EXPERT SYSTEM AND ITS CAPABILITIES

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INTRODUCTION

The approach towards development of fifth generation computers is going to be a remarkable turning point in the information technology because of the emergence of computers with enhanced intelligence is anticipated.

Systems that are capable of image processing, computer aided design, computer aided manufacturing are harbingers of the fifth generation computer applications.

In time to come, with many aspirations of the fifth generation computers coming true, it will render the present day conventional computers and its associated procedural programming techniques, obsolete in many fields.

One of the biggest areas in which this new breed of computers will be used is Artificial Intelligence (AI). Conventional data processing is solely based on information in the form of data. On the contrary, AI is based on knowledge, as well as, sets of instructions how to use the facts and information on how the individual facts are related[1]. It is a branch of information science whose objective is to endow machines with reasoning and perceptual capabilities[2].

AI systems fall into three categories. They are: Expert Systems, Natural Language Systems and Visual, Speech, Touch Perception Systems[3].

This article highlights the most successful area of development under AI, which is the Expert System (ESystem).

WHAT IS AN EXPERT SYSTEM?

ESystem is a program containing knowledge which can perform tasks that require intelligence if done by human. This intelligent knowledge based computer systems

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1. *[FUO 86] p. 504-508*
2. *[CHO 87] p. 42*
3. *[RAN 86a] p. 3,4*

has a wide base of knowledge in a restrictive domain and uses complex inferential reasoning to aid one in a decision making process[4].

In the 1950s, Allen Newell and Herbert Simon at Carnegie-Mellon University studied human problem solving and reasoning to model human cognition and memory. Newell represented a person's long-term memory as **rules** and short term memory as sets of **situations**[5]. Each **rule** is presented in the form: IF **situation** X is recognised, THEN action Y is taken*.

Newell's human problem solving model which works like a rule-evocation process is further developed by research workers at Stanford University.

In the quest of developing intelligent computer programs, the AI scientists at Stanford University discovered special-purpose computer programs that exhibit their expert capabilities in some narrow problem areas. The problem solving power of these programs comes from the knowledge they possess, and not just the manipulation scheme they employ - this is the birth of knowledge based systems called ESystems[6].

Certain special languages having features which make them particularly suitable for AI work were discovered later. LISP was invented by John McCarthy in 1958[7]. PROLOG is a language designed to handle logic. Other AI languages are PLANNER, SAIL and FUZZY.

COMPONENTS OF AN EXPERT SYSTEM

An ESystem consists of a Knowledge Base and an Inference Engine[8].

The Knowledge Base is a collection of facts, relation and procedures which constitutes the knowledge about the particular domain.

The (IF **condition** *THEN* **consequence** *) are simple and common representation of knowledge. The* **consequence** *may be fact or action. Program which holds knowledge in this form is called Rule-based system or Production Rule system.*

4. *[HAR 86] p. 19*
5. *(WAT 86] p. 203,204*
6. *[CHA 84] p. 456*
7. *[CHO 87] p. 43-46*
8. *[WAT 86] p. 16-20*

The experts' knowledge is organised in a form the computer can use to solve specific problems that require expertise, in human like reasoning fashion*

The Inference Engine is the heart of an ESystem. This inference mechanism handles the knowledge in the Knowledge Base through scheduler , rule-intepreter , co-processors and interfaces[9,10].

The scheduler determines which facts, rules and relationship should be used by selecting a control strategy.

The rule-intepreter processes the rule selected by scheduler. It matches up the rule with the known facts and performs the action specified by the rules.

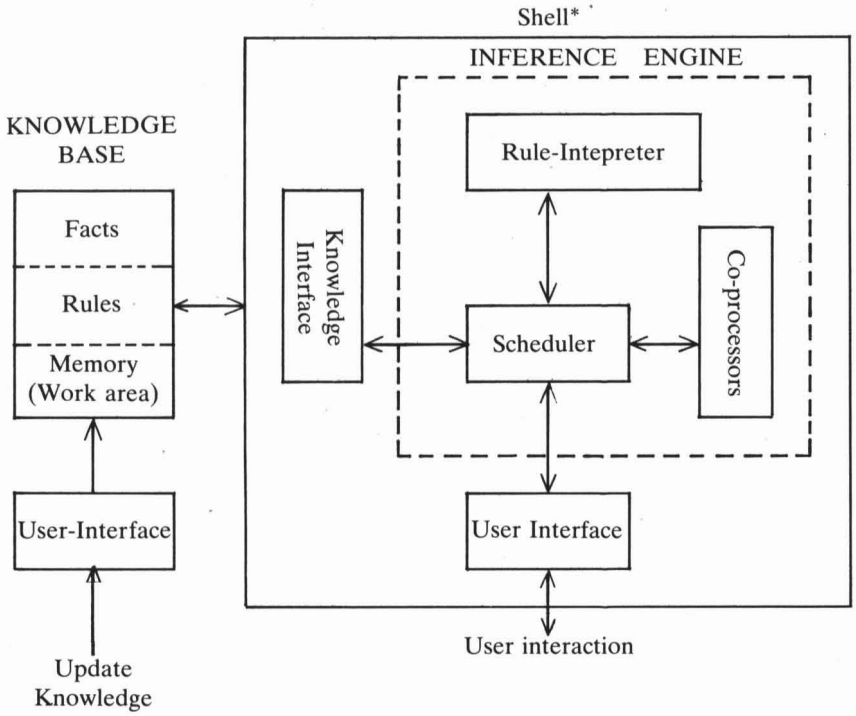
The co-processors help handle fact and data that are not completely defined and to explain the facts, rules and decision processes that are used by Inference Engine to arrive to a solution.

The knowledge interface aids the communication between the Knowledge Base and Inference Engine. The user interface enables the user to supply facts and data; enables the system to ask question or supply intermediate results or explanation.

Rule-based and Frame-based knowledge representation are successfully in use at present [11]

9. *[CHO87] p. 103-111*
10. *[WEI88] p. 111,221,222*
11. *[RAN86a] p. 63-65*

Fig. 1 Components of an Expert System



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* *A Shell is an inference mechanism component of an ESystem which has been detached from the Knowledge Base. This way, the same Shell can be utilised as a foundation for different applications, by providing different Knowledge Bases. However, the Inference engine for the different types off applications must be compatible.*

Fig. 2 Knowledge Engineering:
Translating from human experts to computers

The process of building an ESystem is called Knowledge Engineering. The knowledge engineers or information scientists are the mediators who interact with domain experts* and extract appropriate knowledge from the former and build the ESystem. Some of the knowledge elicitation techniques used by knowledge engineers are as follows [12,13]:

- Structured Interview
- Protocol Analysis
- Card Sort
- Quiz Game
- Machine Induction

Building and ESystem is like nuturing an infant who eventually, grows to be an adult. Obviously, the growing child would possess greater intelligence than an analogous ESystem because the former could see, hear and talk. On the other hand, an ESystem has to be carefully developed by knowledge engineers through painstaking process of acquiring information from domain experts and append it to the Knowledge Base of the system.

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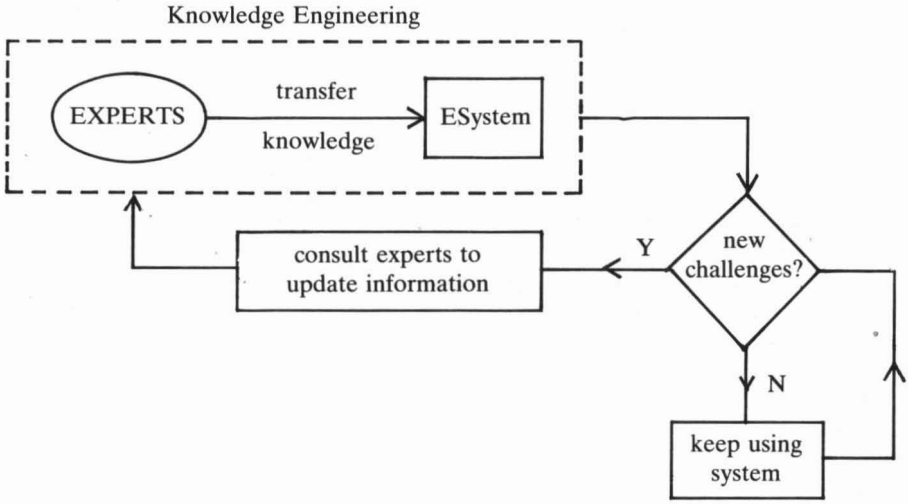
* *Domain expert is defined as a person who through years of training and experience has become extremely proficient at problem solving in a particular domain.*

12. *ASIAN COMPUTER,* **Expert System: How To Get Information Out Of Experts,** *May 88, p. 34-36*
13. *[HAR 86] p. 49-66,71-131*

An ESystem development is a ceaseless process. New challenges appear from time to time, as new cases are dealt with. This requires frequent changes to be done to the Knowledge Base of the ESystem. An ESystem is then, just like a human expert never stops learning. (An ESystem does not die. Unfortunately, such is not the case of an expert individual!)

Designing an ESystem requires many competent and optimistic professionals in the domain area of study as well as computer scientists. This tedious process also demands a lot of time, money and patience.

Fig. 3 ESystem is continuously improved and permanently accumulating



EXPERT SYSTEM AND HUMAN EXPERTS

It should not be miscontrued that ESystem will eventually supersede human experts. What ESystem do well is simply follow an experts line of reasoning systematically, based on knowledge and reasoning skills that has been imparted to it.

An ESystem mimics the decision making process of experts in a certain field by symptom based elimination of all possible causes of the problem - meaning, it narrows down all possibilities until it comes down to a small number of probable causes[14].

An ESystem is also expected to provide realistic solution for relatively incomplete data and subsequently explain how and why it arrived at a particular solution; just like human experts do.

The advantage the ESystem has over a human is that, it definitely outlives an expert's life span. In addition, it is built with knowledge from more than one source. Furthermore, whatever knowledge that has been transfered into it, is not forgotten. Machines do not fall sick or become tired, neither get emotionally excited nor depressed and as mentioned earlier, their memory does not fade over time.

As such, ESystem produce consistent and reliable results at all time and make the knowledge readily available to the user too. It ensures that reasonable hypothesis have not been overlooked by the user and guides him to work in-line with actual evidence.

However, the ESystem draws 'straight' inferences from the narrow and highly specific knowledge domain; unlike human, who is endowed with common sense, is able to make inferences over a wide scope in a very short period of time, especially when tackling problems in an unexpected event.

Since an ESystem is intended to model the behaviour of experts , these experts must exist to provide the model.

Hence, ESystems do not replace experts but they represent the cloned experts in some specific problem areas that make the experts' knowledge available to their counterparts to complement the latter's reasoning.

EXPERT SYSTEM vs. CONVENTIONAL SYSTEM

Firstly, conventional information technology is procedure driven while ESystem is data driven.

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14. [CHA 84] p. 474-477

Secondly, the problem concepts are stored in the Knowledge Base as **non-numeric symbols,** closer to the way the human represents knowledge[15]. The **non-deterministic programs*** under the control of the Inference Engine applies various strategies and heuristics to manipulate these concepts to arrive to possible inferences, calling on a wide range of reasoning power that has been incorporated into it.

On the other hand, conventional system utilises algorithmic or mathematical models reasoned out by human beings themselves to solve problems. Machine is used primarily because of its speed in repetitive calculation.

Thirdly, knowledge is stored in Knowledge Base separately from program control strategies, whereas in conventional softwares, the data and control flow are combined in the program code[16].

Fourthly, an additional feature that is often required in ESystem is the ability to support uncertainties, incompleteness as well as explain its behaviour and its decisions to the user.

Fifthly, the Knowledge Base of this dynamic system is always growing as shown in figure 3.

While conventional system is designed to work correctly everytime, the ESystem, like human can make mistakes[17]. This is because of the fundamental characteristics of ESystem to provide a solution even if not all the data relevant to the problem is available at the time when the solution is required. However, the system has the potential to learn from mistakes, as it is improved over time by knowledge engineers.

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* *capability to find multiple solutions to a given problem on its own.*

15. *[BON85] p. 16-24*
16. *[WEI88] p. 220*
17. *[WAT86] p. 29,30*

Fig. 4(a) The organisation of a Production-Rule modelled expert system

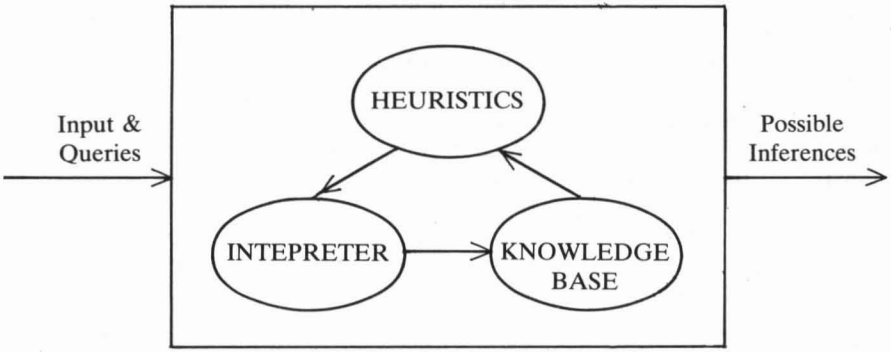
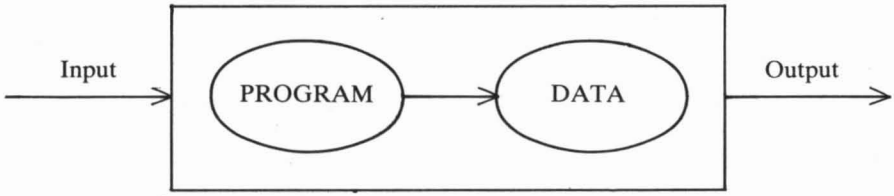


Fig. 4(b) The organisation of a conventional system



From the diagrams in figure 4(a) and 4(b), it can be see that the distinction between knowledge based ESystem and data based conventional information system is the **heuristics.**

WHAT IS HEURISTICS?

The ESystem reasons about its own operational path. However, the path to find a feasible solution that it takes and the resulting outsome are very much dependant on the data provided.

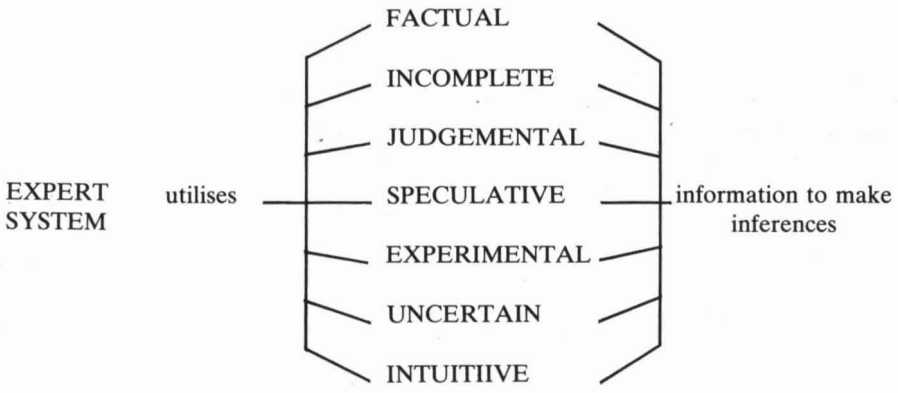
Heuristics applies the ability to chose the best path from various possibilites, using the best stimuli from several available. The process involves weighing up the potential

outcome of different paths and comparing them with the goal. The paths that appear to lead to states near the goal are considered worth pursuing[18,19]

If a promising path leads to a dead-end, the system back-tracks and tries different alternatives. If all paths lead to dead-ends, the system employs rule of thumb to come up with the best possible alternative solution.

Unlike conventional system, there is no known predetermined sequence of steps (algorithm) to lead to the solution.

Fig. 5 Types of information utilised by an expert system[20]



TODAYS PERFORMANCE OF EXPERT SYSTEMS

ESystem is a rapidly expanding field in AI arena. In United States, major universities, namely Stanford, Carnegie-Mellon and MIT; research institutions and private corporations like Rand Corp., Xerox, Schlumberger, Teknowledge, APEX are churning out ESystem for specific application.

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18. [HAR86] p. 20
19. [WEI88] p. 29
20. [RAN86a] p. 63-65

Some of the different, major application areas of ESystem can be classified as below:

Diagnosis

Systems to recommend remedies for illness, trouble-shoot electronics problems debug computer software hardware and so on. One of the most successful types of ESystems in use today are diagnosis systems.

Repair

Systems to develop repair plans for computer maintenance, communication network and avionics and space equipment repair.

Instruction

These systems contain knowledge and techniques for presenting instructional material including computer aided instruction (CAI) tools.

Intepretation

Systems for surveillance, image analysis, speech understanding and signal intepretation.

Prediction

Systems which can infer or guess the consequences from observed situation. Examples of systems which are in use are weather forecasting, traffic estimation, crop estimation and military forecasts.

Design and Planning

These systems are used to help minimize constraints including cost, time, material etc. Computer system configuration, circuit layout, building design, software development tools are some examples.

Monitor and Control

Systems used in real time applications to monitor and control complex tasks in power plant, air traffic control, disease control and business applications.

The summary and bibliography of the many expert systems that have been developed in each of the major application areas is detailed in the following references:

I. [WAT 86] chap. 24,25,26

II. [RAN 86b] chap. 1 - 10.

I include here, a short list of ESystems that have already been developed and are currently in use for medical and industries application; shown in table 1(a) and 1(b) respectively.

Table 1(a)
Expert systems developed for medical application

	Name	area of expertise
-	MYCIN	Blood infections & Meningitis
-	INTERNIST	Internal medicine
-	ONCOCIN	Cancer
-	CASNET	Glaucoma
-	PIP	Renal disorder
-	VM	Monitoring patients in ICU
-	PUFF	Pulmonary infections
-	IRIS	Ophthamology
-	DIGITALIS	Cardiology
-	CRYSALIS	Protein analysis
-	SAM	Artinel hypertension

Table 1(b)
Expert systems developed for industries

	Subject	Name	area of expertise
-	Chemistry	DENDRAL	Interpretation of mass-spectrograph data
		SYNCHEM	Organic synthesis
-	Physics	MECHO	Solutions of problems in mechanics
		SOPHIE	Analysis of electrical circuits
		SACON	Resistances of materials
-	Geology	PROSPECTOR	Mineralogy
		LITHO, DIPMETER, DRILLING ADVISOR	Petroleum
-	Mathematic	AM, MACSYMA, REDUCE	Discovery of concepts integrals, differential equation etc.
-	Computer Systems	DART	Fault diagnosis
		PECOS, DEDALUS, PSI, PROGRAMMER'S APPRENTICE SAFE	Program synthesis
-	Manufacture	GARI	Advice on factory organization
-	Military	HASP/SIAP	Signal processing

THE PROMISES OF EXPERT SYSTEM

ESystems are new and sophisticated way to profit through the use of computers, emphasizing better ways of decision making. These dynamic systems are heading out of research and development laboratories into commercial, industrial and financial environment - promising revolutionary changes in the business world.

The medical domain seems the most popular. Many ESystem have been developed and many more are under research and development. There will probably be more technology based changes in health care than any other major industry, with respect to the great demand for more ESystem in this domain.

The hospitals of tomorrow, will make use of Point-of-Service[21] workstations, where clinical information about a patient is entered at the time he is examined. Also, immediate and accurate information retrieval will help in the diagnosis and effective treatment of patient's illness.

The success in a particular application area will instigate development of ESystem for new areas.

For example, there is a growing need for CAI ESystems because the application of AI in CAI promises to change the drill-and-practice style in the current instructional softwares. Intelligent CAI programs can assess each students level of understanding and tailor the instruction to suit the student.

If several ESystem co-exist in a business environment, each performing distinct type of services; a single integrated system could be created that has the capabilities of all the various systems, analogous to the Intergrated Software packages that we have today.

As time passes, experience accumulates, and more powerful ESystems become available. We can expect to see ESystems of the future will have intelligent interaction between computer and user to a higher degree of userfriendliness than that has been achieved by the current range of forth generation computer softwares. In fact, ESystems are projected to provide the fifth generation languages[22].

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21. *ASIAN COMPUTER,* **Computer In Hospitals,** *July 88, p. 32*
22. *[CHO 87] p. 64*

The broader objective is to build autonomous-cooperative systems which will closely assist human in their daily work, and function with little human intervation.

These realizable ESystem could be updated by the users themselves. Then, the need for knowledge engineers to play the intermediary role can be eliminated. These systems would become potentially usable by a very large group of people.

Computer hardware advances have also made possible, integrated ESystem chips, where the ESystem is embedded in microprocessor chips being produced, called bio-chips[23,24]. This wiil soon give rise to the birth of ESystem run on portable special computers that can be carried around by ESystem-users to their work places.

The Japanese goverment has made public commitments towards development of generalised marketable ESystems which coincide with its traditional role as mass-producer of established technology. Major problems are under way at Japan Information Processing Development Centre (JIPDEC) and Institute of New Computer Technology (ICOT)[25].

In England, France and US, the private software firms that work in the areas of AI are focusing on financial and planning applications[26].

Apart from Japan, other Asian countries like Singapore and Hong Kong are showing keen interest towards research into automated reasoning which is relevant to the design and implementation of ESystem. The Hong Kong and Shanghai Banking Corp. and Cathay Pacific Airlines have installed AI systems in their head offices to develope ESystems for computer systems maintenance, planning and specialised office automation[27]

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23. *[WAT86] p. 221*
24. *[CHO87] p. 54*
25. *[BIS86] p. 41-44*
26. *[CHO87] p. 60*
27. *ASIAN COMPUTER,* **Artificial Intelligence,** *Jan 87, p. 1*

ESystem has become the hottest area in AI and is expected to grow into a multibillion dollar industry by end of the decade. According to President of a Canada based software company, DataCap Ltd., Mrs. Ayla Weston, Asian region is a promising market for ESystem. She says Esystem is not widely used here because of lack of awareness and not because of non-viablilty[28].

So, when the Asians realize the true capabilities of ESystem, there will be a dramatic change in the information technology here too!

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28. *STAR,* **IN-TECH Section,** *24 Jan 1989, p. 2*

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