Expert Systems Overview

Reference Books

- Artificial Intelligence: Promise and Performance
- Giarratano, Riley.1994. Expert Systems: Principles and Programming, PWS Publishing Company, Boston. (UBE - 325)

- Gonzales & Dankel, The Engineering of Knowledge Based Systems, Prentice Hall, 1993

- Luger, G., Stubblefield, W.A., Artificial Intelligence: Structures and Strategies for Complex Problem Solving, The Benjamin/Cummings Publishing Company, inc., 1993. (UBE - 34)

Refernces

- Awad Elias M.Building Expert Systems: Principals, Procedures and Applications 1996. (UBE- 334)

Acknowledgement

Most of these slides are taken from the lecture notes of

Alan Hamilton, IT62 Expert Systems, University of Stirling

Definition

- According to Darlington:

  "An expert system is a program that attempts to mimic human expertise by applying inference methods to a specific body of knowledge."

- According to Turban:

  "An expert system is a system that employs human knowledge captured in a computer to solve problems that ordinarily require human expertise."

Introduction to Expert Systems
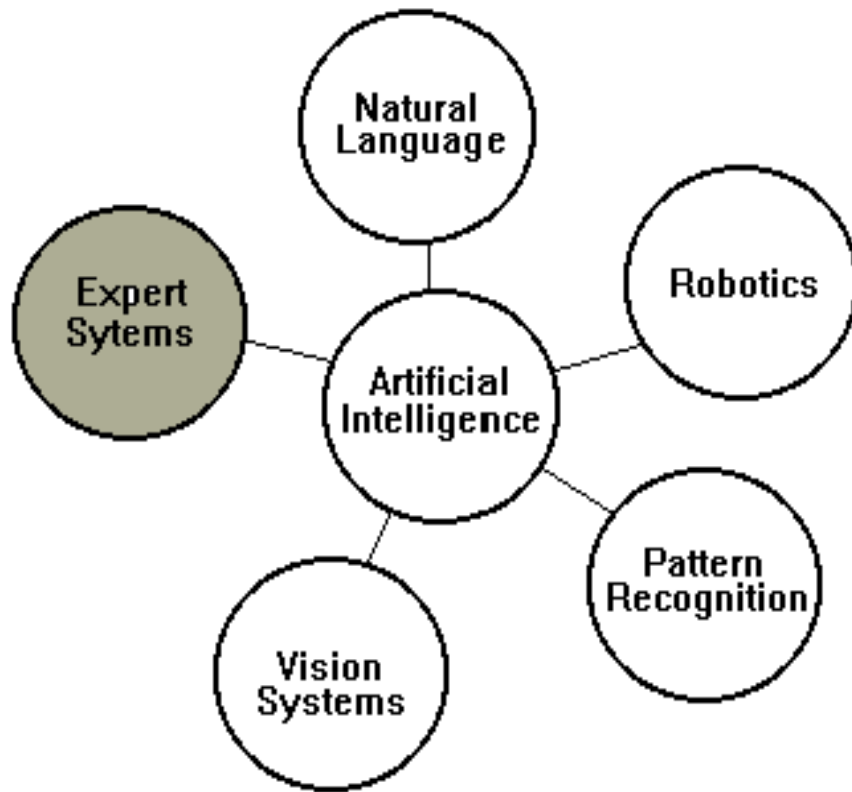
Historically Expert Systems grew with AI, and can be regarded as a branch of AI.

Definition of AI

Artificial Intelligence (AI) is the part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics we associate with <u>intelligence in human behavior</u> – understanding language, learning reasoning, solving problems and so on.

Barr and Feigenbaum, 1981

Introduction to Expert Systems

- Initially, attempts were made to make computers 'intelligent' in a *general* way.
- In 1960s Allan Newell and Herbert Simon wrote computer programs to test the hypothesis that intelligent behavior resulted from heuristic search.
  - GPS is aimed at finding general principles of intelligent problem solving.

Introduction to Expert Systems

- It was quickly realized that the way to make progress was to focus on particular application domains, and expert systems started to appear. Early ones were
  - **DENDRAL** – molecular structure of chemical compounds.
  - **MYCIN** – diagnosis of bacterial infections.

Introduction to Expert Systems

Pioneer work			
1955	Herbert Simon, Allen Newell	Carnegie Mellon	Logic Theorist: proved theorems using propositional logic
1960	Marvin Minsky John McCarthy Claude Shannon	MIT Dartmouth Bell Labs	LISP

Early Expert Systems

1960	DENDRAL	Feigenbaum & Buchanan (Stanford)	Identify chemical constituents
1970	MYCIN	Stanford	diagnosis of infectious diseases
1970	MACSYMA	MIT	Math expert system
1970	HEARSAY	Carnegie Mellon	Speach recognition
1977	PROSPECTOR	Stanford Research Inst Duda, Hart, Barnett	Mineral diagnosis
1978	XCON	McDermott	Computer configuration

Expert Systems

- The term **_expert system_** is used in a seminal paper by Alan Turing in 1937 related to a study in AI.

- **_An Expert System (ES)_** is a computer program that <u>reasons</u> using <u>knowledge</u> to solve <u>complex problems</u>. (Feigenbaum, 1992)

- Traditionally, computers solve complex problems by arithmetic calculations; and the knowledge to solve the problem is only known by the human programmer.

Expert Systems

Expert systems are different from traditional application programs in that their capability to deal with challenging <u>real world problems</u> through the application process that reflect <u>human judgment and intuition.</u>

Expert systems should not be confused with cognitive modeling programs, which attempt to simulate human mental architecture in detail. Expert systems are practical programs that use heuristic strategies developed to solve specific classes of problems.

Expert Systems Applications vs Conventional Systems Applications

Expert Systems Applications	Conventional Systems Applications
Knowledge is fragmented and implicit, is difficult to communicate except in small "chunks", and is often distributed amongst individuals who may disagree.	Knowledge is complete and explicit, and is easily communicated with formulas and algorithms.
Rules are complex, conditional and often defined as imprecise "rules of thumb".	Rules are simple with few conditions.
The finished system captures, distributes and leverages expertise	The finished product automates manual procedures

Expert Systes Applications vs Conventional Systems Applications

Expert Systems Applications	Conventional Systems Applications
Problem-solving demands dynamic, context-driven application of facts, relationship and rules	Problem-solving requires predictable and repetetive sequences of actions.
System performance is measured in degrees of accuracy and completeness where explanations may be required to establish correctness.	Simple criteria are used to determine accuracy and completeness.

Some Concepts in Expert Systems and Conventional Systems

Expert Systems	Conventional Systems	Brief Comment
Inferencing	Program Flow	Inferencing is non-sequential
Knowledge Base	Database	Knowledge Base contains data and strategies
Object Class	Relational Table	Object structure is logical not physical
Object Instance	Relational Table Record	Represents data only, not procedures
Object Attribute	Relational Table Field	Object attributes are inherited, not redefined
Rule	If.. Then Statement	Rule execution is not sequential

Expertise

- Expertise is task-specific knowledge acquired and developed from training, reading and experience. It may consist of
  - Facts, theories, rules, procedures.
  - Guidelines (heuristics) based on intuition
  - Strategies or approaches
  - Meta knowledge
- Most organizations recognize the value of expertise but have difficulty in controlling or quantifying it.
- All individuals have expertise, but it is often unconscious, and there are different levels of expertise.

Expertise

- There is more involved than just 'problem solving' or 'reasoning'. Also important are:

  - Storage of knowledge
  - Dealing with complexity
  - Representation of expertise
  - Confidence in results

Experts

- Experts are people who have uncommon expertise. To be useful, experts must have other qualities also. They should be able to
  - Recognize and formulate problems
  - Explain
  - Organize knowledge (make connections)
  - Determine relevance
  - Solve problems
- We may regard such abilities as desirable in programs or systems which aim to be 'expert'

Structure of an Expert System

- An ES will normally have two aspects:
  - A development environment
  - A consultation environment
- The former is used by the system builder to modify the system. The later is used by the non-expert to obtain knowledge or advice.

- It is the latter which is thought of as an ES.

Structure of an Expert System

- ## An ES is a program with various components:

  1. Knowledge acquisition subsystem
  2. Knowledge base
  3. Inference engine
  4. User interface
  5. Explanation subsystem
  6. Blackboard
  7. Knowledge refinement subsystem

- The last two of these will not necessarily occur.
- We shall consider the others in more detail later.

Architecture of ES
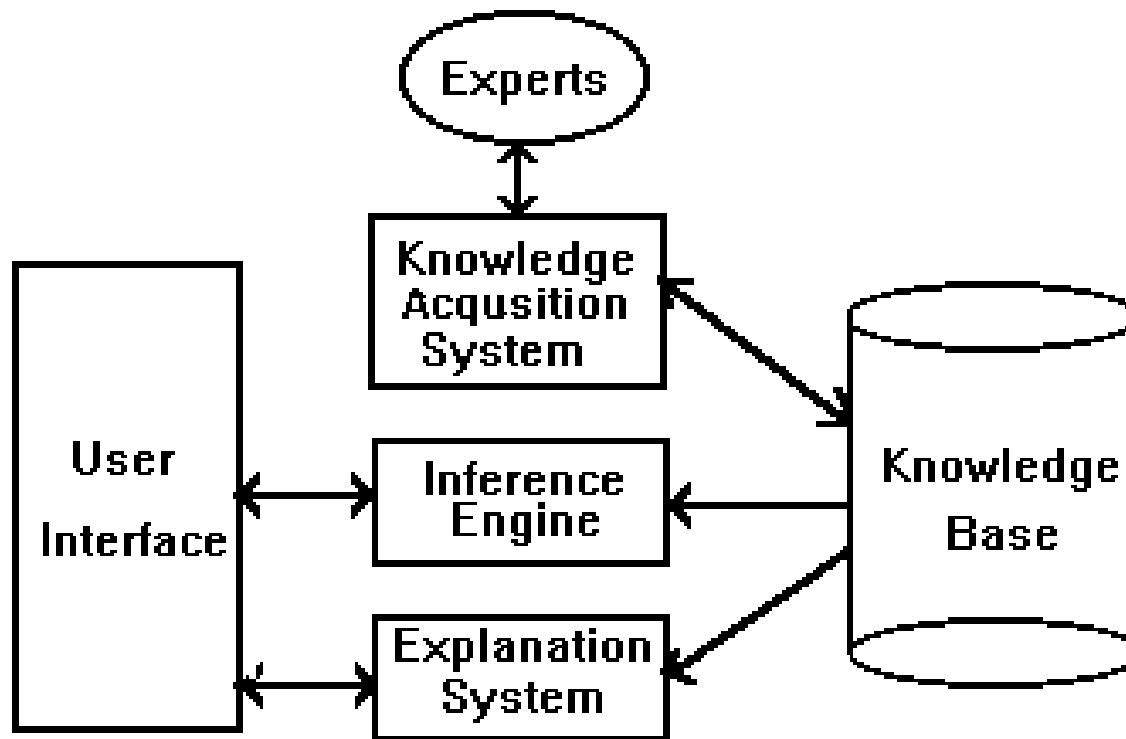
The User Interface

- The user of an ES can be a tester, a tutor, a pupil, or a customer.

- User Interface style could be menu-driven, question and answer, natural language or graphics interface

- User interface facilities are designed to recognize
  - The mode of the user
  - The level of the user's expertise
  - Nature of the transaction

The User Interface

- An ES may obtain input from an online data source (database,text file, web page, etc).

- An ES may be used to monitor a physical system, in which case input may come directly from sensing devices.

- An ES may be used to control a physical system, in which case output will be signals to the system.

- When interacting with humans, standard HCI (*Human-Computer Interaction*) concerns apply.

Knowledge-base

- The power of problem solving is primarily the consequence of the knowledge base and secondarily on the inference method employed.

- A storehouse of knowledge primitives. The design of knowledge representation scheme impacts the design of the inference engine, the knowledge updating process, the explanation process and the overall efficiency of the system.

- Therefore the selection of the knowledge representation scheme is one of the most critical decision in ES design.

Components of the knowledge of the ES

- **Facts:** Ex: Milk is white.

- **Procedural rules**: Well defined invariant rules that describe fundamental sequences of events and relations relative to the domain. (Always check the traffic before merging onto the freeway.)

- **Heuristic rules**: Rules of thumb gained by experience. An expert also has a general conceptual model of the subject domain and an overall scheme for finding a solution.

Knowledge Update

- Manual
  - by the knowledge engineer
 - domain expert

- Machine learning

Knowledge Engineering

- Knowledge engineering is the process of acquiring specific domain knowledge and building it into the knowledge base. Knowledge extraction can be done by

  interviews, observation of the expert at work, evaluation of the material used by the expert.

- This process is termed **knowledge acquisition**. It involves problem definition, implementation, and refinement as well as representing facts and relations acquired from an expert.

Knowledge Engineering
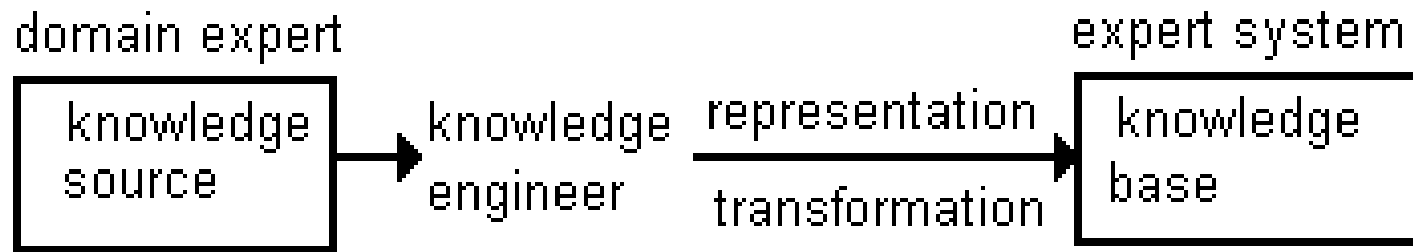
Inference Engine

- The inference engine controls the reasoning involved when the system is run.

- It has its own mechanism for interpreting the stored knowledge (in the appropriate form), and for sequencing the steps involved in reaching conclusions.

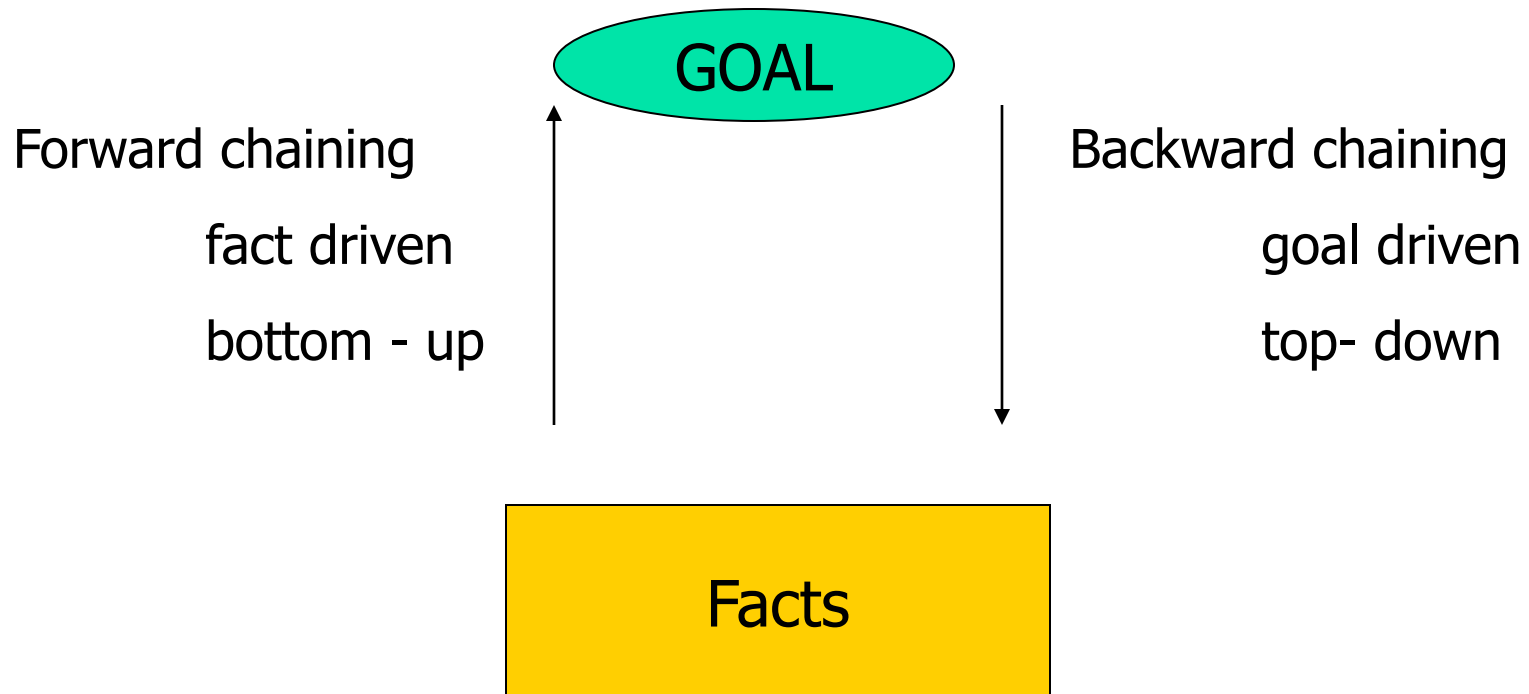- *Inference* here means any of the methods by which the system reaches conclusions.

Inference Engine

- Facts   All animals breathe oxygen.
           All dogs are animals.

- Infer   All dogs breathe oxygen.

Inference Mechanisms

GOAL

Forward chaining

Backward chaining

fact driven

goal driven

bottom - up

top- down

Facts

The selection of the inference paradigm strongly influences the overall performance of the ES

Explanation System

- If the user is to have confidence in the output from an ES, it will be important for the ES to have ways of explaining how its conclusions were arrived at.

It will be useful to allow the user to ask

- In response to a question from the ES:
  WHY (did you ask that question)?

- After a conclusion has been presented:
  HOW (did you reach that conclusion)?

Blackboard

This just means a place where temporary working may be stored, where it is accessible to various component parts of a large ES.

This may include, for example, a (dynamic) 'agenda' --- a list of tasks to be done (by the ES).

It may also include a list of intermediate conclusions, or results of searches, in order to avoid duplication of effort.

Not all ES will use (or need) a blackboard.

Knowledge Refinement Subsystem

Knowledge refinement means analyzing experience and adjusting the body of stored knowledge as a result.

People do this all the time, and a good ES can do it too.

This may consist merely of saving previous results for future reference, to avoid repeating searches or computations.

OR it may involve feedback from the user, e.g.

You (the ES) gave me this advice and it was BAD/GOOD

ES Development Tools

- Conventional Programming
- Symbolic Programming
- ES Shells

Expert Systems

ES's are:

1. Open to inspection, both in presenting intermediate steps and in answering questions about the solution process.

2. Easily modified, both in adding and deleting skills from the knowledge base.

3. Heuristic, in using knowledge to obtain solutions

Development of Expert Systems will allow us not only to provide very powerful technical capabilities but also to further nurture our own understanding of human thought process.

An ideal ES should include:

- Extensive specific knowledge from the domain of interest.
- Extensive database interfaces
- Application of several techniques.
- Support for heuristic analysis.
- Capacity to infer new knowledge from existing knowledge.
- Decisions under uncertainty
- Decisions with unknowns
- Symbolic processing.
- An ability to explain its own reasoning.

Advantages over human experts

- Always and instantly available and performs the same level of expertise.
- Has direct and instantaneous access to the necessary databases and is not bound to the limited, biased and imperfect recollections of the human.
- It is logical, objective and consistent.
- It doesn't forget or make mathematical errors.
- It multiplies the expertise of the firm by being accessible to the other divisions.
- It is a repository for the storage of the knowledge of those experts from whose input it was developed.

Benefits of expert systems

- Scarce expertise made available.
- Integration of expertise from different sources.
- Improved quality (e.g. where an ES assists in design).
- Ability to work with incomplete information.
- Reduced system downtime (ES monitors or finds faults).
- Training (users gain expertise from the ES).
- Makes expertise available in remote locations.
- ES can work faster than people.
- Reliability (ES will not get tired or bored).

Limitations of expert systems compared to human experts:

- A human expert is aware of the cultural factors.
- Human experts are generally aware of the scope and limitations of their knowledge.
- When faced with a new situation a human expert may develop a new and brilliant approach to solving the problem.
- People wish to communicate with other people.
- Human experts are more flexible.
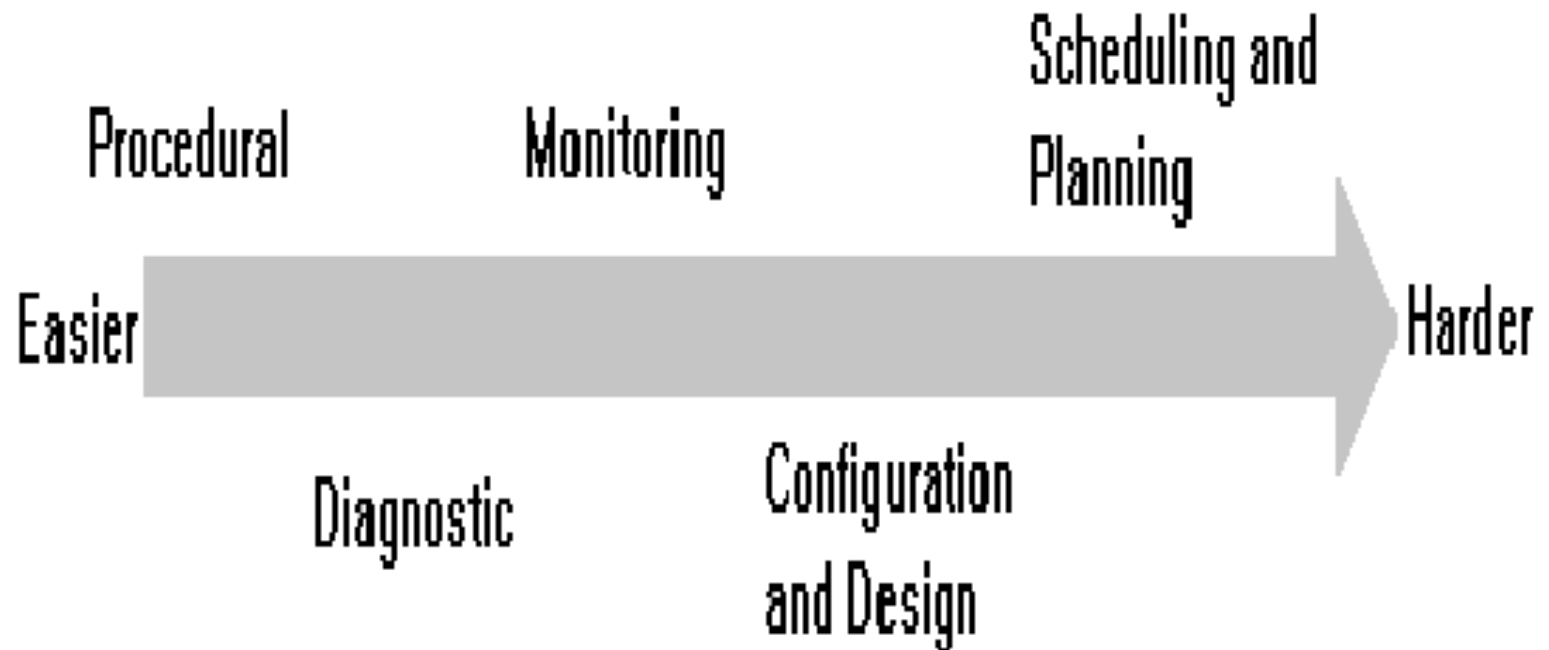
Problems with expert systems

- Expert systems are difficult and expensive to develop and maintain.

- Like all software, ES may contain errors. But unlike other software systems, ES may be designed to cope with incomplete or inconsistent information.

- If an ES gives a wrong conclusion, it may be difficult to know whether this was caused by an error in the system or by an error in the information given to it.

Problems with expert systems

- ES are designed to be used by non-experts. As above, they are designed not to fail, so errors may show only in wrong conclusions, and a user without expertise may not be in a position to recognize a wrong conclusion.

What Problems Can Expert Systems Solve?

Procedural   Monitoring   Scheduling and
                                        Planning

Easier ────────────────────────────────► Harder

            Diagnostic   Configuration
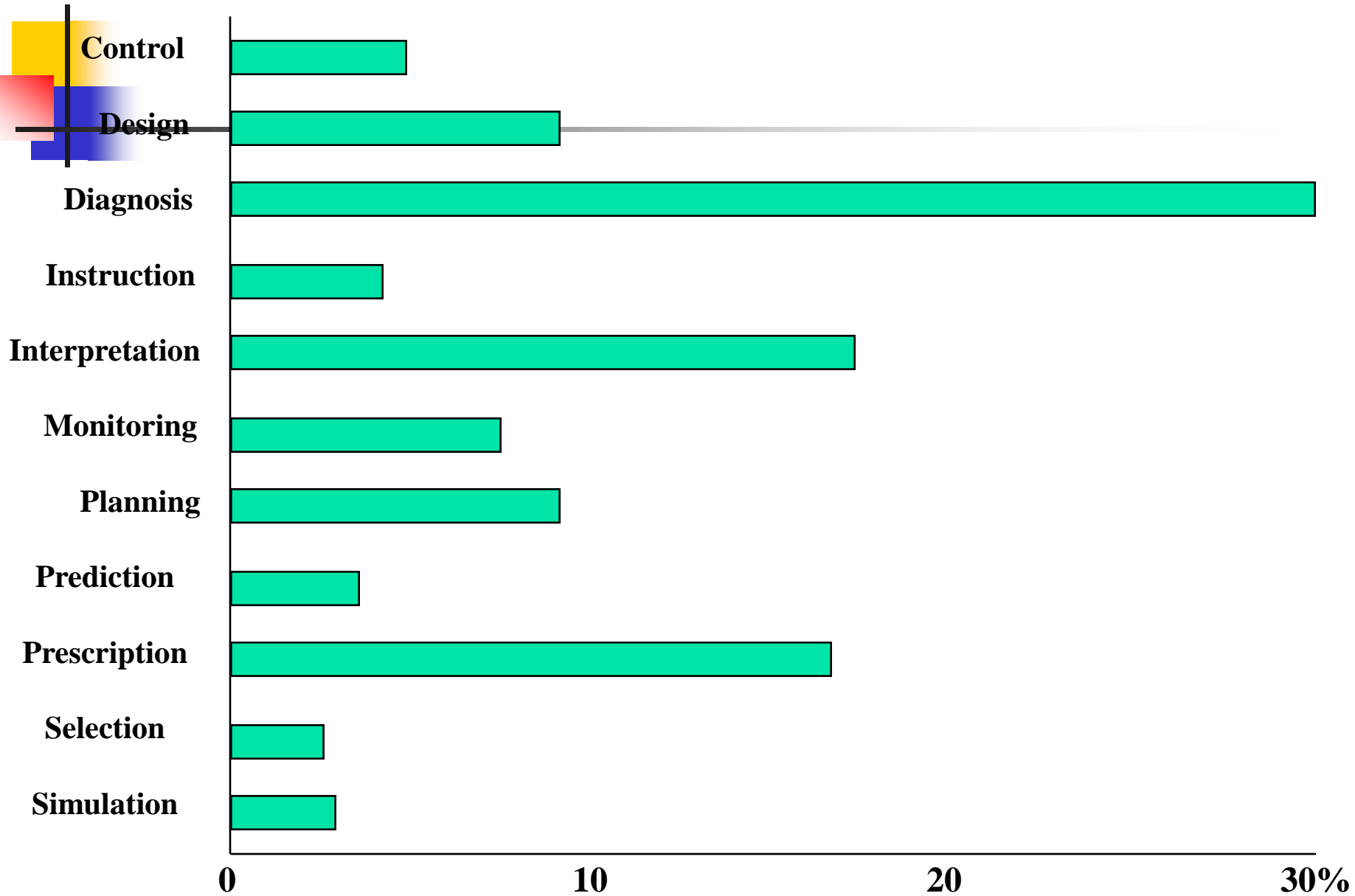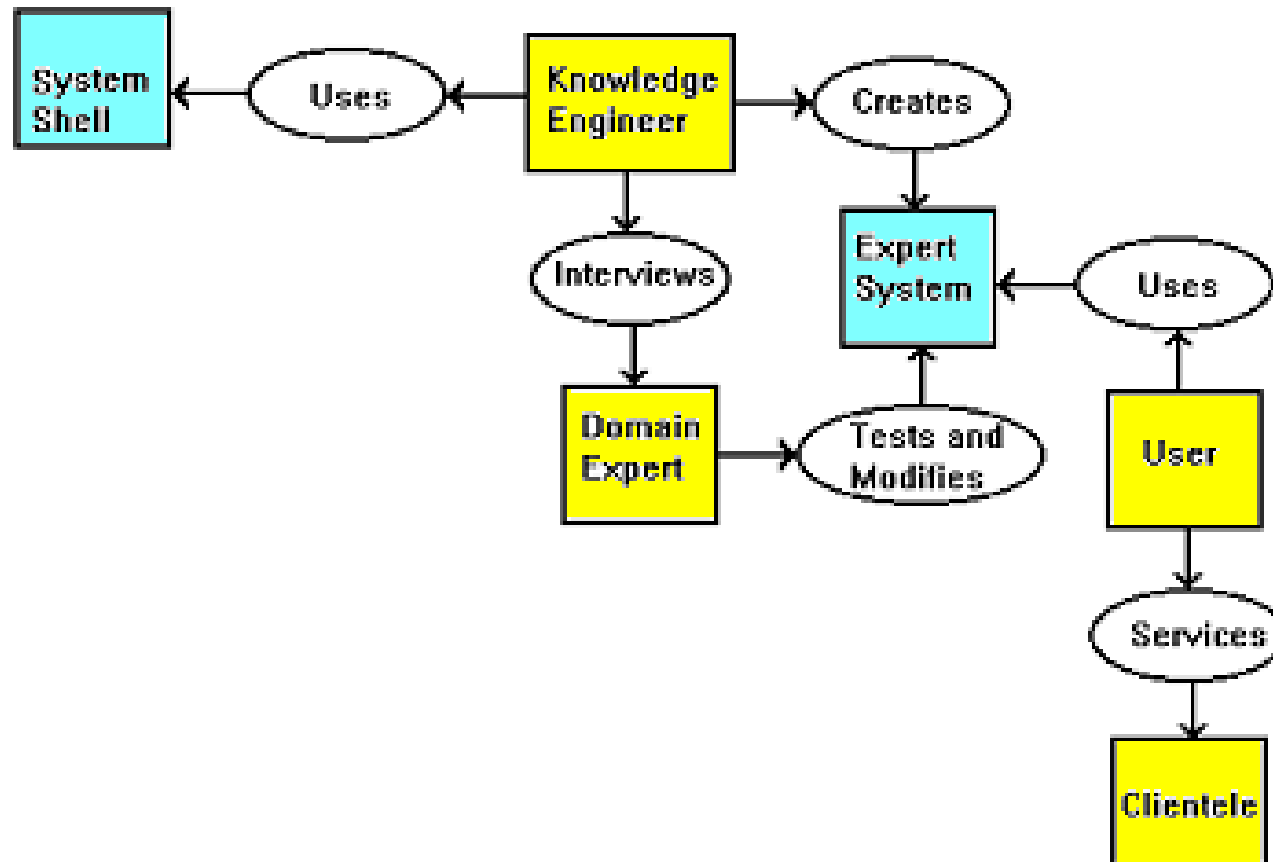   and Design

Where to use expert systems?

- It is important to match expert systems technology with problems of appropriate scope and complexity. Both end of the spectrum should be avoided. Expert systems that solve trivial problems are a waste of time and money, expert systems that provide simplistic answers to complicated problems are also wasteful.

Survey of Problem -Solving Approaches

Approach	Percentage
Control	
Design	
Diagnosis	
Instruction	
Interpretation	
Monitoring	
Planning	
Prediction	
Prescription	
Selection	
Simulation	

0   10   20   30%

Expert Systems Personnel and Their Roles

Expert System Consultation

Example: SELECT AUTO

'Select Auto' is an imaginary (rule-based) expert system designed to assist a user to make a right decision when buying a new car. It asks questions about the user's need and preferences, and makes recommendations of suitable choices of model.

Query:

The desired car is made in

1. **United States**
2. **A foreign country**
3. **Don't know**

Response by user (say): 2

Expert System Consultation (2)

Query:

Quality is

1. The highest concern
2. Of high concern
3. Don't know

Response by user (say): 1

Expert System Consultation (3)

Query:

The price of the car is

    1. Important

    2. Unimportant

    3. Don't know

At this point the user may wish to inquire why the system is asking this particular question, so

Response by user (say): WHY

Expert System Consultation (4)

The system will display rule(s) in which price s a factor.

RULE NUMBER: 5

IF:

     (1)   The price of the car is important and

     (2)   The payment is in installments

THEN

    The monthly payment is [will be] determined

Now the user answers the question

Query:

Monthly payment is to be no more than price of the car is

1. Important
2. Unimportant
3. Don't know

Response by user (say): 1

Expert System Consultation (6)

The questions continue

Query:

The price of the car is

1. $100
2. $150
3. $200
4. $250
5. $300

Response by user (say): 4

Expert System Consultation (7)

Query:

Acceleration should be

1. strong
2. moderate
3. Don't know

Response by user (say): 2

Expert System Consultation (8)

Query:

Desired engine size is

1. 100 – 1500 cc
2. 1501 – 2000 cc
3. Over 2000 cc
4. Don't know

Response by user (say): 2

And so on.

Expert System Consultation (9)

Eventually the system will exhaust its questions and will come to a conclusion.

The conclusion may be that there does not exist a car which has all the attributes which are sought. Another consultation may be tried with different responses

Expert System Consultation

Alternatively, the system may make a recommendation:

Values based on a -100 to $+100$ scale   Value

----

1. Toyota Corolla   51
2. Renault Megane   23

The system has displayed the two best makes with their calculated scores.

General Features

The same question should not be asked twice and the system should remember the answers given.

The order in which questions are asked may depend on the answers given.

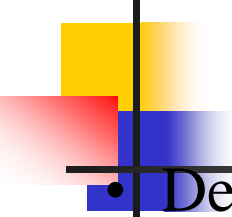"Don't know" options may be interpreted as "don't care".

The responses here are all menu selections. In general, an ES may be designed to accept answers in any from. It may even allow multiple answers.

Evaluation of Expert Systems- The Turing Test

Wall
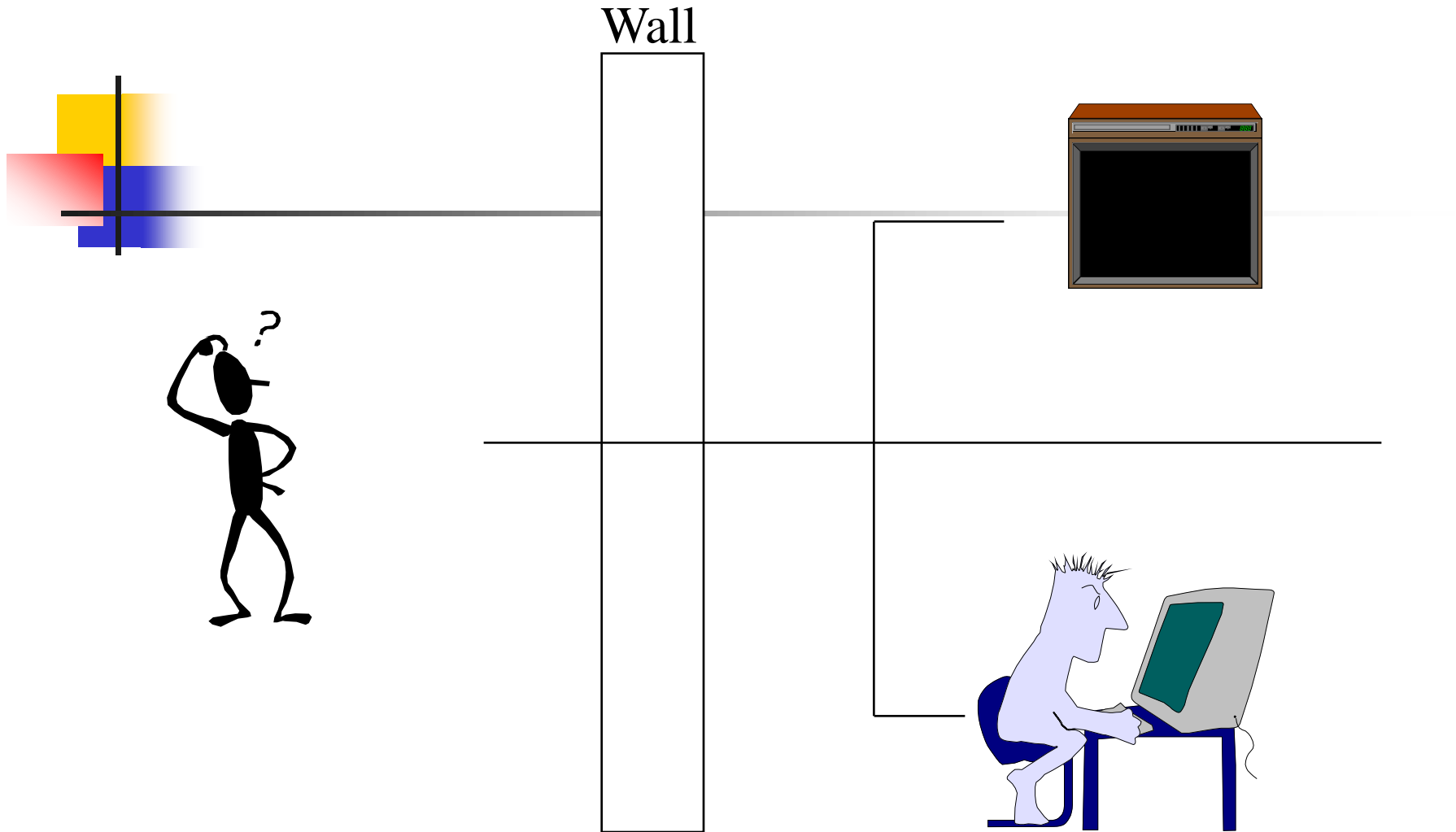
In the Turing test a human communicates with an unseen respondent through a terminal, not knowing if the respondent is a person or a machine. If the tester mistakes computer answers for human answers, the computer successfully passes the Turning test.

ELIZA

- Developed by MIT 1966
- Called ELIZA after Shaws play - it could be taught to speak increasing well
- It picked up words from its conversational partner
- Transform this into a canned response

ELIZA's opening statement (appears on the terminal screen):

Do you have any problems?

Human: Yes. I am unhappy. (types response on the terminal screen)

ELIZA: Why are you unhappy?

Human: My friend is mean to me.

ELIZA: Tell me about your friend. (Rogerian Psychoanalyst)

It could fool people into thinking it was a real person but it contained no intelligence.