Artificial Intelligence

Knowledge (expert) systems

Dictionary Definition of Knowledge

- A clear and certain perception of something; the act, fact, or state of knowing; understanding.
- Learning; all that has been perceived or grasped by the mind.
- Practical experience; skill; as a knowledge of seamanship.
- Acquaintance or familiarity such as with a fact or place.
- Cognizance; recognition.
- Information; the body of facts accumulated by mankind.
- Acquaintance with facts; range of awareness, or understanding.

– *Webster's New Twentieth Century Dictionary of the English Language (Second Edition)*

Knowledge Systems Definition

- Knowledge refers to the codified experience of agents
  - Codified means knowledge has been formulated, recorded, and made ready for use
  - Experience is source of information for solving problems
  - Codified experience must be organized and generalized to guide future action
- **"Knowledge is what we have learned from our experiments"**

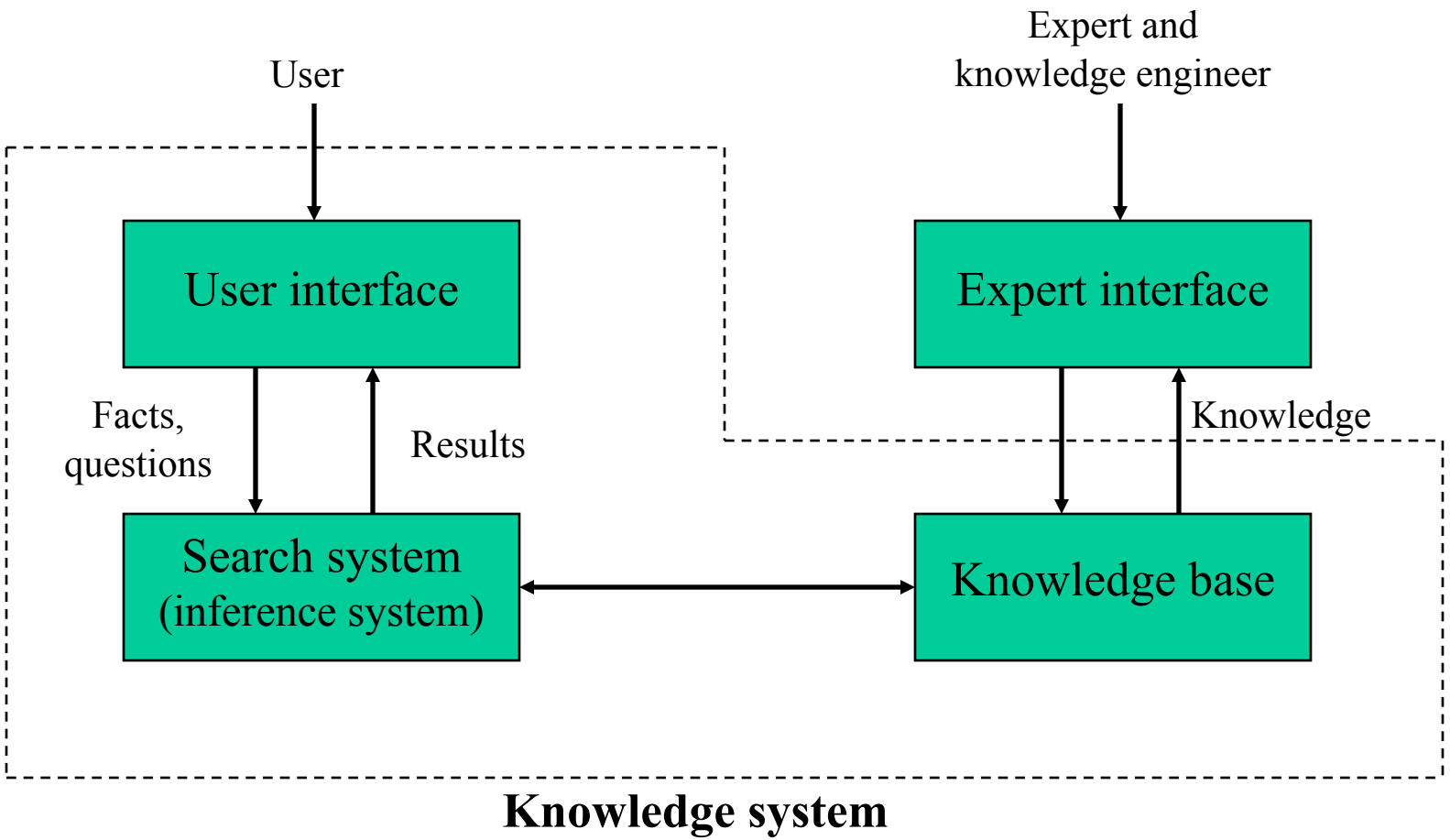
Bodies of Knowledge

- Domain knowledge
  - General terminology and facts of domain without focus on a particular task
    - e.g., facts about *general chemistry*, but not limited to just chemical synthesis
- Task knowledge
  - Terminology, computational models, and facts associated with performing a kind of task
    - e.g., knowledge and models about a *scheduling* task

Expert Systems

- A computer program whose performance is guided by specific, expert knowledge in solving problems
  - Focus on problem solving
  - Knowledge is that which can guide a search for solutions
- "Expert" knowledge means narrow specialization and substantial competence *****
  - Less breadth and flexibility than human experts
  - (Just like a Ph.D. dissertation!)
- Knowledge system vs. expert system
  - Focuses attention on the knowledge that systems carry, rather than if it constitutes expertise
- Expert-level advisors or consultants
  - Smart spreadsheet, intelligent patient monitor, financial advisor, therapy critic, cognitive coprocessor

Parts of a Knowledge System



Expert Systems are generally…

- Open to inspection
  - Present intermediate steps and answer questions about the solution process
- Easily modified
  - With adding/deleting from knowledge base
- Heuristic
  - Using often imperfect knowledge (“tricks”, “rules-of-thumb”)

Appropriate Problem has…

- The need justifies the cost of building the system
- Human expertise is not available in all situations
- Problem may be solved using computational reasoning techniques
- Problem is well-structured with no Common Sense reasoning required (otherwise too hard!)
  - More on this later!
- Problem may not be solved with traditional computing methods
- *Cooperative* and articulate experts exist
- Problem is of proper size and scope

Knowledge System Scenarios

- Participatory design
  - Involves several people in three roles working together to develop the system
    - User, domain expert, and knowledge engineer
  - Emphasizes communication among participants
  - Most common in practice

Design Team

- Domain expert
  - Experience solving problems in domain
  - Knows little about creation of knowledge systems
  - Spells out skills to knowledge engineer
- Knowledge engineer (you!)
  - AI expert, has experience building knowledge systems
  - Knows little about the expert's domain
- End user
  - Understanding of job, determines major design constraints
  - Make this person happy!
- All need to learn concepts and terminology of task to communicate efficiently

Working Together

- Begins with knowledge engineer gaining some familiarity with problem domain
  - Helps in communicating with domain expert
  - Background reading, interviews, etc.
- Next, extract expert's problem-solving knowledge
  - Give experts sample problems and get determine techniques used in their solution

Relations to Psychology

- Goals
  - Gain insights about nature of mental processing
  - Learn about intermediate steps in solving problem
  - Identify knowledge used for problems
- "Verbal" data **hypothesis**
  - Information used during performance of task is reportable in verbal protocols
  - Information reported in verbal protocols is used in problem solving
  - CURRENT RESEARCH SHOWS NOT ALWAYS TRUE (other methods exist)

Types of Cases

- Typical cases
  - Use during problem identification stage
- Random cases
  - Random cases selected from case file
  - Check for gaps in coverage
- Extreme and tough cases
  - Involves unusual circumstances
  - Reveals hidden assumptions and exceptions from typical cases

Types of Added Constraints

- Limited time to solve problems
  - Limit time expert has to solve problem
  - Provide insights into expert's search strategy
- Withholding information
  - Leave out information usually available
    - e.g., no patient history before interpreting x-ray
    - This provides evidence about the extent to which history data are used in the interpretation process
  - But, more left out is less reliable as evidence

Knowledge Acquisition Problems

- Human skill is practice-based ("learn by doing")
  - After years of practice, skills are highly integrated and often not explicitly/individually retrievable
- Individual's expertise can be influenced by social processes, hidden agendas, etc.
  - Not necessarily "factual" about the world
- Expertise changes over time!
  - Lifelong learning

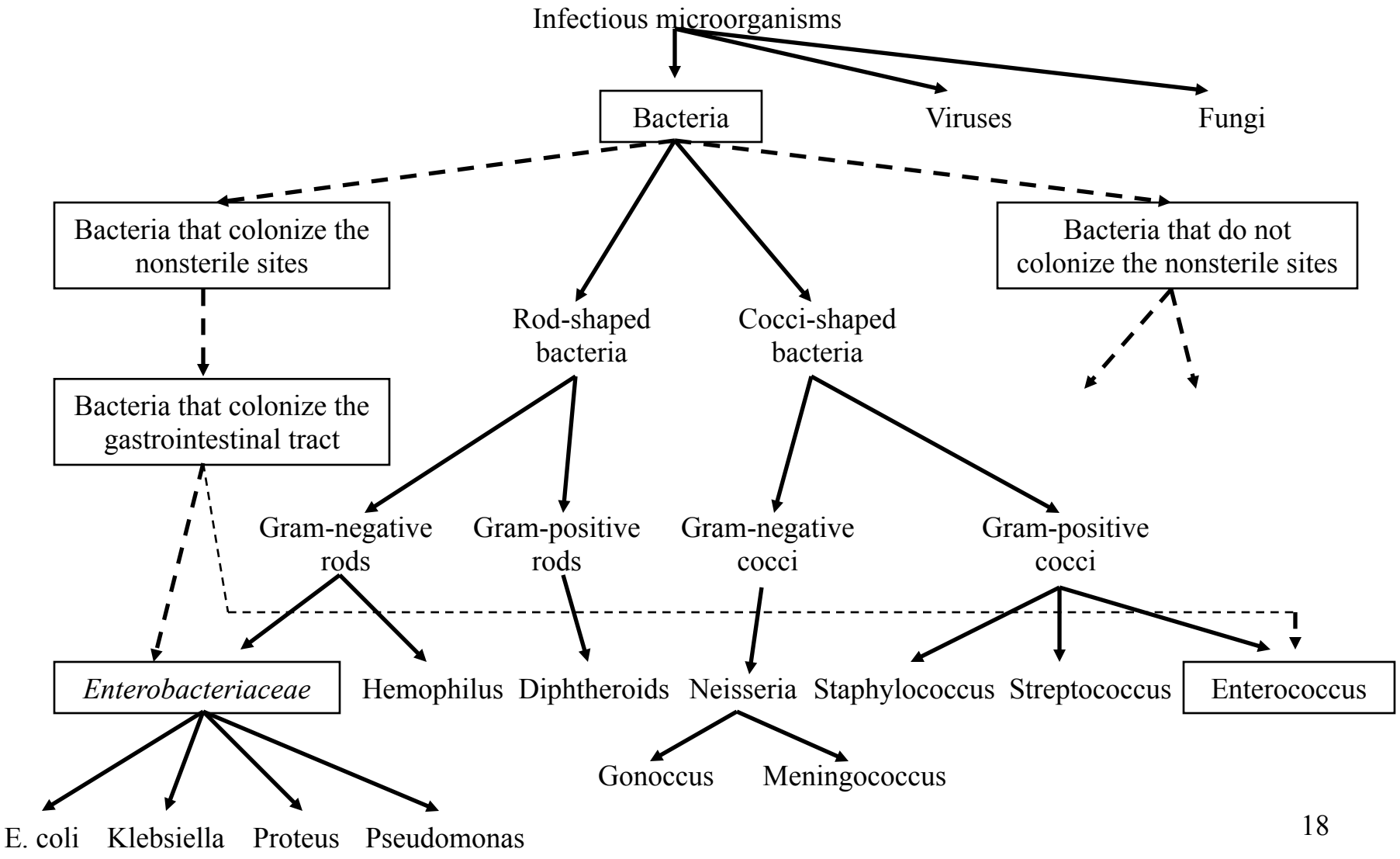
System Design Process

- After distilling knowledge used for tasks, begin actual design of the system
  - Selecting ways to represent knowledge
  - Determining the search strategy
  - Designing the user interface
- Build prototype to test
- Refine by progressive approximation
  - Problem solving mistakes leads to correction or additions to knowledge base
- Need never be considered “finished”
  - Always limitations or shortcomings

Example System: MYCIN

- MYCIN (Buchanan & Shortliffe, 1984)
- Expert system that consults on diagnosis of infectious diseases
  - Especially bacterial infections of the blood
  - Also makes therapy recommendations
- Use of explicit knowledge base
  - Search for solutions guided by KB
- Opened up niche for a new kind of AI system
- Widely studied and imitated
  - Good starting point for learning about knowledge systems

MYCIN: Solution Space Taxonomy



MYCIN

- MYCIN is a goal-driven (backward-chaining!) expert system
  - A possible infecting organism forms goal that is either confirmed or eliminated
- After answers to questions suggest meningitis, goes into full goal-driven mode
  - After sees that patient has had headaches and other abnormal neurological signs (suggests meningitis)
  - Tries to determine actual infecting organism
  - Considers each infecting organism it knows about, and attempts to eliminate or confirm each hypothesis in turn
- Looks for goal with certainty of 1 (absolutely certain)
  - When confidence measures for rule get below threshold (.2), search is terminated

A Dialog with MYCIN

1) Patient's name: (first-last):

   ** FRED BRAUN

2) Sex:

   ** M

3) Age:

   ** 55

4) Are there any cultures for Fred Braun which may be related to the present illness, and from which organisms have been grown successfully in the microbiology laboratory?

   ** Y

[continued next slide]

A Dialog with MYCIN

CULTURE-1

5) From what site was the specimen for CULTURE-1 taken?

** BLOOD

6) Please give the date and time when CULTURE-1 was obtained. (mo/da/yr time)

** June 20, 1977

The first organism isolated from the blood culture of 20-JUN-77 (CULTURE-1) will be referred to as:

ORGANISM-1

7) Enter the laboratory-reported identity of ORGANISM-1:

** UNKNOWN

[continued next slide]

A Dialog with MYCIN

8) Enter the stain of ORGANISM-1:

** NEG

9) Is ORGANISM-1 rod or coccus (etc.):

** ROD

10) What is the form of the individual organisms?

** FUSIFORM

(50 more questions follow!!!)

[continued next slide]

A Dialog with MYCIN

Gives diagnose of a probable infection type and associated organisms

INFECTION-1 IS **BACTEREMIA**

<ITEM-1> E. COLI [ORGANISM-1]

<ITEM-2> KLEBSIELLA [ORGANISM-1]

<ITEM-3> ENTEROBACTER [ORGANISM-1]

<ITEM-4> KLEBSIEELA-PNEUMONIAE [ORGANISM-1]

Inside MYCIN

- Translates pseudo-English rules to and from internal production-rule representation
  - Uses key-words and templates to guide translation into internal symbol structures
  - Implemented as production rules in LISP

RULE-177

If 1) the infection is primary-bacteremia, and
2) the site of the culture is one of the sterile sites, and
3) the suspected portal of entry of the organism is the gastro-intestinal tract,

Then there is suggestive evidence (.7) that the identity of the organism is bacteroides

Subsystem of MYCIN

- Explanation systems
  - Mechanism to explain or justify conclusions
  - “transparent box” rather then “black box”
  - User can discard conclusion if disagree
- MYCIN explanation program built from collection of specialist subprograms
  - Designed to answer particular kinds of queries
  - Examine diagnosis rule trace of system

Question and Answering

** IS ORGANISM-1 A STREPTOCOCCUS?

No. the identity of ORGANISM-1 IS e.coli (.74) bacteroides (.7) klebsiella-pneumoniae (.4) pseudomonas-aeruginosa (.22) …

** WHY DID YOU RULE OUT STREPTOCOCCUS AS A POSSIBLITY FOR ORGANISM-1?

RULE033 could have been used to determine that the identity of ORGANISM is streptococus. However, clause 2 of RULE033 [“the morphology of the organism is coccus”] was already known to be false for ORGANISM-1, so the rule was never tried.

** HOW DID YOU KNOW THAT CULTURE-1 WAS FROM A STERILE SOURCE?

I used RULE189 to conclude that this blood culture was taken from a sterile source. This gave a cumulative CF of (1.0). The last question asked before the conclusion was made was 7.

MYCIN

- Evaluation of MYCIN
  - Mistakes can be life-threatening
    - Overlooking infecting agent can be catastrophic
- Evaluated using a form of Turing test
  - 10 randomly selected case histories of meningitis
  - Re-diagnosed by MYCIN and eight practitioners at Stanford Medical School
    - Included five faculty, one research fellow in infectious diseases, one resident physician, one medical student
  - Actual therapy for cases by doctors also included
  - Evaluated by eight infectious-disease experts away from Stanford
    - Blind review (not given which was computer diagnosis)

MYCIN

Experts Evaluate MYCIN and Nine Other Prescribers		
Prescriber	**Score***	**Percent**
MYCIN	55	69
Faculty-5	54	68
Fellow	53	66
Faculty-3	51	64
Faculty-2	49	61
Faculty-4	47	59
Actual Rx	47	59
Faculty-1	45	56
Resident	39	49
Student	28	35

* Evaluators rated each diagnosis as acceptable or unacceptable, giving one point for each acceptable rating. Perfect score is 80 points (10 cases x 8 reviewers).

MYCIN

Number of Cases in Which Therapy Missed a Treatable Pathogen	
Prescriber	**Number**
MYCIN*	0
Faculty-5	1
Fellow	1
Faculty-3	1
Faculty-2	0
Faculty-4	0
Actual Rx	0
Faculty-1	0
Resident	1
Student	3

*MYCIN gave fewer drugs than human experts on average

MYCIN

- MYCIN performed at least as well as the Stanford experts
  - Not surprising, as knowledge base represents combined expertise of some best medical minds
  - MYCIN did not overprescribe for infections
- Little agreement among human experts concerning correctness of diagnoses
  - No unanimous endorsement from evaluators

MYCIN

- MYCIN too slow to give speedy response in doctor-computer interaction
  - Nearly 600 rules to check
  - Session lasted about one-half hour
  - Lots of typing
- MYCIN could not extrapolate to other situations
- MYCIN's explanations were limited
  - Not give deeper understanding
- FOLKLORE:
  - MYCIN asked if patient was pregnant even after been told patient was male!

Interesting Developments from MYCIN

- EMYCIN
  - First "expert shell" developed from MYCIN
    - An expert system shell is a program that facilitates the development of expert systems.
- NEOMYCIN
  - Developed for training doctors
  - Take them through various example cases, checking their conclusions and explaining where they went wrong

Knowledge vs. Complexity

- MYCIN demonstrated
  - Complexity of the world
    - Systems need to model that complexity
  - Role of knowledge
    - More complex the task, more knowledge necessary
- An increase in number of rules suggests program and task are more complex

Knowledge vs. Complexity: The Knowledge Hypothesis

- "Knowledge is power"
  - Was new style of building AI systems
  - Integral part of building knowledge systems
- The Knowledge Hypothesis
  - "To achieve a high level of problem-solving competence, a symbol system must use a great deal of domain-specific, task-specific, and case specific knowledge"

Knowledge Hypothesis Failure?

- Chess
  - Was widely believed that excellent chess play required large amounts of knowledge
  - Grand-master estimated to have 50,000 situations in head
  - Path was to put more knowledge in the programs
- Seems to be wrong here
  - Powerful chess programs got their edge through faster computing on specialized parallel processors
    - Search more deeply
  - Knowledge hypothesis not universal
- However… recent chess systems not based on brute-force and compute power

Summary

- Knowledge
  - The codified experience of agents
- Expert system
  - System whose performance is guided by specific, expert knowledge in solving problems
- Participatory design and knowledge acquisition
  - Gain insights about nature of mental processing
- MYCIN
  - Expert system that consults on diagnosis of infectious diseases
- The Knowledge Hypothesis
  - Need lots of knowledge for complex world