Expert Systems

Also Known as Rule-Based Systems

Introduction

- Based upon capturing knowledge through hand-engineered sets of rules.
- Very popular in the 1970s
- Held lots of promise…….
- "*Within a generation… the problem of creating 'artificial intelligence' will largely be solved*"
  Marvin Minsky 1967 (was *said* to have quoted this)

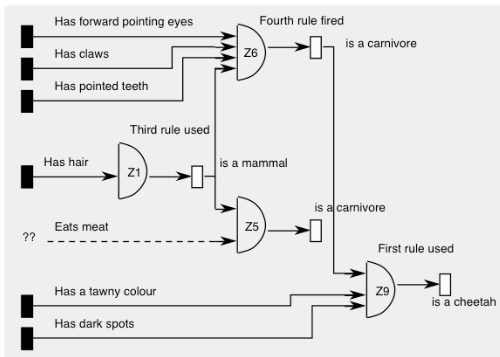
Dendral

- The 1st ever Expert System
  - Stanford University
  - 1965
  - Chemistry
  - Helped analysis of mass spectrographs

Work on the very first expert system was by Edward Feigenbaum and Bruce Buchanan done in the mid-60’s. It was called Dendral and its purpose was to help chemists analyse unknown chemicals from mass spectrographs. Later systems, including Mycin were derived from Dendral.

Introduction

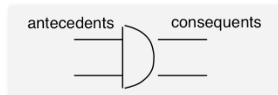
- Expert systems are collections of rules
  - typically chains of *if-then* relations



Rule based deduction systems encompass knowledge using a framework of rules. They are typically built using chains of *if-then* relations which reached many hundreds in large systems. Popular in the mid-70's they gained much attention as a promising approach to achieve artificial intelligence.

Notation

- Antecedants
  - The *if* part
- Consequents
  - The *then* part
- A rule may have multiple antecedants and consequents



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A single rule can contain several *if* statements and one or more *then* statements:

Rule n	If	if_1
		if_2
		if_3
	then	$then_1$
		$then_2$

The *if* statements identify appropriate situations. The *then* statements may specify assertions which are evaluated by further rules.

Forward Chained Rules

- Forward chaining
  - The process of going from *ifs* to *thens*
  - Rule *triggered* or *fired* only if all *ifs* satisfied

Forward chaining

The process of going from *if* patterns to *then* statements is known as forward chaining.

Some terms

Whenever an if pattern is matched against an assertion, the antecedent is *satisfied*.

Whenever all the if patterns of a rule are satisfied, the rule is said to be *triggered*.

Whenever a triggered rule establishes a new assertion, it is *fired*.

Working Memory & Rule Base

- The key ingredients of an expert system are
  - Rule base
    - The collection of rules
  - The Working memory
    - The collection of all assertions from triggered rules

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The key ingredients of an expert system are

The working memory

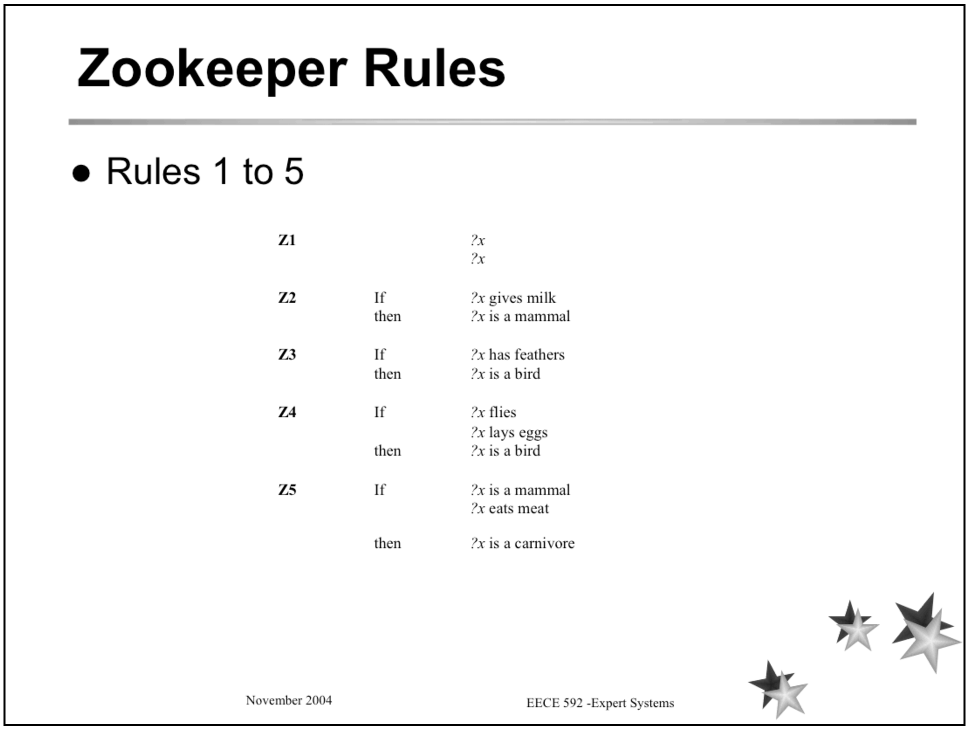
> This is the collection of assertions as related to the symbols used for a specific application.

The rule base

> The set of constraints that enable procedures to seek new assertions or to validate a hypothesis.

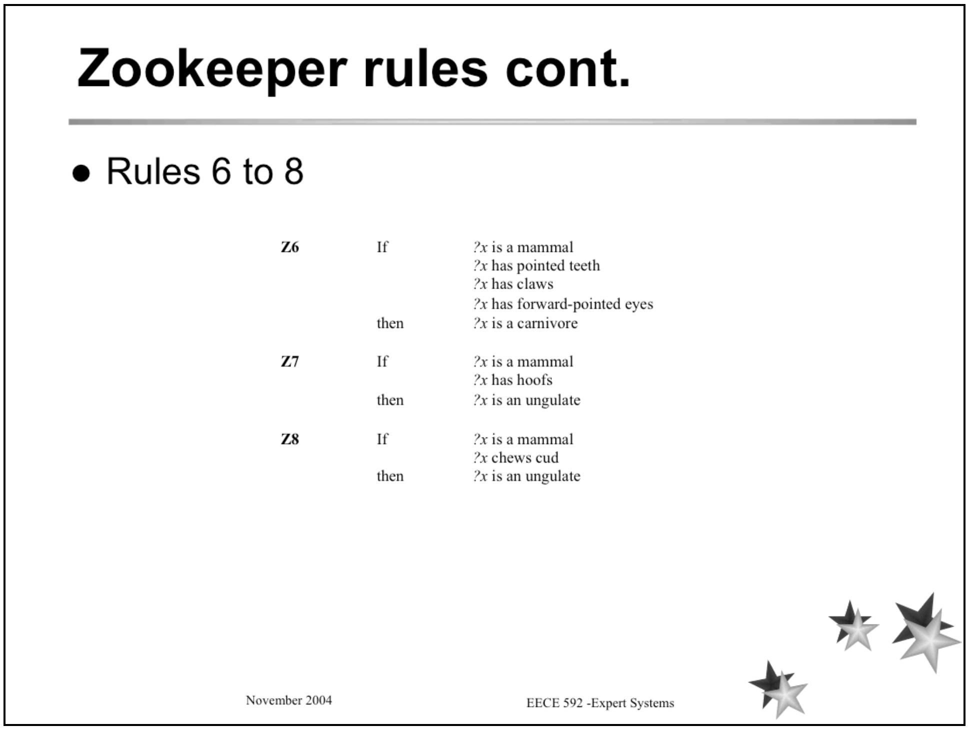
Example of a Forward Chained System

- Zookeeper
  - from Winston, P.H., “Artificial Intelligence”, 3rd edition, 1992.
  - Forward chained system containing just 15 rules



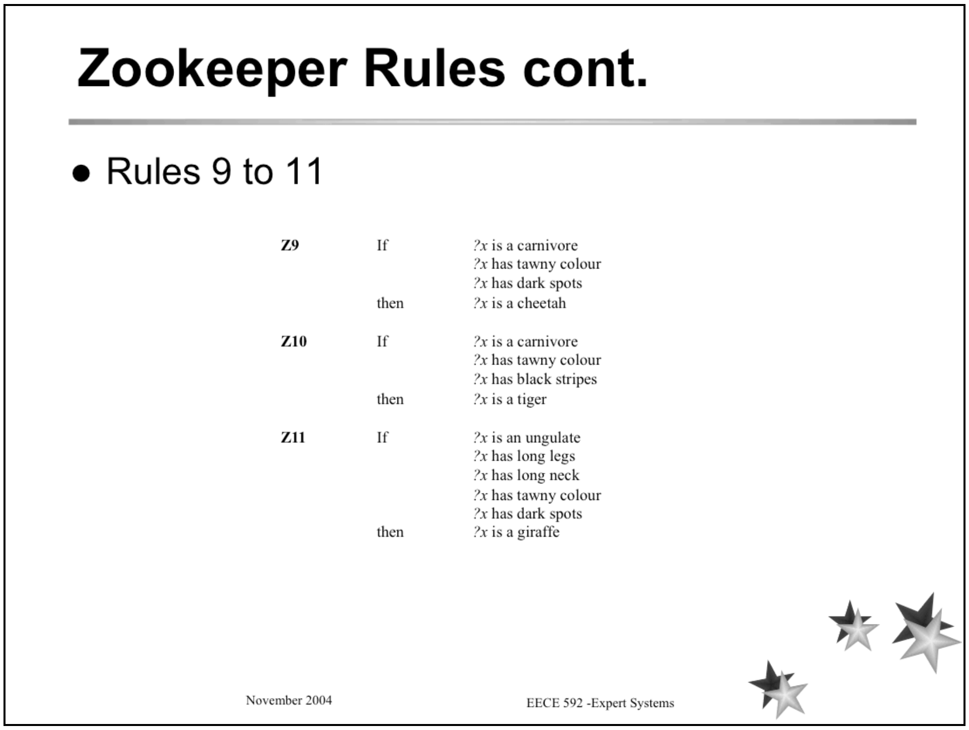
Rules 1 to 5 of 15

Z1	If	*?x* has hair
	then	*?x* is a mammal
Z2	If	*?x* gives milk
	then	*?x* is a mammal
Z3	If	*?x* has feathers
	then	*?x* is a bird
Z4	If	*?x* flies
		?x lays eggs
	then	*?x* is a bird
Z5	If	*?x* is a mammal
		?x eats meat



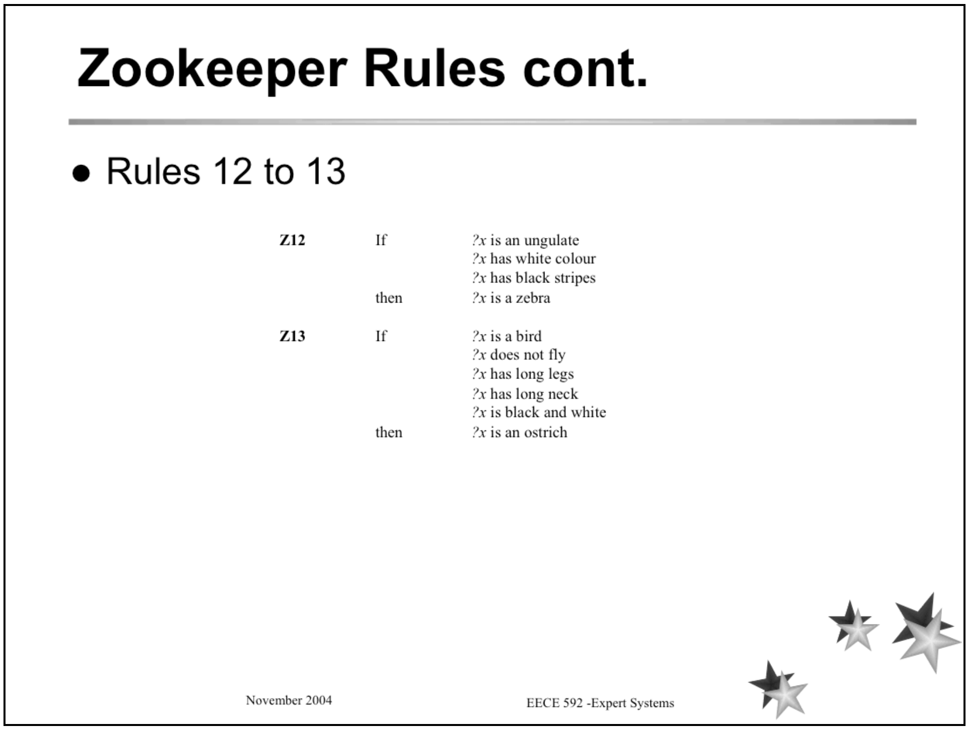
Rules 6 to 8 of 15

Z6	If	*?x* is a mammal
		?x has pointed teeth
		?x has claws
		?x has forward-pointed eyes
	then	*?x* is a carnivore
Z7	If	*?x* is a mammal
		?x has hoofs
	then	*?x* is an ungulate
Z8	If	*?x* is a mammal
		?x chews cud
	then	*?x* is an ungulate



Rules 9 to 11 of 15

Z9	If	*?x* is a carnivore
		?x has tawny colour
		?x has dark spots
	then	*?x* is a cheetah
Z10	If	*?x* is a carnivore
		?x has tawny colour
		?x has black stripes
	then	*?x* is a tiger
Z11	If	*?x* is an ungulate
		?x has long legs
		?x has long neck
		?x has tawny colour
		?x has dark spots
	then	*?x* is a giraffe



Rules 12 to 13 of 15

Z12	If	*?x* is an ungulate
		?x has white colour
		?x has black stripes
	then	*?x* is a zebra
Z13	If	*?x* is a bird
		?x does not fly
		?x has long legs
		?x has long neck
		?x is black and white
	then	*?x* is an ostrich

Zookeeper Rules cont.

- Rules 14 to 15

Z14	If	*?x* is a bird
		?x does not fly
		?x is black and white
		?x swims
	then	*?x* is a penguin
Z15	If	*?x* is a bird
		?x is a good flyer
	then	*?x* is an albatross

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Rules 14 to 15 of 15

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Forward Chaining in Action

- Identify the following animal:
  - – Has hair
  - – Chew cud
  - – Has long legs
  - – Has long neck
  - – Has tawny colour
  - – Has dark spots

An example of forward chaining.

In this case to identify an animal using forward chaining:

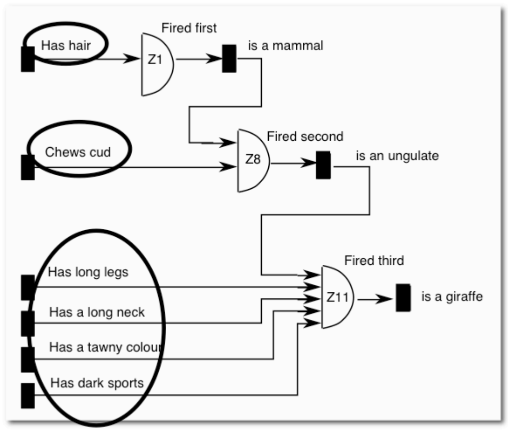
− until the animal is identified,

− for each rule, try to support the antecedents by matching against known facts.

− for matched rules, assert the consequences.

Forward Chaining in Action cont.

- Working Memory:
  - Has hair
  - Chew cud
  - Has long legs
  - Has long neck
  - Has tawny colour
  - Has dark spots
  - Is a mammal
  - Is an ungulate
  - Is a giraffe



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The black squares on the left represent assertions which are supplied as inputs to the system. The assertions, through forward chaining, lead to the conclusion that the unknown animal is a giraffe. Note that the working memory is updated as new assertions are made.

Backward Chaining

- Forward chaining is used to reach a fact/ decision
- Backward chaining is used to verify a hypothesis
  - The rule base is traversed in reverse, backwards instead of forwards.

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In deduction systems based on forward chaining, decisions are reached from a given set of assertions to new deduced assertions until a fact is reached.

A rule based system can also begin with a *hypothesis* and work backwards recursively through the *antecedent - consequent* rules to assertions which support the hypothesis.

This is known as backward chaining.

Backward Chaining in Action

- Identify the following animal:
  - Has forward pointing eyes
  - Has claws
  - Has pointed teeth
  - Has hair
  - Has tawny colour
  - Has dark spots
- Hypothesis is that it is a cheetah - verify hypothesis

To identify an animal:

− form a hypothesis for what animal is suspected.

− for a given hypothesis

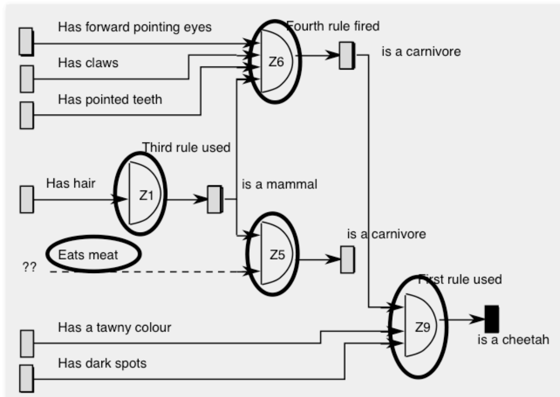
− for each rule whose consequent matches the current hypothesis

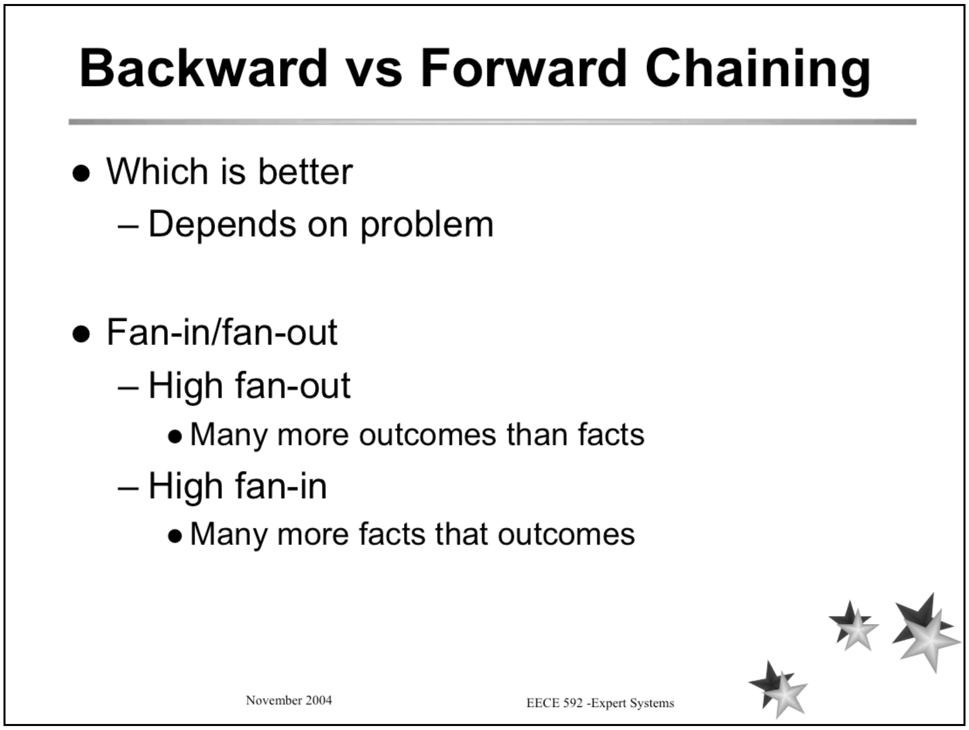
− try to support each of the rule’s antecedents by matching it to assertions or by backward chaining and creating new hypotheses.

− if all the rules antecedents are supported announce success and conclude that the hypothesis is true.

Backward Chaining in Action cont.

- Working memory
  - Has forward pointing eyes
  - Has claws
  - Has pointed teeth
  - Has hair
  - Has tawny colour
  - Has dark spots
  - Is a mammal
  - Is a carnivore
  - Is a cheetah





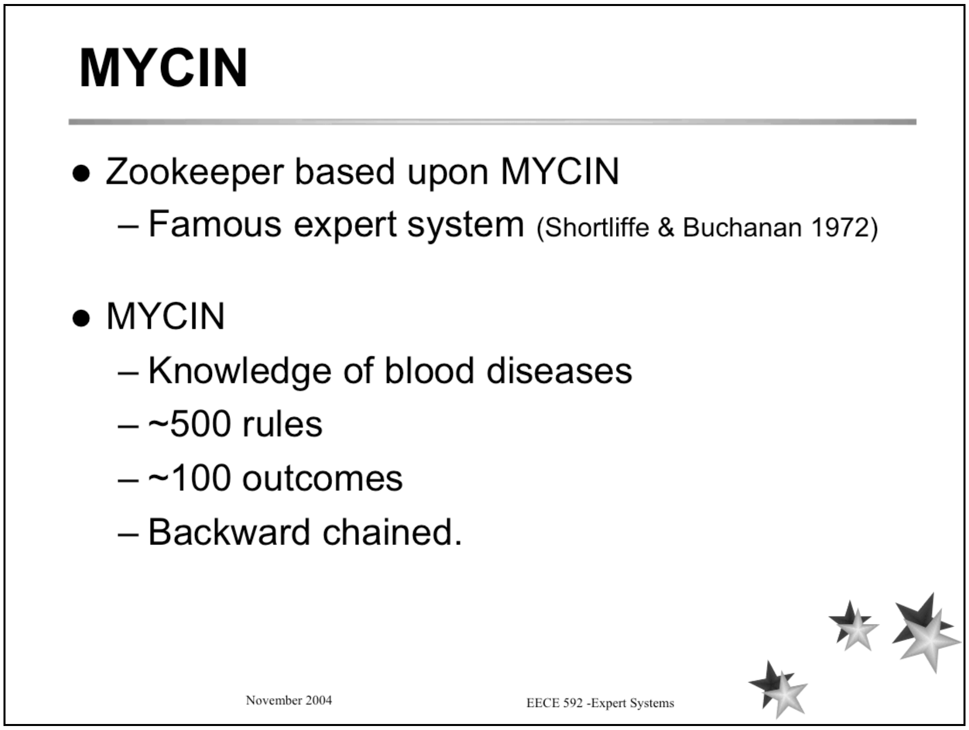
Which is better?

Usually, the problem itself determines which approach would be more efficient.

Fan-in / Fan-out

Winston talks about the terms *fan-in* and *fan-out* of rules and uses fan out as a general rule of thumb.

> If a set of facts can lead to many conclusions then there is a high degree of fan-out which argues for backward chaining.
>
> If the rules are such that a typical hypothesis can lead to many questions, the system exhibits a high degree of fan-in for which forward chaining is more efficient.



Zookeeper is based on MYCIN (Shortliffe and Buchanan, 1972), historically one of the most famous rule based systems.

MYCIN, designed for diagnosing infectious diseases of the blood, intended to help physicians in prescribing disease specific drugs. MYCIN is composed of about 500 antecedent-consequent rules giving it the ability to recognize about 100 causes of bacterial infection.

A MYCIN Rule

- Example of a rule

```
if      blood_pressure = extremely_low
                    skin_colour = ashen
        then
                    conclude vivacous = false
                    (confidence = 0.95)
```

- Imprecisions in the decision process are handled by propagation of confidence measures.

The confidence measures are used to handle the imprecision involved with diagnosis. Confidence manipulations are based upon *fuzzy logic* and are somewhat adhoc in nature.

One reason why MYCIN is based upon backward chaining is the nature in which it is used. Typically physicians tend to think about one hypothesis at a time - this way questioning can be kept relevant. Forward chained systems can jump about seemingly at random.

Comparison with NN

- Expert system can justify a decision
  - NN cannot
  - Critical for medical diagnosis!
- Experts cannot process vast amounts of information
  - NN can
  - E.g. visual processing.

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Neural Nets vs. Expert Systems

In some applications, it would be ridiculous to rely upon an automated system that is incapable of explaining its result. An example of this is medical diagnosis. Without reasoning or knowing the machines level of confidence, a physician could not be comfortable with any diagnostic assistance provided. Although neural networks could no-doubt be trained to perform equally well as expert systems, it is very unlikely that they could easily generate an accurate explanation. On the other hand, rule based systems facilitate this very easily.

Advantages of Expert Systems

- Ability to preserve expertise
  - E.g. NASA experts reaching retirement age
- Ability to think rapidly
  - Useful in automated stock trading
- Often the only approach
  - Necessity in automated trajectory control
  - Loan approval

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Appeal of expert systems

Expert systems allow us to preserve expertise. For example, in many programs it is useful if experience of key personnel can be captured in a re-useable way. NASA is facing this problem as many of their experts are reaching retirement age.

For some applications, quick action is important. For example stock trading by computers places a great emphasis on speed.

In some areas, automated decision making is often the only viable approach. Loan approval would otherwise require a team of financiers to establish credit worthiness if expert systems were not available.

Problems with Expert Systems

- Construction/debugging non-trivial
- Very difficult to extract human knowledge
- Not all problems suited to rule-based approaches
  - E.g. face recognition

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Critique of expert systems

Construction and debugging of a knowledge base is one of the biggest practical problems faced in the development of an expert system.

It is often very difficult to get a human expert to express knowledge in terms of rules and confidence factors.

Not all problem domains can be naturally expressed in terms of if-then rules. For example, it would be very tedious to construct an expert system for recognizing images, even simple pixel patterns.