Lecture 6:

Introduction to Expert Systems

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BIS4435

OVERVIEW

1. Definition of an expert system (ES)
2. Origins of ES
3. Intelligence and expertise
4. Knowledge representation
5. Early symbolic systems
6. Knowledge–based systems
7. Knowledge engineering
8. Areas of application
9. Advantages and Limitations of ES

WHAT IS AN EXPERT SYSTEM?

Expert Systems (ES) are computer programs that try to replicate knowledge and skills of human experts in some area, and then solve problems in this area (the way human experts would).

- ES take their roots in *Cognitive Science* — the study of human mind using combination of AI and psychology.
- ES were the first successful applications of AI to real–world problems solving problems in medicine, chemistry, finance and even in space (Space Shuttle, robots on other planets).
- In business, ES allow many companies to save $ millions

HISTORICAL BACKGROUND

1943 Post, E. L. proved that any computable problem can be solved using a set of IF–THEN rules.

1961 GENERAL PROBLEM SOLVER (GPS) by A. Newell and H. Simon.

1969 DENDRAL (Feigenbaum, Buchanan, Lederberg) was the first system that showed the importance of *domain–specific knowledge* (expertise).

1970s MYCIN (Buchanan & Shortliffe) medical diagnosis system introduced the use of *certainty factors*.

1982 R1 (aka XCON) by McDermott was the first commercial ES (by 1986 it was saving DEC $40 millions p.a.).

COMPUTERS vs MINDS

- Let’s face it, unlike computers, humans are generally not very good in dealing with numbers and precise computations.
- Humans use symbols and language to solve problems, and they can do it creatively and in many different ways.
- Computers compute very fast, but they use pre–programmed algorithms, which are very limited for specific tasks.

SYMBOLIC and SUB–SYMBOLIC REPRESENTATION

Plane

Train

Car

Symbolic representations are discrete units (explicit), usually expressed in formal language (i.e. words, sentences).

Sub–symbolic representations are not single symbols, but information properties (implicit) of many objects (e.g. probability distributions, weights in neural networks, etc).

000001100000
000110011000
001100001100
011111111110
110000000011

Hybrid systems involve both types of knowledge representation.

A HUMAN EXPERT

Consider several examples:

- A doctor
- Chess grands–master
- Financial wizard
- A chef

What is different between them? Can you say that one is more intelligent than another?

INTELLIGENCE vs EXPERTISE

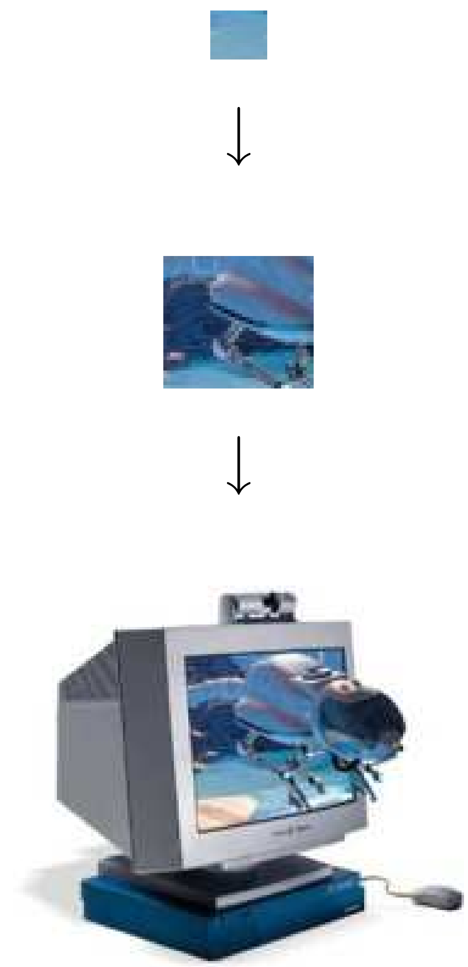
- Expertise and intelligence are not the same things (although they are related).
- Expertise requires long time to learn (e.g. it takes 6 years to become a doctor).
- Expertise is a large amount of knowledge (in some domain).
- Expertise is easily recalled.
- Intelligence allows you to use your expertise (apply the knowledge).
- Expertise enables you to find solutions much faster.

DATA → INFORMATION → KNOWLEDGE

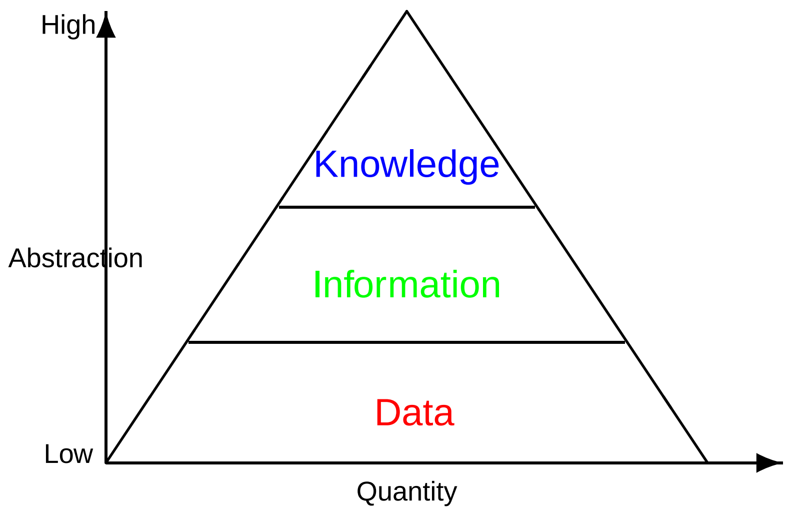
Data — measurements or records about events (prices, temperature, etc). Data can be numerical, alphabetical, images, sounds, etc.

Information — analysed and organised data such that we know its characteristics (average, range, variance, distributions, clusters, etc).

Knowledge — information put into a specific context (e.g. distribution of oil prices, a map of London, etc).



LEVELS OF ABSTRACTION



- Data, Information and Knowledge can be classified by levels of abstraction and quantity.
- Knowledge is the most abstract and exists in the smallest quantity.

Knowledge itself can have levels of abstraction: concrete (knowledge about the specific problem), domain specific (class of problems) and abstract (many classes of problems).

PRODUCTION SYSTEMS

Production systems (or rule–based systems) are programs that instead of conventional algorithms use sets of IF–THEN rules (*production rules*). Unlike in algorithms, the order in which these rules should be used is not specified. It is decided by the program itself with respect to a problem state.

- In 1943, Post proved that any computable problem can be implemented in a production system.
- Cognitive scientists became interested in production systems because they seemed to represent better the way humans think and solve problems.

PRODUCTION SYSTEM EXAMPLE

IF	saturday OR sunday	THEN	go to cinema
IF	NOT (saturday OR sunday)	THEN	go to work
IF	go to cinema	THEN	go outside
IF	go to work AND NOT at work	THEN	go outside
IF	NOT (can go outside)	THEN	stay home
IF	good weather	THEN	can go outside
IF	raining	THEN	have an umbrella
IF	raining AND have an umbrella	THEN	can go outside

EARLY EXPERT SYSTEMS

- In 1961, A. Newell and H. Simon wrote a program called *General Problem Solver* (GPS) that could solve many different problems using only a small set of rules.
- GPS used a strategy known as *means–ends analysis*.
- GPS produced solutions very similar to those people came up with.
- Methods that can be applied to a broad range of problems are called **weak** methods (because they use weak information about the problem domain). Their performance, however, is also usually weak.

KNOWLEDGE–BASED SYSTEMS

- DENDRAL (Feigenbaum et al, 1969) was a program that used rules to infer molecular structure from spectral information. The challenge was that the number of possible molecules was so large, that it was impossible to check all of them using simple rules (weak method).
- The researchers consulted experts in chemistry and added several more specific rules to their program. The number of combinations the program had to test was reduced dramatically.
- DENDRAL demonstrated the importance of the *domain–specific* knowledge.

KNOWLEDGE ENGINEERING

The process of designing an ES is called **knowledge engineering**. It consist of three stages:

Knowledge acquisition : the process of obtaining the knowledge from experts (by interviewing and/or observing human experts, reading specific books, etc).

Knowledge representation : selecting the most appropriate structures to represent the knowledge (lists, sets, scripts, decision trees, object–attribute–value triplets, etc).

Knowledge validation : testing that the knowledge of ES is correct and complete.

MAIN AREAS OF APPLICATION

The main areas of application of ES are (Waterman, 1986):

Interpretation —drawing high–level conclusions based on data.

Prediction —projecting probable outcomes.

Diagnosis —determining the cause of malfunctions, disease, etc.

Design —finding best configuration based on criteria.

Planning —proposing a series of actions to achieve a goal.

Monitoring —comparing observed behaviour to the expected behaviour.

Debugging and Repair —prescribing and implementing remedies.

Instruction —assisting students in learning.

Control —governing the behaviour of a system.

ADVANTAGES AND LIMITATIONS OF ES

Advantages:

- Increased productivity (find solutions much faster than humans).
- Availability of expertise (human experts can be at one place at a time).
- Can be used in dangerous environments (e.g. in space).

Limitations:

- Difficulty in engineering, especially acquiring the expertise.
- Mistrust by the users.
- Effective only in specific areas (areas of expertise).