

MYCIN

- Developed at Stanford University in 1972
- Regarded as the first true “expert system”
- **Assists physicians in the treatment of blood infections**
- Many revisions and extensions over the years

The MYCIN Task

- Physician wishes to specify an “antimicrobial agent” - basically an antibiotic - to kill bacteria or arrest their growth
- Some agents are poisonous!
- None is effective against all bacteria
- Most physicians are not expert in the field of antibiotics, so
 - When in doubt, antibiotics were prescribed (overprescription is still huge problem!)
 - Expertise could be needed fast

Adapted from COM362 presentation, John McIntyre, Sunderland University
COM362 Knowledge Engineering - Classic Case Studies

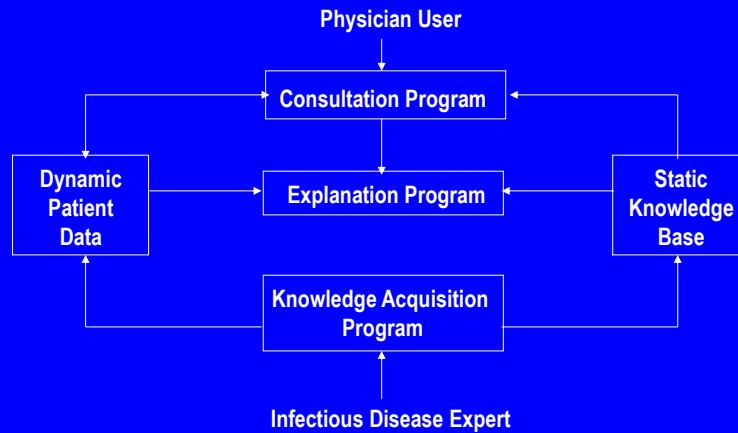
The Decision Process

- There are four key questions in the process of deciding on treatment:
 - **Does the patient have a significant infection?**
 - **What are the organism(s) involved?**
 - **What drugs might be work to treat the infection?**
 - **What is the best choice of drug or combination of drugs to treat the infection?**

MYCIN Components

- **KNOWLEDGE BASE:**
 - facts and knowledge about the domain
- **DYNAMIC PATIENT DATABASE:**
 - information about a particular case
- **CONSULTATION MODULE:**
 - asks questions, gives advice on a particular case
- **EXPLANATION MODULE:**
 - answers questions and justifies advice
- **KNOWLEDGE ACQUISITION PROGRAM:**
 - adds new rules and changes existing rules

Basic MYCIN Structure



The MYCIN Knowledge Base

- Where the rules are held
- Basic rule structure in MYCIN is:
*if condition₁ and....and condition_m hold
then draw conclusion₁ and....and condition_n*
- Rules written in the LISP-like form
- Rules can include certainty factors to help weight the conclusions drawn

An Example Rule (English)

IF:(1) The stain of the organism is Gram
negative, and
(2) The morphology of the organism is rod, and
(3) The aerobicity of the organism is aerobic

THEN:

There is strongly suggestive evidence (0.8) that
the class of the organism is *Enterobacteriaceae*

COM362 Knowledge Engineering
Classic Case Studies

7

Example Rule (Lisp)

```
(defrule 73
  if (site culture is blood)
    (gram organism is neg)
    (morphology organism is rod)
    (aerobicity organism is anaerobic)
  then .9
    (identity organism is bacteroides))
```

8

Example Metarule (English)

If The infection is pelvic-abscess
AND There are rules that mention in their
premise Enterobacteriaceae
AND There are rules that mention in their
premise gram positive rods
THEN There is suggestive evidence that the
rules dealing with Enterobacteriaceae
should be invoked before those dealing
with gram positive rods

9

Calculating Certainty

- Rule certainties are related to probabilities
- Therefore must ~ apply the rules of probability in combining rules
- Multiplying probabilities which are less than certain results in lower and lower certainty!
- Eg $0.8 \times 0.6 = 0.48$

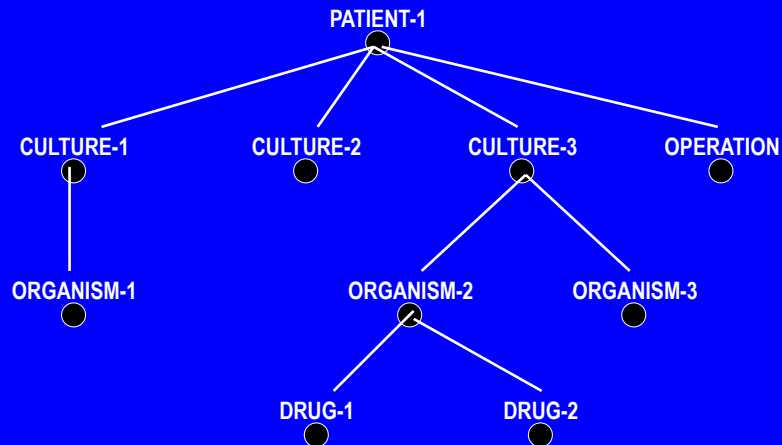
Other Types of Knowledge What Does Mycin Need to Know?

- Facts and definitions such as:
 - lists of all organisms known to the system
 - “knowledge tables” of clinical parameters and the values they can take (eg morphology)
 - classification system for clinical parameters and the context in which they are applied (eg referring to patient or organism)
- Much of MYCIN’s knowledge refers to 65 clinical parameters

MYCIN’s Context Trees

- Used to organise case data
- Helps to visualise how information within the case is related
- Easily extended and adapted as more clinical evidence becomes available

Example Context Tree



COM362 Knowledge Engineering
Classic Case Studies

13

MYCIN Control Structure

- Uses a goal-based strategy to attempt to find evidence for a particular disease
- Establishes sub-goals required to satisfy the top level goal
- General approach: backward chaining

14

Top Level Goal

IF:(1) There is an organism which requires therapy;
and
(2) consideration has been given to any other
organism requiring therapy
THEN:
compile a list of possible therapies, and
determine the best one in this list

MYCIN Subgoals

- Sub-goals are a generalised form of the top-level goal
- Sub-goals to first antecedent consider the proposition that there is a particular organism
- Exhaustive search on all relevant rules to test this proposition (until or unless one succeeds with total certainty)
- (Flavor more like exhaustive search than backward chaining)

Selection of Therapy

- Done after the diagnostic phase is complete
- Two phases:
 - Select list of candidate drugs
 - Choose preferred drugs or combinations of drugs from the list
- Therapy rules consider:
 - Sensitivity of organism to drug
 - Contraindications on the drug

Example Recommendation

IF: The identity of the organism is *Pseudomonas*

THEN:

I recommend therapy from the following drugs:

- 1 - COLISTIN (0.98)
- 2 - POLYMYXIN (0.96)
- 3 - GENTAMICIN (0.96)
- 4 - CARBENICILLIN (0.65)
- 5 - SULFISOXAZOLE (0.64)

Sample System Output

```

7-JUN-74 16:27:27
-----PATIENT-1-----
1) Patient's name: (first-last)
**JEREMIAH SAMPLE
2) Sex:
**MALE
3) Age:
**60
I will refer to the most recent positive culture for which you desire
therapeutic advice as:

-----CULTURE-1-----
4) From what site was the specimen for CULTURE-1 taken?
**BLOOD
=BLOOD
5) How many days ago was this blood culture (CULTURE-1)
obtained?
**2
  
```

```

I will refer to the first offending organism from this blood culture
(CULTURE-1) as:

-----ORGANISM-1-----
6) Enter the identity (genus) of ORGANISM-1:
**UNK
7) Staining characteristics of ORGANISM-1 (gram):
**?
WHAT IS THE STAIN OF ORGANISM-1?
Expected responses are: ACIDFAST GRAMPOS GRAMNEG
Enter HELP for list of user options.
**GRAMNEG
8) Is ORGANISM-1 a rod or coccus (etc.):
**ROD
9) Were any organisms that were significant (but no longer require
therapeutic attention) isolated within the last approximately 30
days?
**YES

-----CULTURE-2-----
10) From what site was the specimen for CULTURE-2 taken?
**SPUTUM
11) How many days ago was this upper-resp culture
(CULTURE-2) obtained?
**4 1/2 DAYS
PLEASE USE DECIMAL NUMBERS FOR FRACTIONS
4 1/2 DAYS NOT A RECOGNIZED RESPONSE
WHAT IS THE NUMBER OF DAYS SINCE THE SPECIMEN
FOR THIS UPPER-RESP CULTURE WAS ACQUIRED?
Expected responses are: NUMBER OF DAYS
Enter HELP for list of user options.
**4.5
I will refer to the prior organism from this upper-resp culture
(CULTURE-2) as:

-----ORGANISM-2-----
12) Enter the identity (genus) of ORGANISM-2:
**PSEUDOMONAS
13) Any other significant organisms isolated from this upper-resp
culture (CULTURE-2)?
**YES
  
```

After Additional Questions

44) How many of the cultures were positive for ORGANISM-1?
**2

[Note that the certainty factor (CF) for RULE044 is calculated from the answers to questions 43 and 44. CF's are explained in Chapter 4.]

45) Any other organisms isolated from this blood culture (CULTURE-1) for which you would like a therapeutic recommendation?
**NO

46) Does Jeremiah Sample (PATIENT-1) show any evidence of infection at a site inaccessible to culture (e.g., brain, bone, liver, etc.)?
**NO

47) Were any additional positive specimens recently drawn from Jeremiah Sample (PATIENT-1) which revealed one or more organisms for which you wish therapeutic advice?
**NO

[MYCIN has now asked all questions necessary in order to decide (a) whether ORGANISM-1 is significant, and (b) the likely identities of ORGANISM-1.]

My therapy recommendation will be based on the following possible identities of the organism(s) that seem to be significant:

- <Item 1> The identity of ORGANISM-1 may be PSEUDOMONAS
- <Item 2> The identity of ORGANISM-1 may be KLEBSIELLA
- <Item 3> The identity of ORGANISM-1 may be ENTEROBACTER
- <Item 4> The identity of ORGANISM-1 may be E.COLI
- <Item 5> The identity of ORGANISM-1 may be PROTEUS (Subtype unknown)

MYCIN

[MYCIN now begins asking questions to assist with drug selection.]

48) On a scale of 0 to 4, where higher numbers indicate increasing severity, how would you rate Jeremiah Sample (PATIENT-1)'s degree of sickness?
**4

49) Does Jeremiah Sample (PATIENT-1) have a clinically significant allergic reaction to any antimicrobial agent?
**NO

[Considering GENTAMICIN for use against ORGANISM-1 . . .]

[Rec 1] My preferred therapy recommendation is as follows:

In order to cover for Items <1> <2> <3> <4> <5>:
Give the following in combination:

- 1 GENTAMICIN
Dose: 1.7 MG/KG Q8H - IV OR IM
Comments: MODIFY DOSE IN RENAL FAILURE
- 2 CARBENICILLIN
Dose: 25 MG/KG Q2H - IV
Comments: MODIFY DOSE IN RENAL FAILURE

Do you wish to see the next choice?
**YES

[Considering COLISTIN for use against ORGANISM-1 . . .]
[Rejecting SULFISOXAZOLE for use against ORGANISM-1 . . .]

[Rec 2] Next best therapy recommendation:

In order to cover for Items <1> <2> <3> <4>:
Give: COLISTIN

Dose: 1.25 MG/KG Q6H - IM
Comments: MODIFY DOSE IN RENAL FAILURE

Do you wish to see the next choice?
**NO

[The Consultation System (Subprogram 1) is now finished. Control therefore automatically passes to the Explanation System (Subprogram 2).]

How Could Mycin be evaluated?

Need to Decide

- Data to use (what characteristics are desirable?)
- Assessment criterion ("gold standard" for comparison to experts)
- How to handle experts disagreement

Evaluating MYCIN

- Many studies show that MYCIN's recommendations compare favourably with experts for diseases like meningitis
- Study compared on real patients with expert and non-expert physicians:
 - MYCIN matched experts
 - MYCIN was better than non-experts

Evaluation Procedure

- 10 diverse meningitis case studies selected by physician unfamiliar with Mycin.
- Diversity guidelines: ≤ 3 of viral; at least one each of tuberculosis, fungal, viral and bacterial
- Gold standard: Treatments by 8 experts who'd published on meningitis.
- Comparison: Test results classified as equivalent, acceptable, or unacceptable. "acceptable" if majority assigned "acceptable" or better

Example Evaluation

Blind evaluation of prescriptions from MYCIN and 9 other providers, for 10 real cases.

• Prescriber	%Acceptable	Pathogen Missed
• MYCIN	70	0
• Prior Rx	70	0
• Faculty-4	50	0
• Faculty-1	50	1
• Faculty-2	50	1
• Fellow	50	1
• Faculty-3	40	0
• Faculty-5	30	0
• Resident	30	1
• Student	10	3

27

MYCIN Limitations

- Research tool with limited knowledge base - only covers a small number of infectious diseases
- Doctors reluctant to use it (trust and enjoyment)
- Poor interface

Mycin Lessons

- Expert systems can match domain experts
- The control structure was *simple*---backwards chaining search---but sufficed.
- High quality performance arose from system knowledge, in the form of rules
- MYCIN lead to emycin, an expert system “shell” for to which developers could add their own rules

29

Knowledge Engineering (More on this in B552!)

- How are rule-based system rules generated?
- Process:
 - Interview experts
 - Determine right level of abstraction
 - Determine units of knowledge
 - Code rules
 - Test and repeat

Form of Rules

- Rules are “If-then” rules
- Rules may refer to specific assertions in memory or may include variables to match any fact with the correct form
- To avoid a flood of specific rules, rules should infer aspects of the environment one bit at a time
- They need to “blur” some details

In-Class Exercise: Developing Rules

- Form small groups (4-5 people)
- Pick topic for forward-chaining system (e.g., controlling traffic lights, deciding a class to take, deciding whether to go to a restaurant)
- Thinking of PEAS description for domain, think of rules connecting sensor inputs to intermediate conditions and then actions.
- We’ll ask for volunteers to summarize their rules

Illustration for Self-Driving Car

- Sensors include car engine warning lights
- IF (and (warning-light ?light)
 - (illuminated? ?light)
 - (severe-condition-indicator ?light))
- THEN (add (goal stop-car))
- IF (and (goal stop-car)
 - (current-speed high))
- THEN (add (goal slow-car))
-

Considerations for Driving Rules

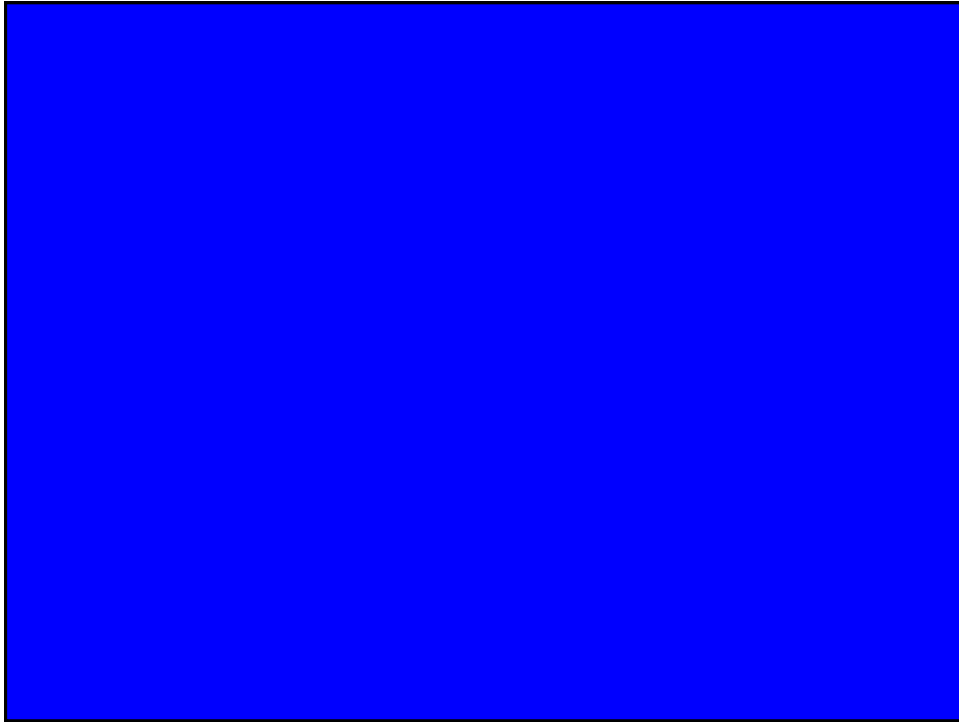
- Safely slowing a car may depend on closeness of other vehicles and their speed
- Safely stopping may depend on the lane you're in and whether the shoulder is clear

If-then in Programming vs. in Rule-Based Systems

- In programming, “If-then-else” is for control: determines what the program does next.
- In rule-based systems, “If-then” is usually for updating system beliefs: If one belief holds, another can be added.
- Example:
 - If the fire alarm is going off and it isn’t raining, there’s a fire
- In RBSes, what’s important is that the conclusion can be drawn, not necessarily when

If-then in Programming vs. in Rule-Based Systems (continued)

- Rule-based systems rules have no “else” clause. If rule doesn’t fire, rule has no effect.
- Rule-based systems rules could be applied in any order.
 - At each step, system collects rules which are triggered (conditions are met)
 - Conflict resolution strategies determine which one to fire
 - Cycle repeats



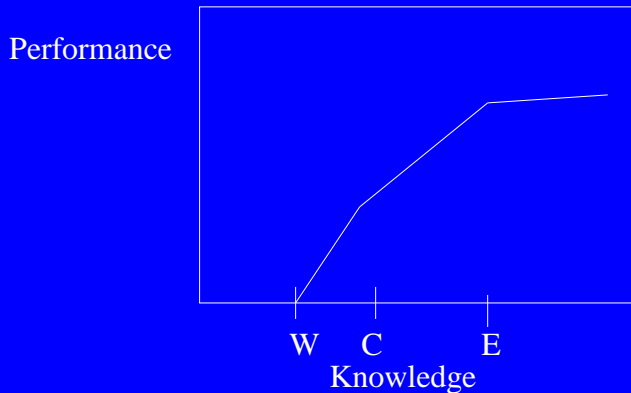
On The Thresholds of Knowledge

(Lenat & Feigenbaum, 1987)

- The Knowledge Principle
 - Knowledge is Power
 - A system exhibits intelligent understanding and action at a high level of competence primarily because of the *specific* knowledge it can bring to bear.

The Competence Threshold

- Difficult tasks succumb nonlinearly to knowledge.



Some Tenets

- *The Explicit Knowledge Principle:* Much of the knowledge in an intelligent system needs to be represented explicitly
- *The Knowledge is all there is hypothesis:* No new control structures are needed
 - “When searching a space of size 1, it is not crucial in what order you expand the nodes”
- *The Breadth Hypothesis:* Intelligent performance often requires falling back on general knowledge or analogizing to specific knowledge from far-flung domains

Some Tenets (Continued)

- *Knowledge facilitates learning:* If you don't know much, you won't learn quickly
- *The Empirical Inquiry Hypothesis:* AI should embody hypotheses in programs, gather data by running them, and to revise based on surprising behaviors
- *The Difficult Problems Hypothesis:* There are too many ways to solve simple problems. Raising required system level and breadth of competence makes it easier to test and raise its intelligence

"Breadth is Within Our Grasp"

- A KB of under a million frames will provide a significant performance increase
- A sufficient research agenda is
- Slowly hand-code a broad knowledge base
- When enough knowledge is present, system will assimilate from reading, data bases, etc.
- System will then be able to go beyond frontiers of human knowledge by carrying out its own R&D projects

The Cyc Project (Lenat)

- First aim: Capture the knowledge in a desk encyclopedia
- Second aim: Capture the background knowledge needed to understand a desk encyclopedia
- Process: Hand coding (“learning by brain surgery”)
- Featured in [The Machine that Changed the World](#) (starting at 49-55min)

The Hoped-For Result: Man-Machine Synergy

- In the “second era” of knowledge systems,
 - the system will be a colleague
 - intelligence will emerge from the interaction

A New Turing Test Proposal, by Barbara Grosz (2012)

- Apply AI systems as part of a team
- See if the team accepts their performance without questioning whether or not they're human

