals and other similar system documentation, containing information with regard to operating procedures, regulations and standard practises, are often expensive to produce and difficult to maintain. These manuals and documentation are often perceived as an absolute necessary part of many system development projects. Most manuals are not written to be read but rather to be defended. The majority of organizations ignore the established fact that few people ever read, still less digest, a manual [4]. Fortunately this is not as serious as it may seem since manuals contain very little or no knowledge based on experience and expertise. They do not contain the actions which will be taken by an expert in the field under a given set of circumstances. Supplementing, or even replacing, manuals by expert systems is probably one of the less difficult but nevertheless rewarding application areas of expert system technology in the Industrial Engineering environment.

Management expert systems

The first large scale and probably still the largest commercial application of computer technology is the area of business computing and information processing. Many managers are almost totally dependent on computerized data processing for performing their managerial duties. At the same time the management activity depends extensively on experience and expertise. Therefore, the management environment seems a very appropriate and potential fruitful application area for expert system technology. Until recently the development of management and business expert systems was severely hampered by the relative incompatibility of expert system development software and traditional business computing software, such as data base managers, business graphics, spreadsheets and various other types of financial and accounting software. Many expert system development tools have recently introduced the capability to interface with existing data base software but the most noteworthy development in this respect is a software product known as Guru. Guru extends the conventional expert system concepts of knowledge representation and processing to embrace well known business computing methods and integrates these facilities in one single development environment [11,17].

The shortage of especially middle management skills is often seen as one of the most important bottle-necks retarding economic growth and development in South Africa. Expert systems may make a significant contribution to alleviating this bottle-neck and Industrial Engineers are in an ideal position in many industries to pursue and facilitate this unique opportunity.

9. CONCLUSIONS

"It is, of course, foolish to predict where any new technology is going or when it will get there".

Eugene Linden

Knowledge and experience is one of the most valuable assets of any organization or company. However, controlling, protecting and expanding this asset is often a difficult and expensive activity. Expert system technology provides the means to capture, save, enhance and distribute the essence of this asset, i.e. expert knowledge, with relative ease and at an affordable price. From an Industrial Engineering perspective, expert system technology should be seen as a way to enhance the capability of skilled and semi-skilled people to solve problems using a computer based approach.

Given the present and growing involvement of Industrial Engineers in computer applications and computerized systems as well as the rapidly expanding application base of expert system technology, very little doubt can exist about the necessity for Industrial Engineers to use or at least to be aware of the potential benefits of this new technology.

The promises and advantages of expert systems, in terms of general industrial productivity improvement, is very significant, specifically for the South African industry. Industrial Engineers have the responsibility to exploit these advantages since they often find themselves in an ideal position to do this effectively.

"I think, therefore I am".

Descartes

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APPENDIX

Selected definitions of Expert Systems

"Expert Systems are computerized systems which are designed to mimic human experts by capturing human knowledge and using it for advising nonexperts so they can solve complex problems that require expertise for their solution". E Turban

"To make a program intelligent and provide it with lots of high quality knowledge specific to a certain problem area". D A Waterman

"An Expert System is a computer program which incorporates the knowledge of one or more human experts, enabling it to make decisions, and explain why they were made". SYNAPSE User's Manual

"An Expert System is a program that aids in solving complex real-world problems that usually require a human expert". Micro-Expert User's Manual

"An Expert System is a computer-based consultant that has access to stored expertise about some problem domain. When an end user presents a particular problem to the expert system, it uses the available expertise to infer some advice which it then reports to the end user". GURU User's Manual

"Expert systems technology, ..., involves the creation of computer software that emulates the way people solve problems". VP-Expert Manual

"An expert system is a computing system capable of representing and reasoning about some knowledge rich domain, such as internal medicine or geology, with a view to solving problems and giving advice". Peter Jackson

"An expert system is : A knowledge-based system that contains expert knowledge rather than general knowledge. It is a problem solving program that solves substantial problems generally conceded as being difficult and requiring expertise". B G Buchanan

"Expert systems are a kind of software system that not only incorporates human expertise but also uses a specific approach to solving the problem of the incorporation of human expertise. This approach is what we call Artificial Intelligence". Henry E Firdman

"In general the goal of AI is to have a machine accurately emulate intelligent human activities. .... In the context of today's technology this means having the computer do intelligent things such as understanding natural English ..... ; and having a computer make decisions and plan as skilfully as a human". Robert Keller

"Expert systems have their origins in traditional data processing. They are the result of continuous attempts to improve and extend the automation of some aspects of human information processing". J L Alty and M J Coombs

"Knowledge-based and expert systems combine information in a data base with procedures for drawing inferences and reaching conclusions about that informations". Mickey Williams

"An expert system is a clone of a human expert. An expert system replicates expert knowledge in a discipline and makes it available on a computer so that you may tap it when you need it". Louis E Frenzel

"An expert system contains knowledge about a particular field to assist human experts or provide information to people who do not have access to an expert in the particular field". Henry C Mishkoff

"Expert systems capture and distribute the human expert's expertise in making judgements under various conditions. They clone experts by capturing knowledge that is perishable, scarce, vague and difficult to apply, distribute or accumulate". David Hu