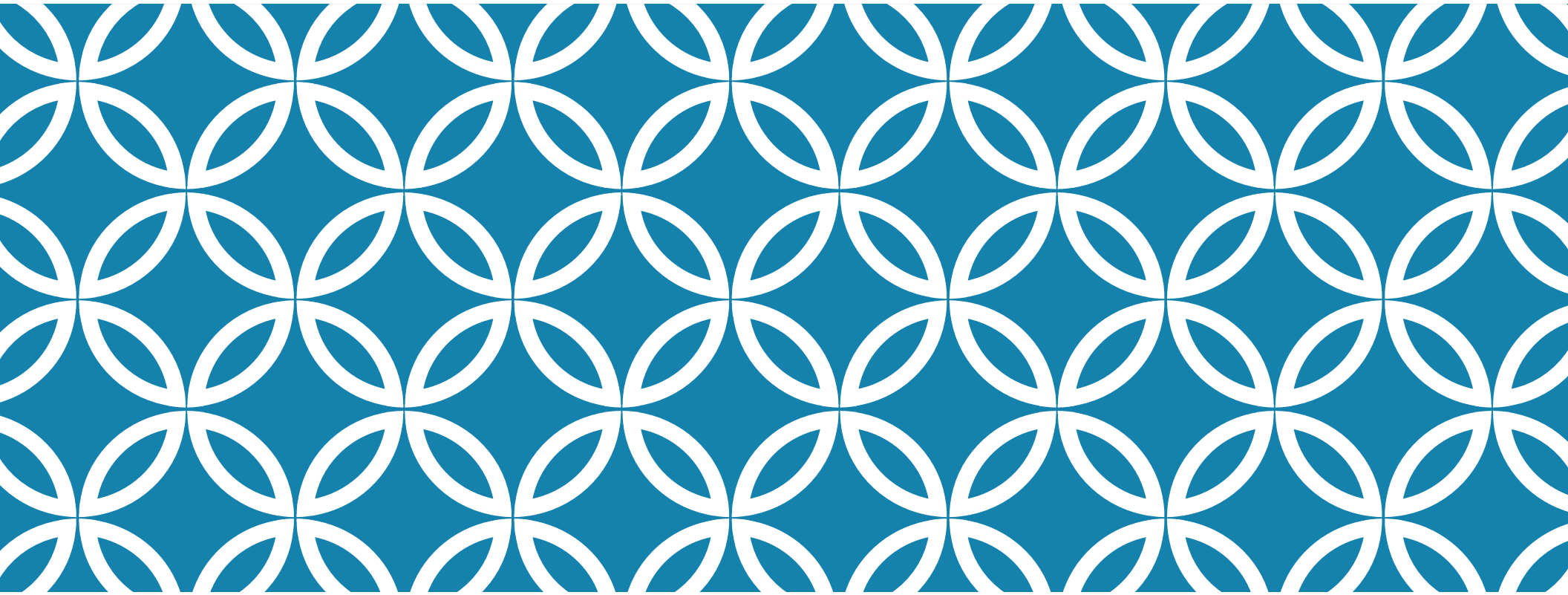


EXPERT SYSTEMS

RECAP

FOL

Quantifiers, for all, there exists, implies and and

De-morgan's law

Forward and backward chaining

EXPERT SYSTEM

Attempt to model expert decision making in a limited domain

Examples: medical diagnosis, computer configuration, machine fault diagnosis

Requires a willing Expert

Requires knowledge representable as rules

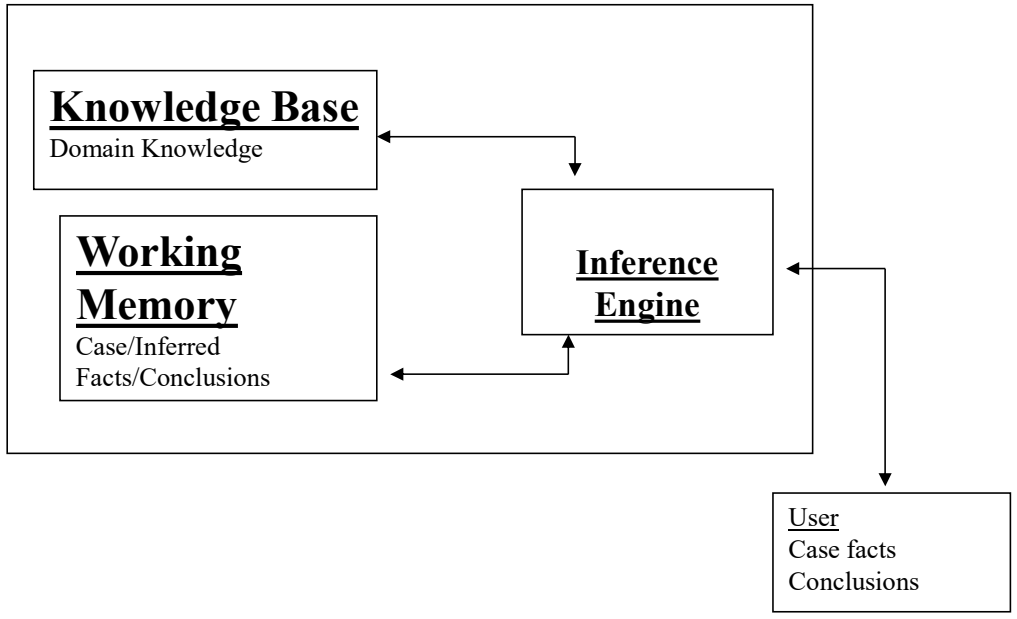
- Doesn't work for chess

Preponderance of evidence for decision, not proof. (Civil law suits)

RULE BASED REASONING SYSTEMS

Expert Systems

A computer program designed to model the problem solving ability of a human expert.



EXPERT & KNOWLEDGE-BASED SYSTEMS

One of AI's greatest areas of success was the development of large-scale problem solving systems

- Originally called expert systems, they would mimic the problem solving processes of domain experts
  - Such as doctors performing diagnosis, or engineers performing design, or wall street analysts selecting stock transactions

Expert systems were originally developed by hand

- And most commonly in some Lisp dialect

It was discovered that many problems were being solved by chaining through rules (if-then statements) that would operate on a collection of facts and partial conclusions

- Called working memory

These rule-based systems led to the first AI tools or shells

- Today, to simplify expert system creation, most people use these AI shells – you just fill in the knowledge, the problem solving processes are already implemented

EXAMPLES AND NON-EXAMPLES

Soybean diagnosis

- Expert codified knowledge in form of rules
- System almost as good
- When hundreds of rules, system seems reasonable.

Chess

- Experts but no codification in terms of rules

WHY BOTHER?

Reproduce Expertise: make available

Record Expertise: experts die

Combine expertise of many

- Didn't work

Teach expertise

- Didn't work

Expand application area of computers

- What tasks can computers do?

ARCHITECTURE

Domain Knowledge as “if-then” rules

Inference Engine

- Backward chaining
- Forward chaining

Calculus for combining evidence

- Construct all proofs, not just one

Explanation Facility: can answer “why?”

PATTERN MATCHING

Expert Systems consisted of two major components

- A knowledge base
  - The knowledge that the system would use to come to conclusions
- An inference engine
  - How to apply the knowledge
- More generically though, the inference engine would embody some form of pattern matching

EXPERT SYSTEMS - KNOWLEDGE BASE

Part of an expert system that contains domain knowledge. Contains highly specialised knowledge on the problem area, as provided by the expert.

It includes problem facts, rules, concepts and relationships

For example: Knowledge for diagnosing blood diseases, portfolio planning, etc.

Typical way of knowledge representation is IF-THEN “rules

CONJUNCTIVE NORMAL FORM

The resolution rules that we studied in last couple of slides apply only on disjunction ($\vee$) of literals (or clauses as they are called).

Every sentence of propositional logic is logically equivalent to a conjunction of clauses.

A sentence expressed as a conjunction of clauses is said to be in conjunctive normal form or CNF.

Example: $(P_{3,3} \vee S_{3,1}) \wedge (\neg S_{3,1} \vee P_{1,2} \vee P_{3,3}) \wedge \ldots$

$B_{1,1} \Leftrightarrow (P_{1,2} \vee P_{2,1})$ INTO CNF?

1. Eliminate $\Leftrightarrow$, replacing $\alpha \Leftrightarrow \beta$ with $(\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)$.

$$(B_{1,1} \Rightarrow (P_{1,2} \vee P_{2,1})) \wedge ((P_{1,2} \vee P_{2,1}) \Rightarrow B_{1,1}) .$$

2. Eliminate $\Rightarrow$, replacing $\alpha \Rightarrow \beta$ with $\neg\alpha \vee \beta$:

$$(\neg B_{1,1} \vee P_{1,2} \vee P_{2,1}) \wedge (\neg(P_{1,2} \vee P_{2,1}) \vee B_{1,1}) .$$

3. CNF requires $\neg$ to appear only in literals, so we "move $\neg$ inwards"

$$(\neg B_{1,1} \vee P_{1,2} \vee P_{2,1}) \wedge ((\neg P_{1,2} \wedge \neg P_{2,1}) \vee B_{1,1}) .$$

4. Now we have a sentence containing nested $\wedge$ and $\vee$ operators applied to literals. We apply the distributivity law from Figure 7.11, distributing $\vee$ over $\wedge$ wherever possible.

$$(\neg B_{1,1} \vee P_{1,2} \vee P_{2,1}) \wedge (\neg P_{1,2} \vee B_{1,1}) \wedge (\neg P_{2,1} \vee B_{1,1}) .$$

CONJUNCTIVE NORMAL FORM (CNF)

- Resolution works best when the formula is of the special form: it is an $\wedge$ of $\vee$s of (possibly negated, $\neg$) variables (called literals).

- This form is called a Conjunctive Normal Form, or CNF:
  - $(y \vee \neg z) \wedge (\neg y) \wedge (y \vee z)$ is a CNF
  - $(x \vee \neg y \vee z)$ is a CNF. So is $(x \wedge \neg y \wedge z)$.
  - $(x \vee \neg y \wedge z)$ is not a CNF

- An AND ($\wedge$) of CNF formulas is a CNF formula.
  - So if all premises are CNF and the negation of the conclusion is a CNF, then AND of premises AND NOT conclusion is a CNF.

CNF AND DNF

- Every truth table (Boolean function) can be written as either a conjunctive normal form (CNF) or disjunctive normal form (DNF)
- **CNF is an $\wedge$ of $\vee$s,** where $\vee$ is over variables or their negations (literals); an $\vee$ of literals is also called a **clause.**
- **DNF is an $\vee$ of $\wedge$s;** an $\wedge$ of literals is called a **term.**

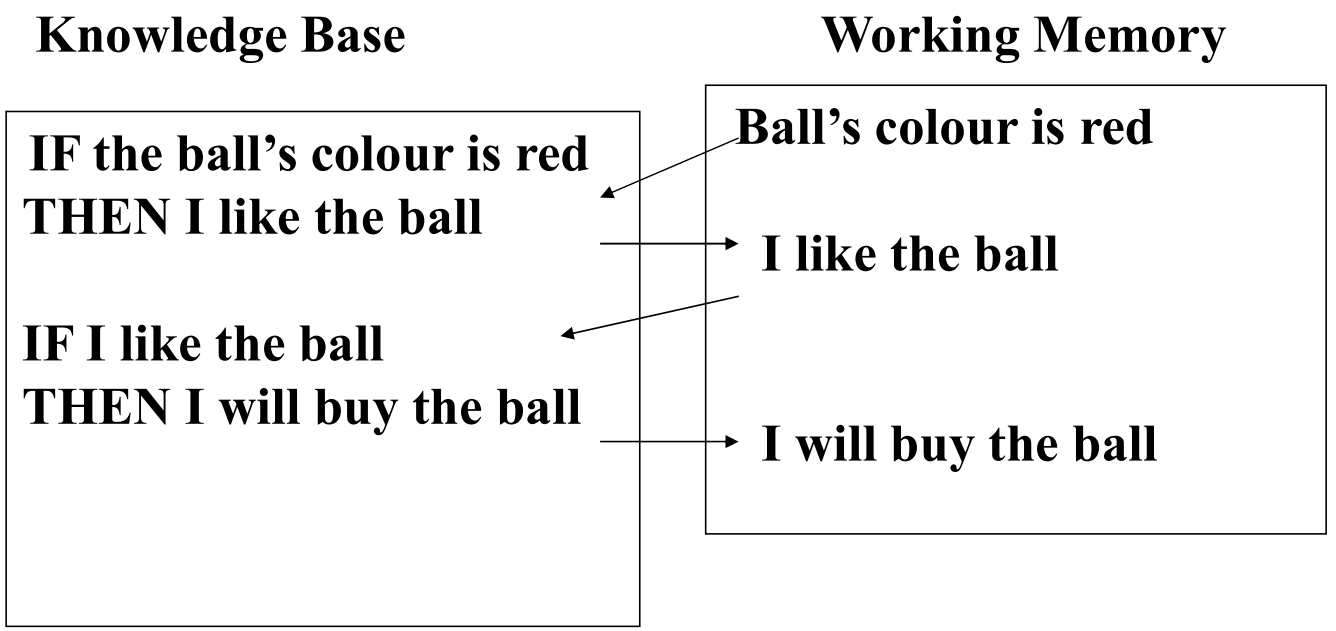
EXPERT SYSTEM – INFERENCE ENGINE

Knowledge processor modelled after the expert's reasoning.

It matches the facts contained in the working memory with the domain knowledge contained in the knowledge base, to draw conclusions about the problem

Example: recognize-act cycle of Production Systems

EXPERT SYSTEMS



EXPERT SYSTEM – WORKING MEMORY

Part of an expert system that contains the problem facts discovered during the session.

It is a model of short term memory of human experts.

Contains all information supplied by the user or inferred by the system

EXPERT SYSTEMS – FORWARD AND BACKWARD CHAINING

forward chaining (data-driven)

- reasoning from facts to the conclusion
- as soon as facts are available, they are used to match antecedents of rules
- a rule can be activated if all parts of the antecedent are satisfied
- often used for real-time expert systems in monitoring and control

backward chaining (query-driven)

- starting from a hypothesis (query), supporting rules and facts are sought until all parts of the antecedent of the hypothesis are satisfied
- often used in diagnostic and consultation systems

EXPERT SYSTEMS - EXPLANATION FACILITY:

This module provides an explanation to the user about “why” an expert system is asking a question and “how” it reached a conclusion

EXPERT SYSTEMS – USER INTERFACE

The interaction between an expert system and user is highly interactive and conducted in a natural language style

EXPERT SYSTEMS – COMPONENTS OF EXPERT SYSTEMS

knowledge base

- contains essential information about the problem domain
- often represented as facts and rules

inference engine

- mechanism to derive new knowledge from the knowledge base and the information provided by the user
- often based on the use of rules

User interface

- interaction with end users
- development and maintenance of the knowledge base

EXPERT SYSTEMS – CONCEPTS & CHARACTERISTICS OF EXPERT SYSTEMS

knowledge acquisition

- transfer of knowledge from humans to computers
- sometimes knowledge can be acquired directly from the environment
  - machine learning, neural networks

knowledge representation

- suitable for storing and processing knowledge in computers

inference

- mechanism that allows the generation of new conclusions from existing knowledge in a computer

explanation

- illustrates to the user how and why a particular solution was generated

MYCIN: 1972-1980

50-500 rules, acquired from expert by interviewing. Blood disease diagnosis.

Example rule:

if stain of organism is gramneg and morphology is rod and aerobicity is aerobic then strongly suggestive (.8) that organism is enterocabateriacease.

Rules matched well knowledge in domain: medical papers often present a few rules

Rule = nugget of independent knowledge

FACTS ARE NOT FACTS

Morphology is rod requires microscopic evaluation.

- Is a bean shape a rod?
- Is an “S” shape a rod?

Morphology is rod is assigned a confidence.

All “facts” assigned confidences, from 0 to 1.

MYCIN

Begins with a few facts about patient

- Required by physicians but irrelevant

Backward chains from each possible goal (disease).

Preconditions either match facts or set up new subgoals. Subgoals may involve tests.

Finds all “proofs” and weighs them.

Explains decisions and combines evidence

Worked better than average physician.

Never used in practice.

Methodology used.

FUZZY SYSTEMS

Knowledge is almost always incomplete and uncertain.

Thus a rule may have associated with it a *confidence factor* or a weight.

The set of methods for using uncertain knowledge in combination with uncertain data in reasoning is called *reasoning with uncertainty*.

A subclass of methods for reasoning with uncertainty is called "fuzzy logic," and the systems are known as "fuzzy systems."

AI WINTER

Expert Systems found useful

- hundreds of successful systems

Consultants and hype ->

- Hundreds of unsucessful systems

Remember:

- needs an expert
- Knowledge needs to be representable as rules

Now on to Probability based approach