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# CS 332 Artificial Intelligence

SCHOOL OF COMPUTER ENGINEERING AND TECHNOLOGY

# CS 332 Artificial Intelligence

**Teaching Scheme**

**Theory: 3** Hrs / Week

**Credits: 3 + 1 = 4**

**Practical:** 2 Hrs / Week

**Course Objectives:**

1) To understand the concept of Artificial Intelligence (AI)
2) To learn various peculiar search strategies for AI
3) To develop a mind to solve real world problems unconventionally with optimality

**Course Outcomes:**

1) Identify and apply suitable Intelligent agents for various AI applications
2) Design smart system using different informed search / uninformed search or heuristic approaches.
3) Identify knowledge associated and represent it by ontological engineering to plan a strategy to solve given problem.

# Syllabus

**Expert System**

Architecture of Expert system, Role of Expert system,

Capabilities of Expert Systems, Inference engine, Knowledge acquisition,

Expert Systems Limitations, Expert systems shells,

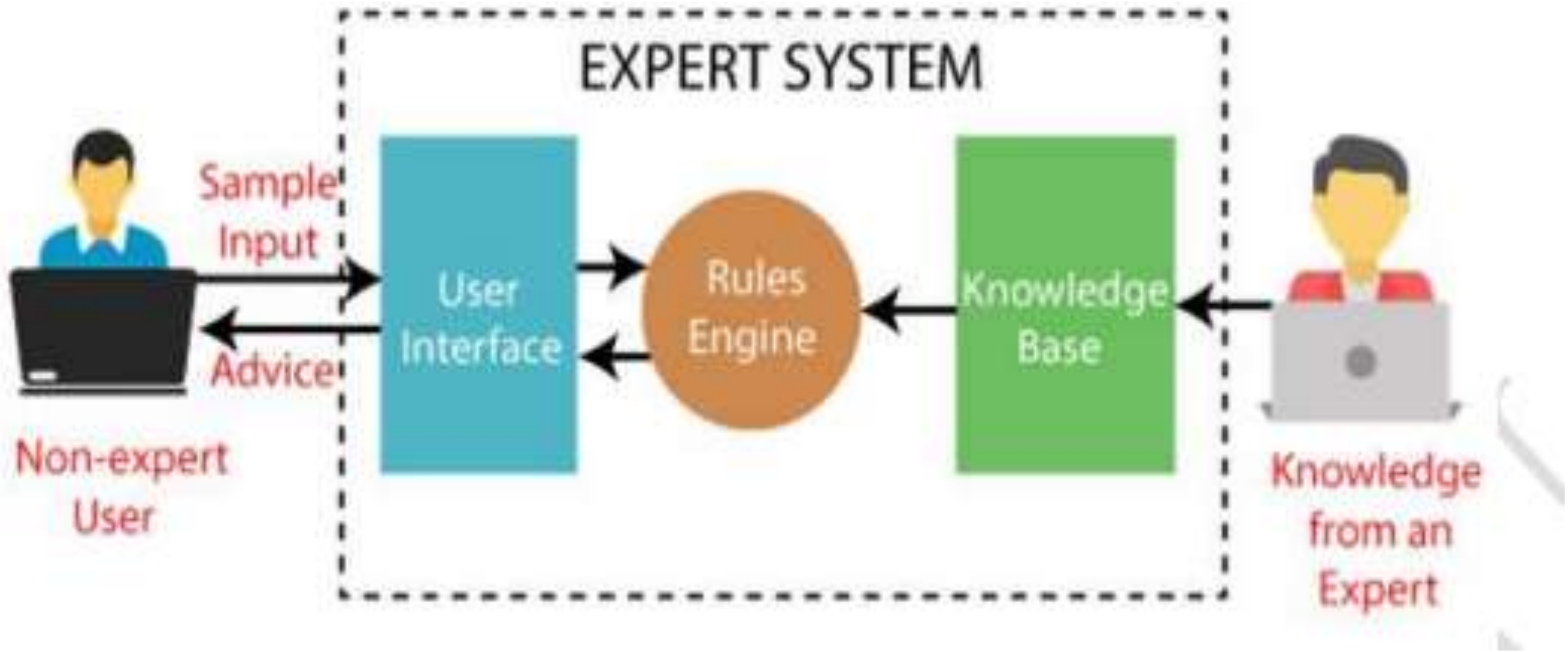
Applications of Expert systems,

Case study of Expert systems- MYCIN

# Expert System

- It is a **computer program** that is designed to solve **complex problems** and to **provide decision-making ability** like a human expert.
- It performs this by extracting knowledge from its knowledge base using the **reasoning and inference rules** according to the user queries.
- The performance of an expert system is based on the expert's knowledge stored in its **knowledge base.**
- The more knowledge stored in the KB, the more that system improves its performance.
- One of the common examples of an ES is a suggestion of spelling errors while typing in the Google search box. tr

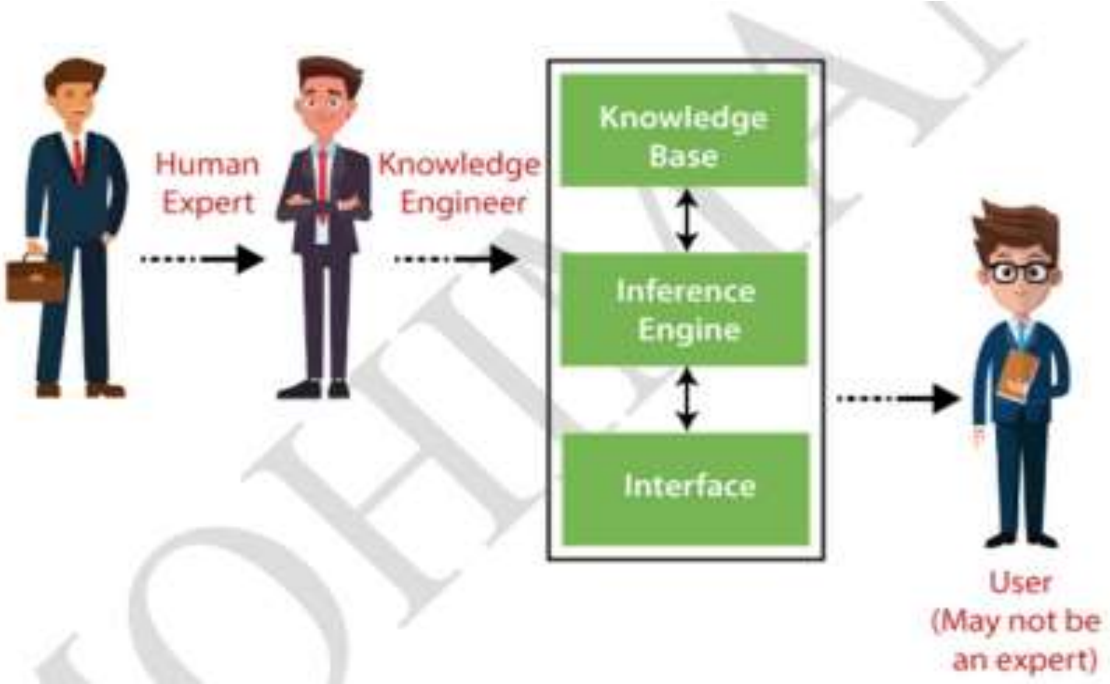
# Architecture



# Components of Expert System

**An expert system mainly consists of three components:**

- User Interface
- Inference Engine
- Knowledge Base



# Components of Expert System

**1. User Interface –**

- The expert system interacts with the user via a user interface
- It takes queries as an input in a readable format, and passes it to the inference engine. After getting the response from the inference engine, it displays the output to the user
- An interface that allows a non-expert to communicate with the expert system and find a solution

# Components of Expert System

**2. Inference Engine (Rules of Engine)**

- Also known as the brain of the expert system
- Main processing unit of the system
- Applies inference rules to the knowledge base (KB) to derive a conclusion or deduce new information
- With the help of an inference engine, the system extracts the knowledge from the knowledge base.

# Components of Expert System

There are two types of inference engine

**Deterministic Inference engine:**

The conclusions drawn from this type of inference engine are assumed to be true.

It is based on facts and rules.

**Probabilistic Inference engine** :

This type of inference engine contains uncertainty in conclusions and based on the probability**.**

# Components of Expert System

Inference engine uses the below modes to derive the solutions

- **Forward Chaining:** It starts from the known facts and rules and applies the inference rules to add their conclusion to the known facts.
- **Backward Chaining:** It is a backward reasoning method that starts from the goal and works backward to prove the known facts.

# Components of Expert System

**3. Knowledge Base**

- Database that contains information and rules of a particular domain or subject.
- Storage that stores knowledge acquired from the different experts of the particular domain
- The more the knowledge base, the more precise will be the Expert System
- Knowledge base as collections of objects and their attributes

**E.g** - Such as a Lion is an object and its attributes are it is a mammal, it is not a domestic animal, etc.

# Components of Expert System

Components of Knowledge Base:

- **Factual Knowledge:** The knowledge which is based on facts and accepted by knowledge engineers comes under factual knowledge.
- **Heuristic Knowledge:** This knowledge is based on practice, the ability to guess, evaluation, and experiences

# Role of Expert system in AI

- An expert system is a computer system that emulates the decision-making ability of a human expert
- Expert systems are designed to solve complex problems by reasoning

**What is the role of AI in information system?**

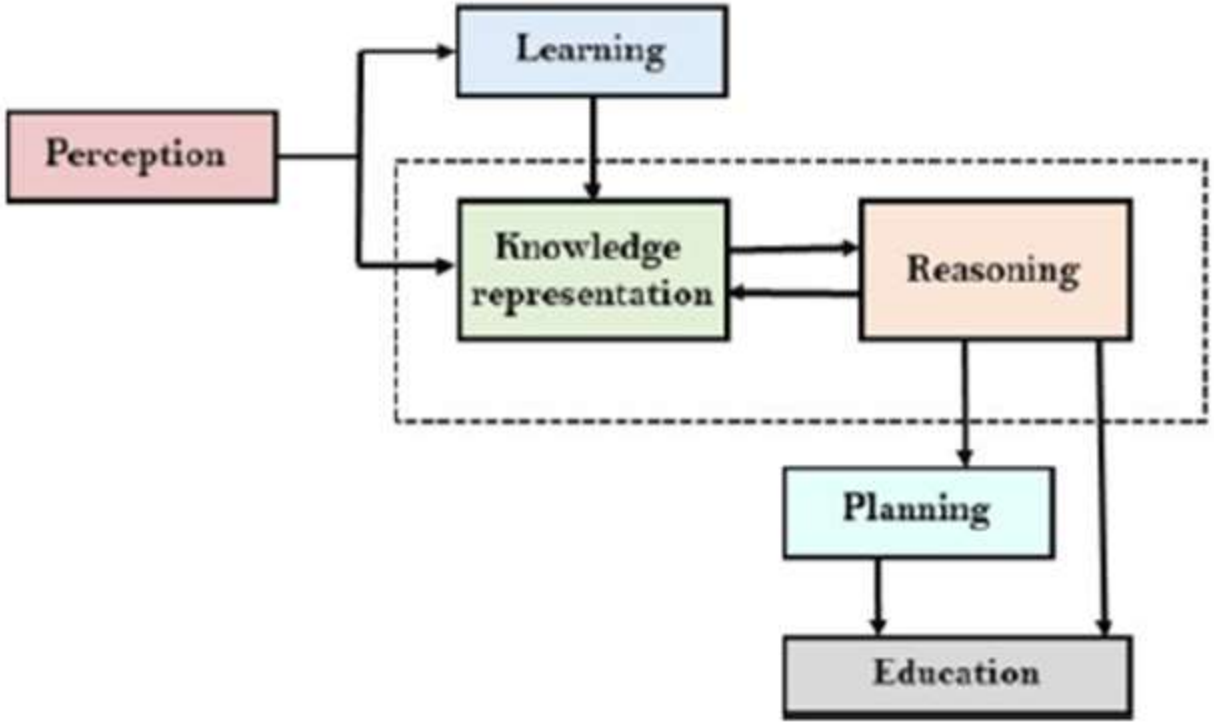
- AI aims at building intelligent systems that are capable of learning, reasoning, adapting, and performing tasks similar to humans.
- And the information technology systems are concerned with capturing, storing, analyzing, and evaluating data to communicate the best output as a piece of information.

# Role of Expert system in AI

An Artificial intelligence system has the following components for displaying intelligent behavior:

- Perception
- Learning
- Knowledge Representation and Reasoning
- Planning
- Execution

# Role of Expert system in AI



# Role of Expert system in AI

- **Perception -** Retrieves information from its Environment. It can be visual, audio or another form of sensory input
- **Learning** – responsible for learning from data captured by Perception comportment
- **knowledge representation and Reasoning -** involved in showing the intelligence in machine-like humans
- The **planning** and **execution** depend on analysis of Knowledge representation and reasoning

# Role of Expert system in AI

**Approaches to knowledge representation**

***1. Simple relational knowledge*** –

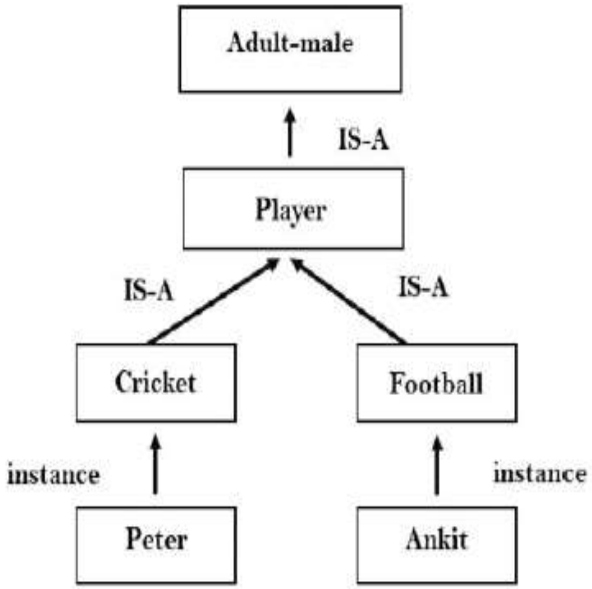
- It is the simplest way of storing facts which uses the relational method, and each fact about a set of the object is set out systematically in columns.
- This approach is famous in database systems where the relationship between different entities is represented
- This approach has little opportunity for inference

| Player | Weight | Age |
|---|---|---|
| Player1 | 65 | 23 |
| Player2 | 58 | 18 |
| Player3 | 75 | 24 |

# Role of Expert system in AI

***2. Inheritable knowledge:***

- All data must be stored into a hierarchy of classes
- Elements inherit values from other members of a class.
- This approach contains inheritable knowledge which shows a relation between instance and class, and it is called instance relation.
- Every individual frame can represent the collection of attributes and its value.
- In this approach, objects and values are represented in Boxed nodes.
- We use Arrows which point from objects to their values.



# Role of Expert system in AI

***3. Inferential knowledge***

- Inferential knowledge approach represents knowledge in the form of formal logics.
- This approach can be used to derive more facts.
- It guaranteed correctness.
- **Example:** Let's suppose there are two statements:

1. Marcus is a man
2. All men are mortal

Then it can represent as;

man(Marcus)

∀x = man (x) ---------|> mortal (x)s

# Role of Expert system in AI

***4. Procedural knowledge:***

- Procedural knowledge approach uses small programs and codes which describes how to do specific things, and how to proceed.
- In this approach, one important rule is used which is If-Then rule.
- In this knowledge, we can use various coding languages such as LISP language and Prolog language.
- We can easily represent heuristic or domain-specific knowledge using this approach.
- But it is not necessary that we can represent all cases in this approach.

# Characteristics of Expert System

- **High level Performance**
  - ✓ Capable of responding at a level of competency
  - ✓ The quality of the advice given by the system should be in a high-level integrity
- **Domain Specificity**
  - ✓ Expert systems are typically very domain specific
  - ✓ The developer of such a system must limit his or her scope of the system to just what is needed to solve the target problem
- **Reliability -** The expert system must be as reliable as a human expert
- **Understandable**
  - ✓ The system should be understandable i.e. be able to explain the steps of reasoning while executing.
  - ✓ Expert system should have an explanation capability

# Characteristics of Expert System

- **Adequate Response time - I**t is able to perform within a small amount of time comparable to or better than the time taken by a human expert to reach at a decision point
- **Use symbolic representations -** ES use symbolic representations for knowledge (rules, networks or frames) and perform their inference through symbolic computations
- **Linked with Metaknowledge** – Expert systems often reason with metaknowledge i.e. they reason with knowledge about themselves and their own knowledge limits and capabilities.
- **Expertise knowledge –** ES must be skillful in applying its knowledge to produce solutions both efficiently and effectively by using the intelligence human expert
- **Justified Reasoning** - This allows the users to ask the expert system to justify the solution or advice provided by it.

# Capabilities of Expert Systems

**The expert systems are capable of**

- **Advising -** It is capable of advising the human being for the query of any domain from the particular ES.
- **Provide decision making capabilities -** It provides the capability of decision making in any domain, such as for making any financial decision, decisions in medical science, etc.
- **Demonstrate a device -** It is capable of demonstrating any new products such as its features, specifications, how to use that product, etc
- **Problem Solving -** It has problem-solving capabilities

# Capabilities of Expert Systems

- **Interpreting the input -** It is capable of interpreting the input given by the user.
- **Predicting results -** It can be used for the prediction of a result.
- **Diagnosing -** An ES designed for the medical field is capable of diagnosing a disease without using multiple components as it already contains various inbuilt medical tools.
- The error rate of successful systems is low, sometimes much lower than the human error rate for the same task.
- ESs make consistent recommendations

# Capabilities of Expert Systems

- ESs are a convenient vehicle for bringing to the point of application difficult-to-use sources of knowledge.
- ESs can capture the scarce expertise of a uniquely qualified expert.
- ESs can become a vehicle for building up organizational knowledge, as opposed to the knowledge of individuals in the organization.
- When use as training vehicles, ESs result in a faster learning curve for novices.
- The company can operate an ES in environments hazardous for humans.

# Knowledge Acquisition

- Knowledge Acquisition is the bottle neck of building Intelligent System.
- It is the process of acquiring the knowledge from human or other sources (E.g Books, Manuals) to solve the problem.

# Knowledge Sources

- Textbooks
- Reports
- Database (Data mining)
- Case Studies
- Empirical Data
- Person Expertise

# Selection of Expert

Ask the organization to provide you with the names of candidate domain experts, that is, those individuals who are believed to have significant expertise within the domain in question.

- Select a domain expert whose **performance is generally acknowledged** to be above and beyond that of most others performing the same task.
- Select an expert with a **successful track record over a period of time.**

# Selection of Expert

- Select an expert who is both willing and able to **communicate personal knowledge**, and who is relatively articulate in doing so.
- Select an expert who is both willing and able to **devote the time necessary** to support the development effort.
- If no expert can be identified, or made available, consider the **development of the rule base through alternative means** (as will be discussed in the sections to follow)

# Interviewing the Expert

**1. There are 4 reasons why Knowledge can't be satisfied to describe the domain**

- For some problems there may not be an expert,
- Some experts are unable to describe what they do,
- Some experts may not reveal their tricks of the trade, and
- Some experts may actually have poor expertise

# Interviewing the Expert

**2. Initial meeting has some purposes**

- Relax individual (expert)
- Explain Problem
- Schedule follow-on meeting
- Evaluate the true extent of expertise of our systems

# Interviewing the Expert

**3. Documentation -** Documentation of the results of the meeting as soon as possible, it should contains such facts:

- Date, time and location of the meeting
- Name of Expert (i.e., if more than one expert is being used)
- List and description of the rules identified during the meeting
- Listing of any new objects, attributes and/or values encountered - and their properties

# Interviewing the Expert

- Identification of any new outside sources and references
- Listing of any new terminology encountered, and associated definitions
- Listing and discussion of any gaps or discrepancies encountered
- Reminders (e.g., of points that need to be clarified)

# Techniques used for extracting Knowledge from a domain expert

## 1. On-site observation

K.E watches the domain expert (D.E.) solving real problems on the job

$$\text{K.E.} \xrightarrow{\text{Watches}} \text{D.E.}$$

Note: difficulties are that the K.E. extracts the rules of solving the problems without expansion from D.E.

# Techniques used for extracting Knowledge from a domain expert

**2. Problem discussion**

K.E. explores the kinds of data, K. and procedures needed to solve the problem through the discussion

K.E. $\xrightarrow{\text{Explores}}$ D.E.

# Techniques used for extracting Knowledge from a domain expert

## 3. Problem description

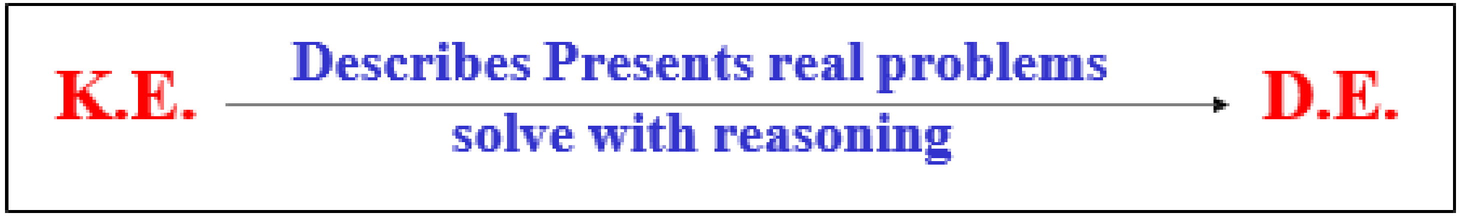
Have the expert describes a prototypical problem for each category of answer in the domain

$$\textbf{K.E.} \underset{\textbf{Prototype}}{\overset{\textbf{Describes}}{\rightleftarrows}} \textbf{D.E.}$$

**Note**: difficulties are that the D.E. describes a prototype (not real problem).

## 4. Problem analysis

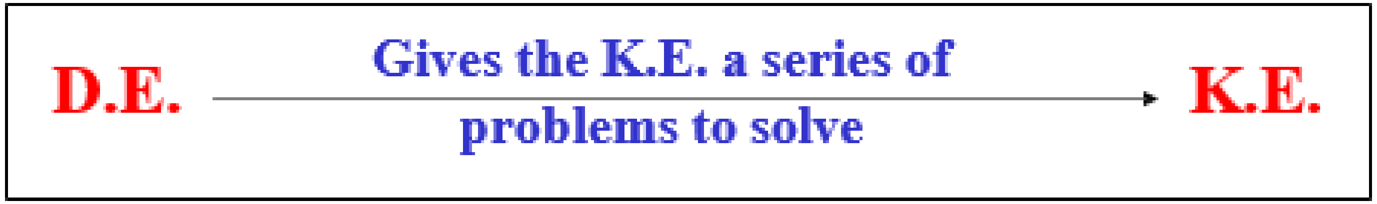
K.E. presents the expert with a series of realistic problems then the D.E solves the problems with reasoning steps (analyze the results).



# Techniques used for extracting Knowledge from a domain expert

**5. System refinement**

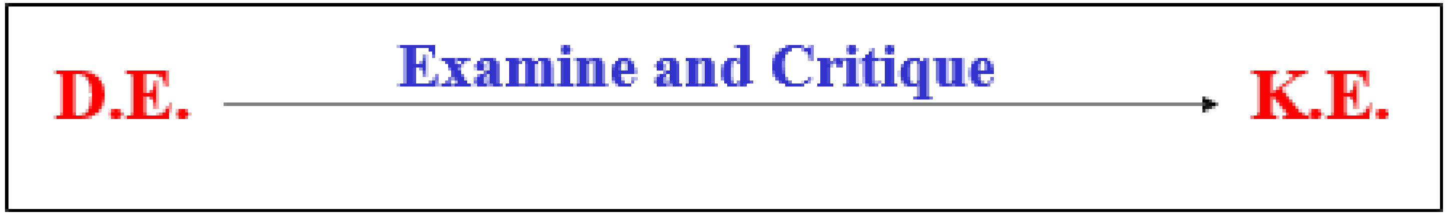
Have the D.E. gives the K.E. a series of problems to solve using the rules acquired from the interviews.



# Techniques used for extracting Knowledge from a domain expert

**6. System examination**

Have the D.E. examine and critique the prototype system’s rules and control structure.



# Advantages of Expert System

- These systems are highly reproducible.
- They can be used for risky places where the human presence is not safe.
- Error possibilities are less if the KB contains correct knowledge.
- The performance of these systems remains steady as it is not affected by emotions, tension, or fatigue.
- They provide a very high speed to respond to a particular query

# Limitations of Expert System

- The response of the expert system may get wrong if the knowledge base contains the wrong information.
- Like a human being, it cannot produce a creative output for different scenarios.
- Its maintenance and development costs are very high.
- Knowledge acquisition for designing is much difficult.
- For each domain, we require a specific ES, which is one of the big limitations.
- It cannot learn from itself and hence requires manual updates.

# Applications of Expert System

- **In designing and manufacturing domain** - Designing and manufacturing physical devices such as camera lenses and automobiles.
- **In the knowledge domain** - Publishing the relevant knowledge to the users. The two popular ES used for this domain is an advisor and a tax advisor.
- **In the finance domain** - Detect any type of possible fraud, suspicious activity, and advise bankers that if they should provide loans for business or not.

# Applications of Expert System

- **In the diagnosis and troubleshooting of devices -** In medical diagnosis, the ES system is used, and it was the first area where these systems were used.
- **Planning and Scheduling** - Planning and scheduling some particular tasks for achieving the goal of that task.

# 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: Shortliffe

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.

# Examples and non-examples

Soybean diagnosis

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

Autoclade placement

- Expert but no codification

Chess

- Experts but no codification in terms of rules

# Forward Chaining Interpreter

Repeat

- Apply all the rules to the current facts.
- Each rule firing may add new facts

Until no new facts are

added. Comprehensible

Trace of rule applications that lead to conclusion is explanation. Answers why.

# Forward Chaining Example

F~~acts:~~

- F1: Ungee gives milk
- F2: Ungee eats meat
- F3: Ungee has hoofs

Rules:

- R1: If X gives milk, then it is a mammal
- R2: If X is a mammal and eats meat, then carnivore.
- R3: If X is a carnivore and has hoofs, then ungulate

Easy to see: Ungee is ungulate.

# Backward Chaining

Start with Goal G1: is Ungee an ungulate?

G1 matches conclusion of R3

Sets up premises as subgoals

- G2: Ungee is carnivore
- G3: Ungee has hoofs

G3 matches fact F3 so true.

G2 matches conclusion of R2. etc.

# The good and the bad

Forward chaining allows you to conclude

anything  Forward chaining is expensive

Backward chaining requires known goals.

Premises of backward chaining directs which facts (tests)

are needed.  Rule trace provides explanation.

# Simple Confidence Calculus

This will yield an intuitive degree of belief in system conclusion.

To each fact, assign a confidence or degree of belief. A number between 0 and 1. To each rule, assign a rule confidence: also a number between 0 and 1.

# Simple Confidence Calculus

Confidence of premise of a rule =

- Minimum confidence of each condition
- Intuition: strength of argument is weakest link

Confidence in conclusion of a rule =

- (confidence in rule premise)*(confidence in rule)

Confidence in conclusion from several rules: r1,r2,..rm with confidences c1,c2,..cm =

- c1 @ c2 @... cm
- Where x @ y is 1- (1-x)*(1-y).

# And now with confidences

Facts:

- F1: Ungee gives milk: .9
- F2: Ungee eats meat: .8
- F3: Ungee has hoofs: .7

Rules:

- R1: If X gives milk, then it is a mammal: .6
- R2: If X is a mammal and eats meat, then carnivore: .5
- R3: If X has hoofs, then X is carnivore: .4

# Simple Confidence Calculus

R1 with F1: Ungee is mammal.

(F4) Confidence F4: C(F4) = .9*.6

= .54

R2 using F2 and F4 yields: Ungee is carnivore (F5).

C(F5) from R2 = min(.54, .8)*.5 = .27

R3 using F3 conclude F5 from R3

C(F5) from R3 = .7*.4 = .28

C(F5) from R3 and R2 = .27 @ .28 =1 –(1-.28)*(1-.27) = .48

# MYCIN

History and Overview

MYCIN Architecture

Consultation System

- Knowledge Representation & Reasoning

Explanation System

Knowledge

Acquisition  Results,

Conclusions

# History

Thesis Project by Shortliffe @ Stanford

Davis, Buchanan, van Melle, and others

- Stanford Heuristic Programming Project
- Infectious Disease Group, Stanford Medical

Project Spans a Decade

- Research started in 1972
- Original implementation completed 1976
- Research continues into the 80’s

# Tasks and Domain

Disease DIAGNOSIS and Therapy SELECTION

Advice for non-expert physicians with time considerations and <u>in</u>complete evidence on:

- Bacterial infections of the blood
- Expanded to meningitis and other ailments

# System Goals

Utility

- Be useful, to attract assistance of experts
- Demonstrate competence
- Fulfill domain need (i.e. penicillin)

Flexibility

- Domain is complex, variety of knowledge types
- Medical knowledge rapidly evolves, must be easy to maintain K.B.

# System Goals (continued)

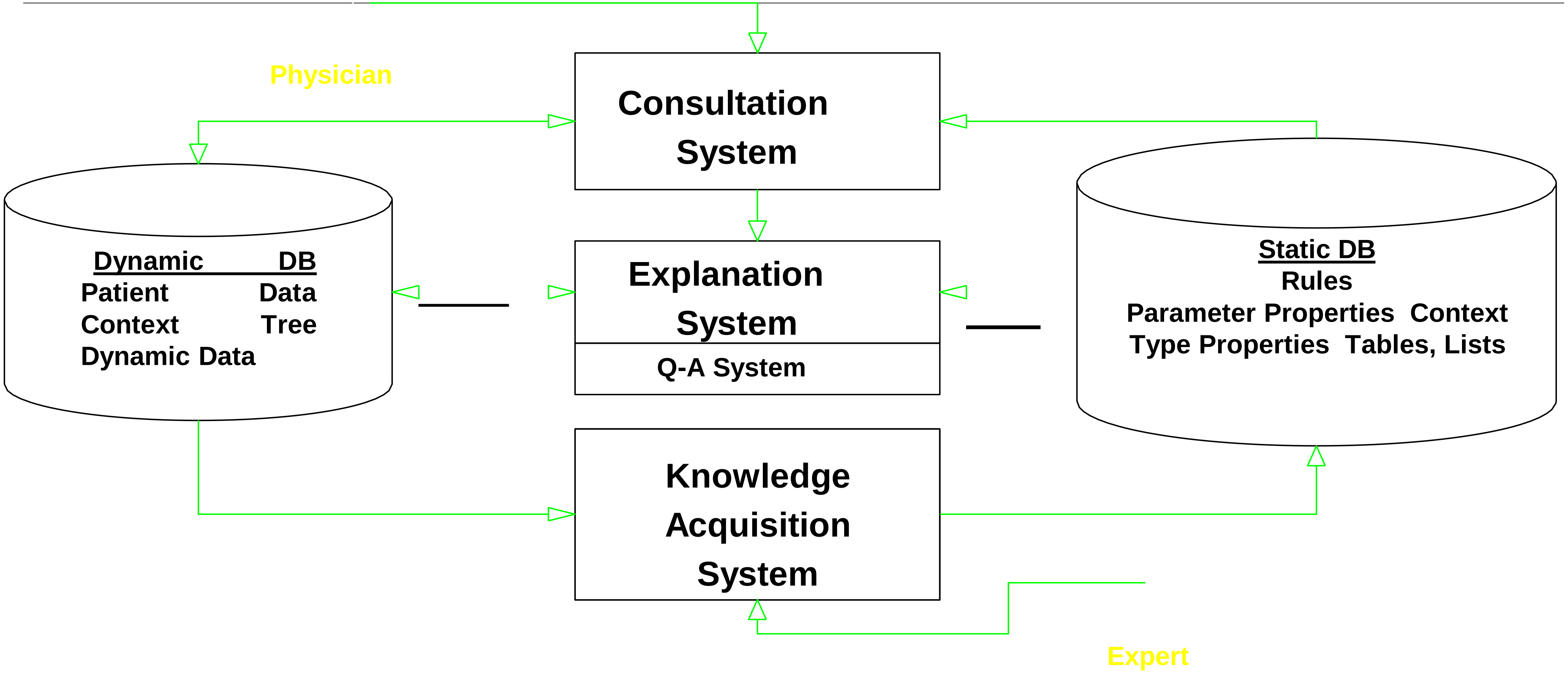
Interactive Dialogue

- Provide coherent explanations (symbolic reasoning paradigm)
- Allow for real-time K.B. updates by experts

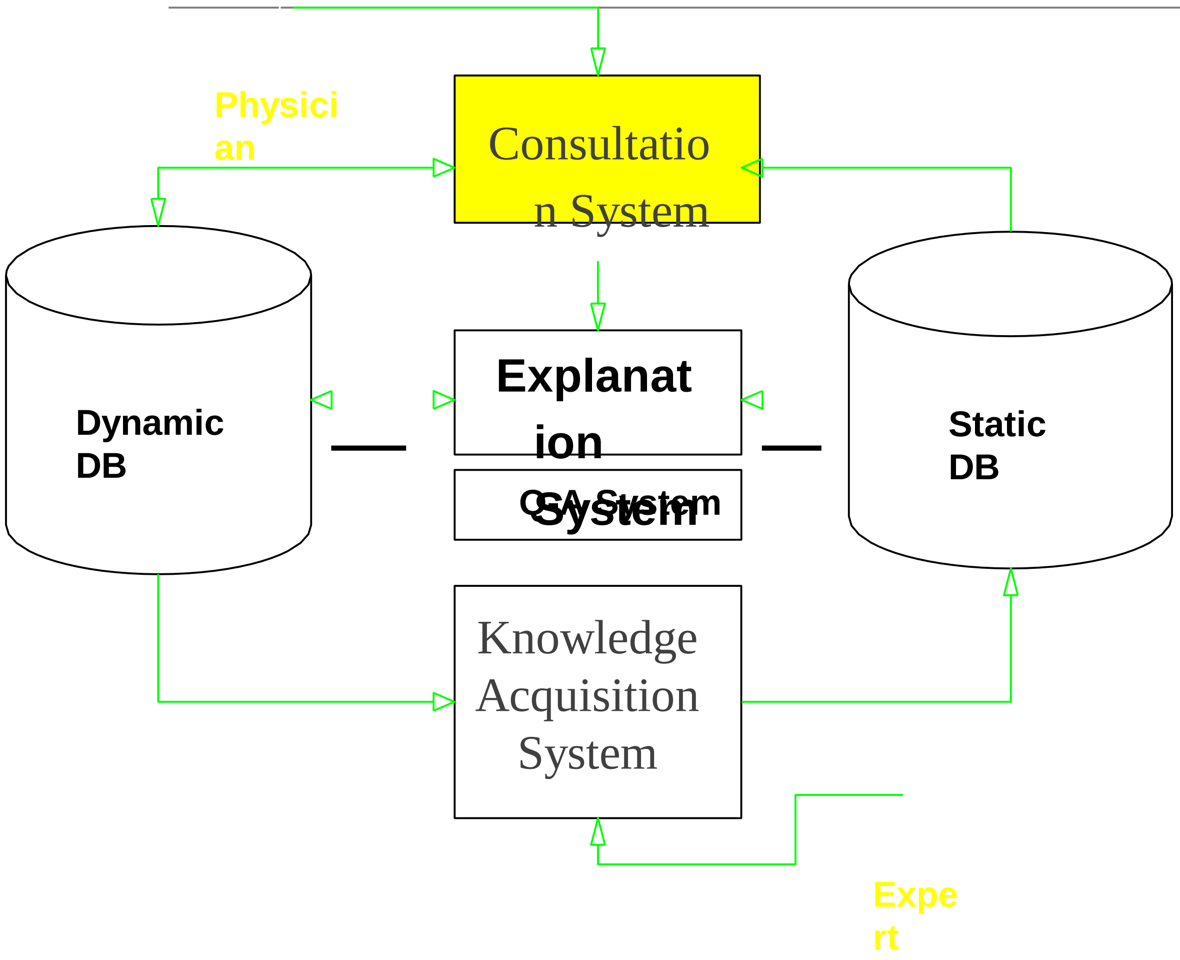
Fast and Easy

- Meet time constraints of the medical field

# MYCIN Architecture



# Consultation System




Performs Diagnosis and Therapy Selection

Control Structure reads Static DB (rules) and read/writes to Dynamic DB (patient, context)

Linked to Explanations

Terminal interface to

Physician

# Consultation System

User-Friendly Features:

- Users can request rephrasing of questions
- Synonym dictionary allows latitude of user responses
- User typos are automatically fixed

Questions are asked when more data is needed

- If data cannot be provided, system ignores relevant rules

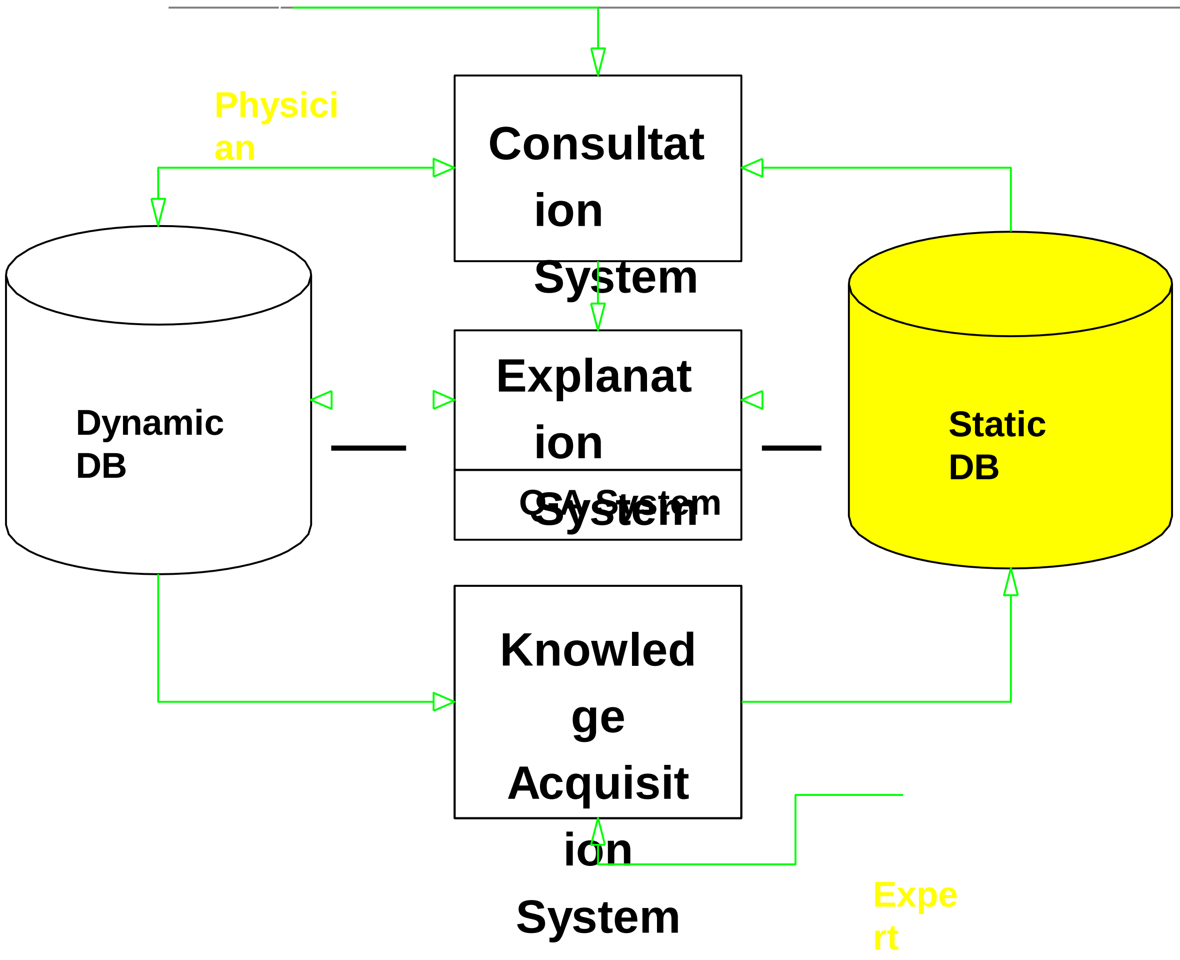
# Consultation "Control Structure"

Goal-directed Backward-chaining Depth-first

Tree Search  High-level Algorithm:

1. Determine if Patient has significant infection
2. Determine likely identity of significant organisms
3. Decide which drugs are potentially useful
4. Select best drug or coverage of drugs

# Static Database




Rules

Meta-Rules

Templates

Rule Properties

Context Properties

Fed from Knowledge Acquisition System

# Production Rules

Represent Domain-specific

Knowledge  Over 450 rules in

MYCIN

Premise-Action (If-Then) Form:
<predicate function><object><attrib><value>

Each rule is completely modular, all relevant context is contained in the rule with explicitly stated
premises

# MYCIN P.R. Assumptions

Not every domain can be represented, requires formalization (EMYCIN)

Only small number of simultaneous factors (more than 6 was thought to be unwieldy)

IF-THEN formalism is suitable for Expert Knowledge Acquisition and Explanation sub-systems

# Judgmental Knowledge

Inexact Reasoning with Certainty

Factors (CF)  CF are not Probability!

Truth of a Hypothesis is measured by a sum of the CFs

- Premises and Rules added together
- Positive sum is confirming evidence
- Negative sum is disconfirming evidence

# Sub-goals

At any given time MYCIN is establishing the value of some parameter by sub-goaling

Unity Paths: a method to bypass sub-goals by following a path whose certainty is known (CF==1)
to make a definite conclusion

Won’t search a sub-goal if it can be obtained from a user first (i.e. lab data)

# Preview Mechanism

Interpreter reads rules before invoking them

Avoids unnecessary deductive work if the sub-goal has already been tested/determined  Ensures self-referencing sub-goals do not enter recursive infinite loops

# Meta-Rules

Alternative to exhaustive invocation of all rules

Strategy rules to suggest an approach for a given sub-goal

- Ordering rules to try first, effectively pruning the search tree

Creates a search-space with embedded information on which branch is best to take

# Meta-Rules (continued)

High-order Meta-Rules (i.e. Meta-Rules for Meta-Rules)

- Powerful, but used limitedly in practice

Impact to the Explanation System:

- (+) Encode Knowledge formerly in the Control Structure
- (-) Sometimes create “murky” explanations

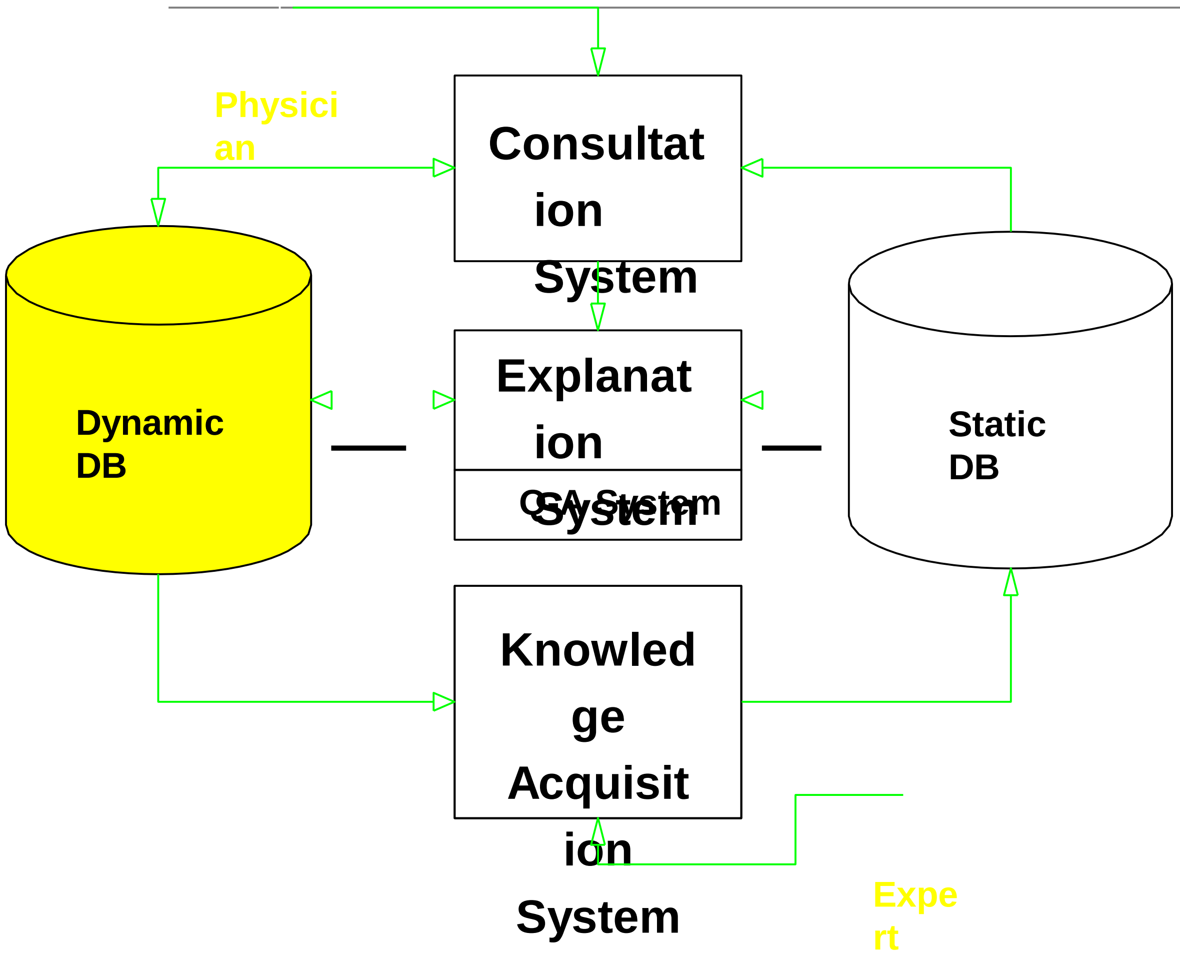
# Templates

The Production Rules are all based on Template structures

This aids Knowledge-base expansion, because the system can "understand" its own representations

Templates are updated by the system when a new rule is entered

# Dynamic Database




Patient Data

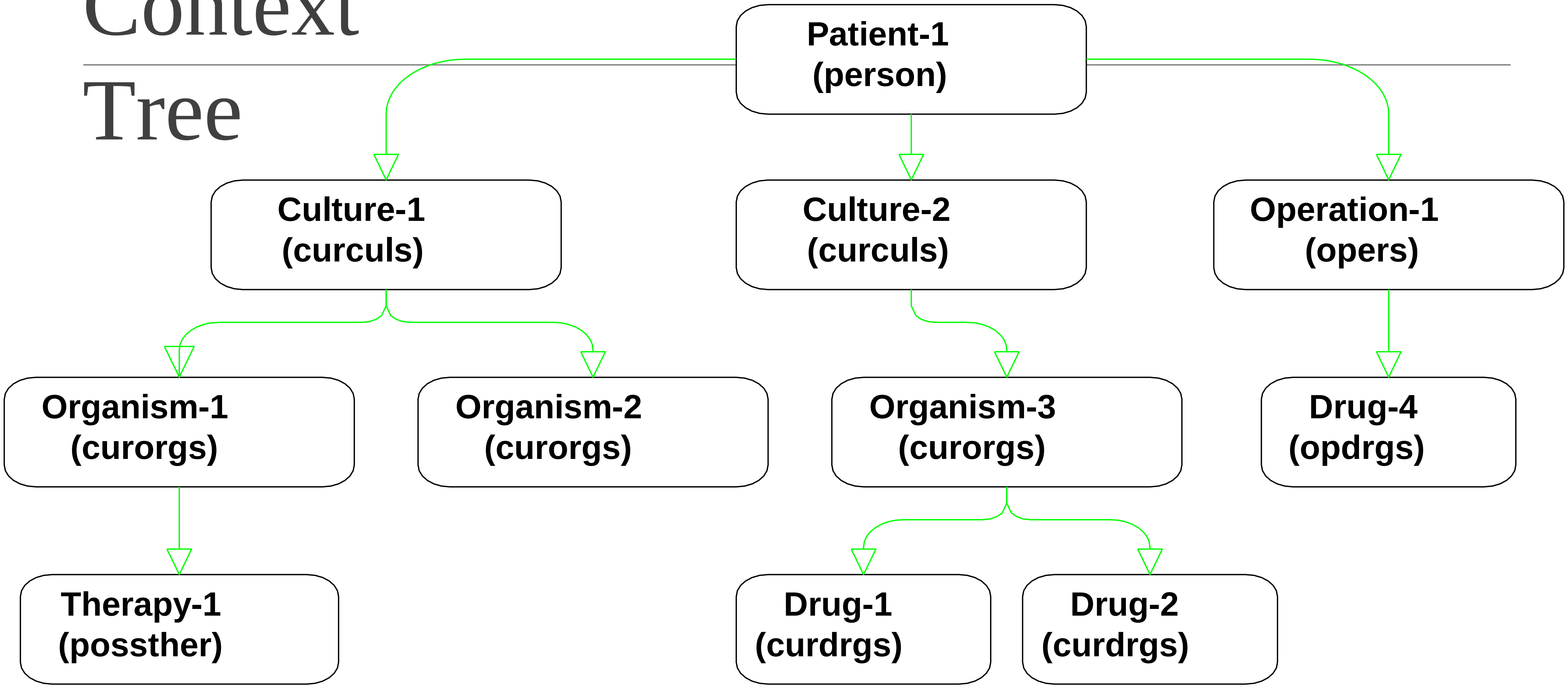
Laboratory Data

Context Tree

Built by Consultation System

Used by Explanation System

# Context Tree



# Therapy Selection

Plan-Generate-and-Test

Process  Therapy List

Creation

- Set of specific rules recommend treatments based on the probability (not CF) of organism sensitivity
- Probabilities based on laboratory data
- One therapy rule for every organism

# Therapy Selection

Assigning Item Numbers

- Only hypothesis with organisms deemed “significantly likely” (CF) are considered
- Then the most likely (CF) identity of the organisms themselves are determined and assigned an Item Number
- Each item is assigned a probability of likelihood and probability of sensitivity to drug

# Therapy Selection

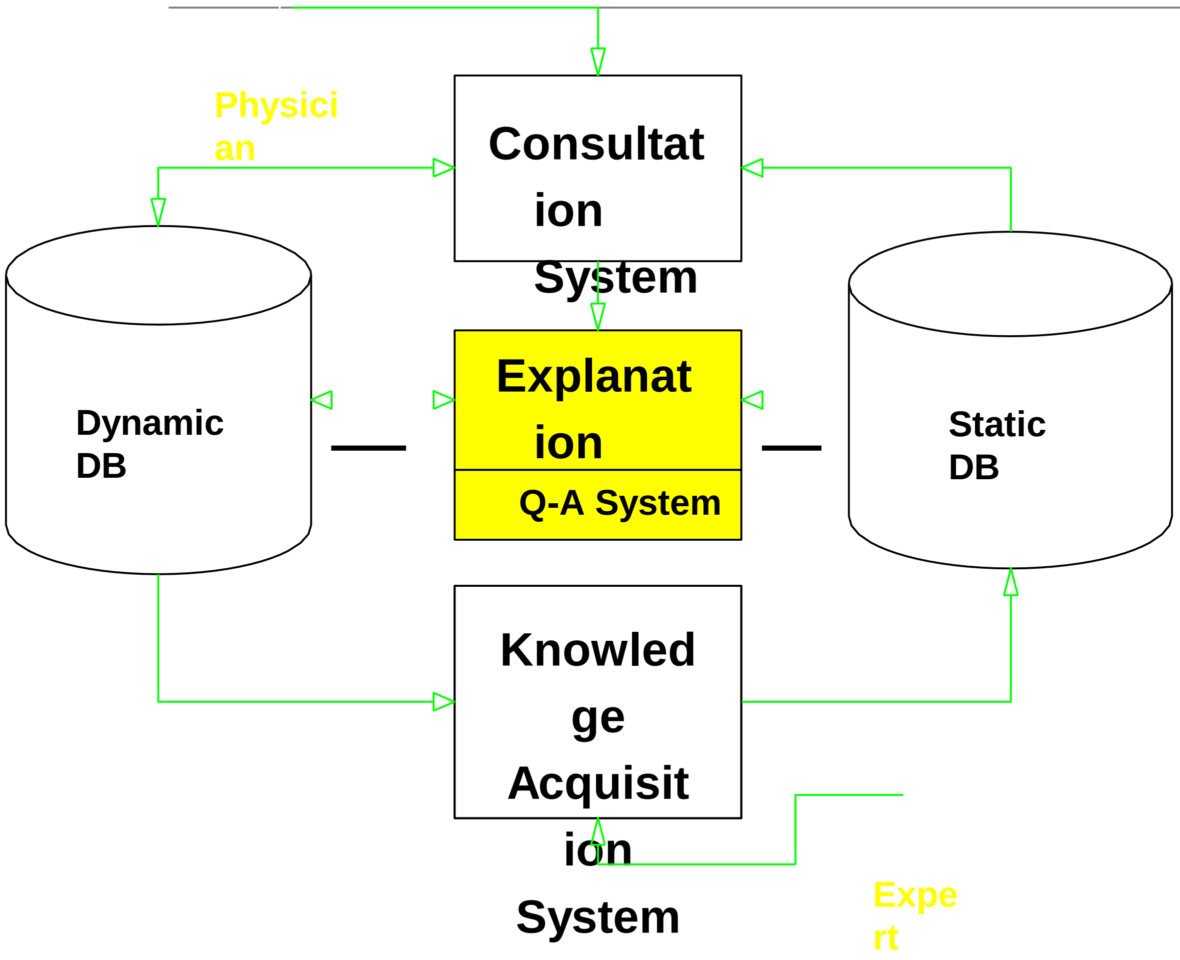
Final Selection based on:

- Sensitivity
- Contraindication Screening
- Using the minimal number of drugs and maximizing the coverage of organisms

Experts can ask for alternate treatments

- Therapy selection is repeated with previously recommended drugs removed from the list

# Explanation System




Provides reasoning why a conclusion has been made, or why a question is being asked

Q-A Module

Reasoning Status Checker

# Explanation System

Uses a trace of the Production Rules for a basis, and the Context Tree, to provide context

- Ignores Definitional Rules (CF == 1)

Two Modules

- Q-A Module
- Reasoning Status Checker

# Q-A Module

Symbolic Production Rules are readable

Each <predicate function> has an associated translation pattern:

```
GRID (THE (2) ASSOCIATED WITH (1) IS KNOWN)

VAL (((2 1)))

PORTAL (THE PORTAL OF ENTRY OF *)

PATH-FLORA (LIST OF LIKELY PATHOGENS)
```

i.e. `(GRID (VAL CNTXT PORTAL) PATH-FLORA)` becomes:

"The list of likely pathogens associated with the portal of entry of the organism is known."

# Reasoning Status Checker

Explanation is a tree traversal of the traced rules:

- WHY – moves up the tree
- HOW – moves down (possibly to untried areas)

Question is rephrased, and the rule being applied is explained with the translation patterns

# Reasoning Status Checker (Example)

32) Was penicillinase added to this blood culture (CULTURE-1)?

****WHY**

[i.e. WHY is it important to determine whether penicillinase was added to CULTURE-1?]

[3.0] This will aid in determining whether ORGANISM-1 is a contaminant. It has already been established that

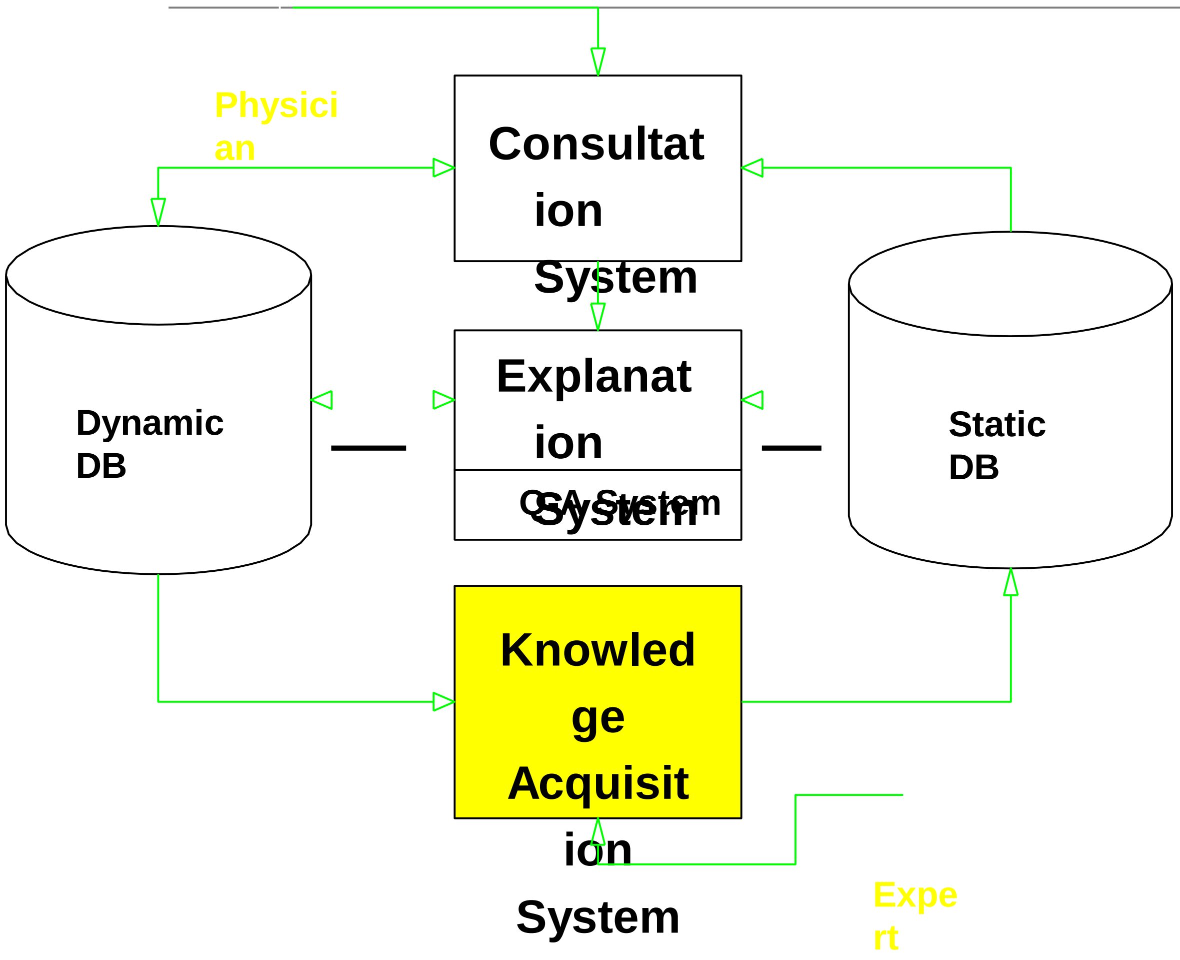
[3.1] the site of CULTURE-1 is blood, and

[3.2] the gram stain of ORGANISM-1 is grampos

Therefore, if

[3.3] penicillinase was added to this blood culture then there is weakly suggestive evidence...

# Knowledge Acquisition System




Extends Static DB via Dialogue with Experts

Dialogue Driven by System

Requires minimal training for Experts

Allows for Incremental Competence, NOT an All-or-Nothing model

# Knowledge Acquisition

IF-THEN Symbolic logic was found to be easy for experts to learn, and required little training by the MYCIN team

When faced with a rule, the expert must either except it or be forced to update it using the education process

# Education Process

1. Bug is uncovered, usually by Explanation process
2. Add/Modify rules using *subset of English* by experts
3. Integrating new knowledge into KB
    - Found to be difficult in practice, requires detection of contradictions, and complex concepts become difficult to express

# Results

Never implemented for routine clinical use

Shown to be competent by panels of experts, even in cases where experts themselves disagreed
on conclusions

Key Contributions:

- Reuse of Production Rules (explanation, knowledge acquisition models)
- Meta-Level Knowledge Use

THANK

YOU FOR

LISTENING

ANY

QUESTION ?