# INTRODUCTION TO EXPERT SYSTEM

# Table of Content

# What is an ES?

- **Expert System (ES)** is a branch of Artificial Intelligence that attempt to mimic human experts.
  - Expert systems can either support decision makers or completely replace them.
  - Expert systems are the most widely applied & commercially successful AI technology.

# What is an ES?

- Prof. Edward Feigenbaum of Stanford University, leading researchers in ES has produced the following definition:

**" . . . An intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution."**

# What is an ES?

- Expertise is the extensive, task-specific knowledge acquired from training, reading, and experience.

- The transfer of expertise from an expert to a computer and then to the user involves four activities:
  - ✓ knowledge acquisition from experts or other sources.
  - ✓ knowledge representation in the computer.
  - ✓ knowledge inferencing, resulting in a recommendation for novices.
  - ✓ knowledge transfer to the user.

# What is an ES?
## CASE: GE Models Human Troubleshooters

**Problem:**

- GE wanted an effective & dependable way of disseminating expertise to its engineers & preventing valuable knowledge from "retiring" from the company.

**Solution:**

- GE decided to build an expert system that modeled the way a human troubleshooter works.
- The system builders spend several months interviewing an employee & transfer their knowledge to a computer.
- The new diagnostic technology enables a novice engineer to uncover a fault by spending only a few minutes at the computer terminal.

**Results:**

- The system is currently installed at every railroad repair shop served by GE.

# Conventional and ES

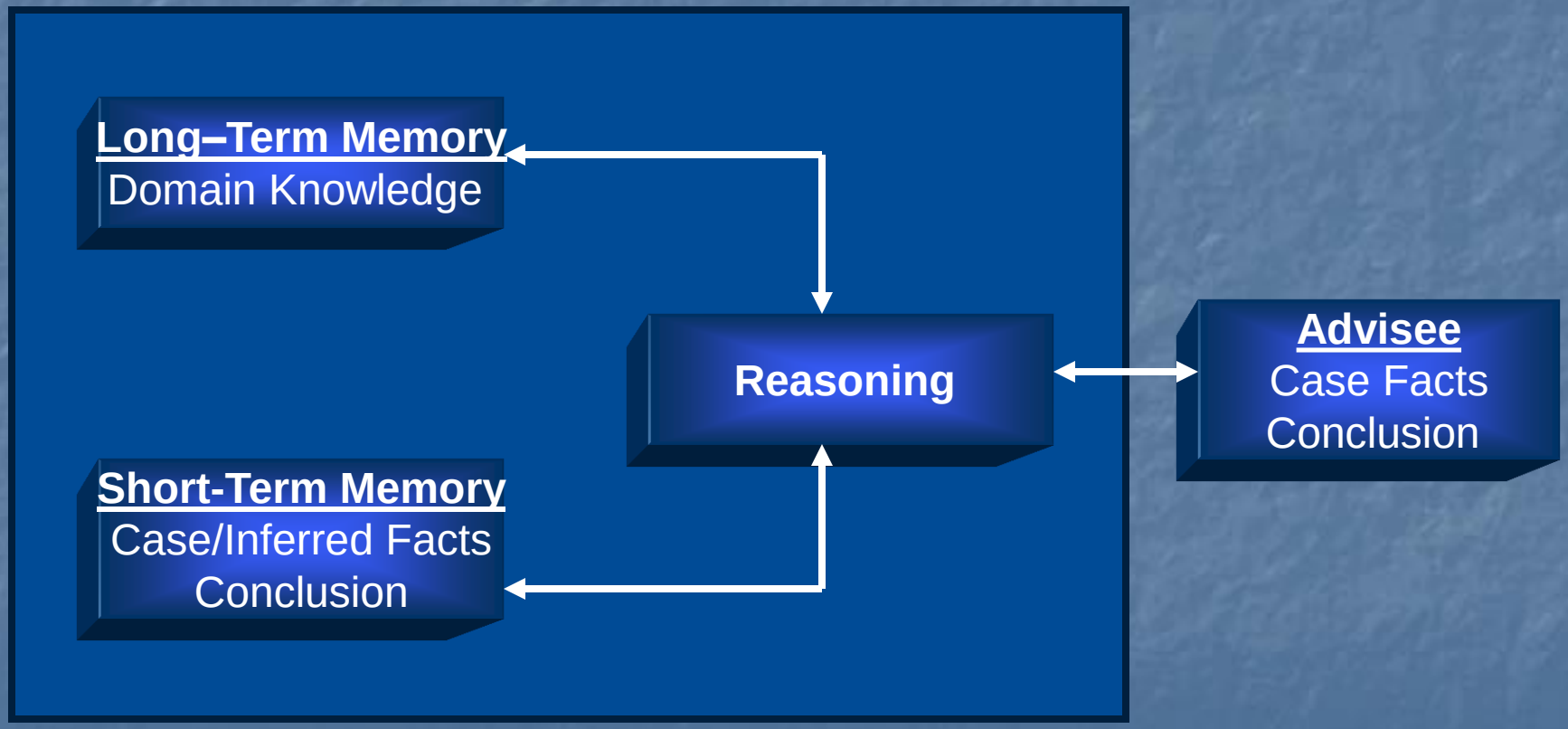
| Conventional Systems | Expert Systems |
| --- | --- |
| Knowledge and processing are combined in one sequential program | Knowledge base is clearly separated from the processing (inference) mechanism (knowledge rules are separated from the control) |
| Programs do not make mistakes (only programmers do) | Program may make mistakes. |
| Do not usually explain why input data are needed or how conclusions were drawn | Explanation is a part of most expert systems |
| The system operates only when it is completed | The system can operate with only a few rules (as a first prototype) |
| Execution is done on a step-by-step (algorithmic) basis | Execution is done by using heuristics and logic |

# Conventional and ES

| Conventional Systems | Expert Systems |
| --- | --- |
| Needs complete information to operate | Can operate with incomplete or uncertain information |
| Effective manipulation of large databases | Effective manipulation of large knowledge bases |
| Representation and use of data | Representation and use of knowledge |
| Efficiency is a major goal | Effectiveness is a major goal |
| Easily deals with quantitative data | Easily deals with qualitative data |

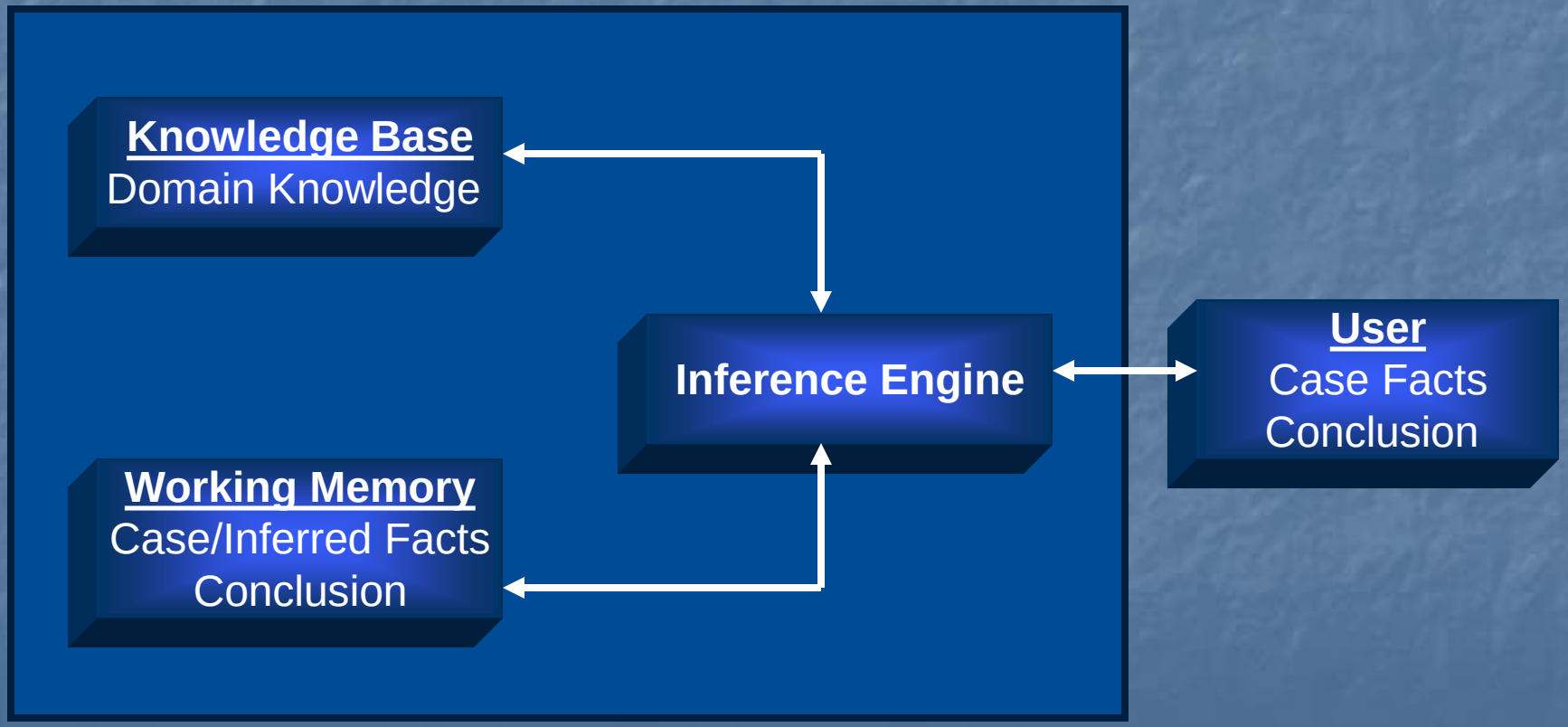
# The Structure of ES

- Human Expert Problem solving



# The Structure of ES

- Expert System problem solving



# The Structure of ES

## THE KNOWLEDGE BASE (LONG TERM MEMORY)

- The key bottleneck in developing an expert system.
- Contain everything necessary for understanding, formulating and solving a problem.
- It contains facts and heuristics.
- The most popular approach to representing domain knowledge is using production rules.

  - **Rule 1**
    IF car won't start
    THEN problem in electrical system
  - **Rule 2**
    IF problem in electrical system
    AND battery voltage is below 10 volts
    THEN bad battery

# The Structure of ES

**WORKING MEMORY (SHORT TERM MEMORY)**

- Contains facts about a problem that are discovered during consultation with the expert system.
- System matches this information with knowledge contained in the knowledge base to infer new facts.
- The conclusion reach will enter the working memory.
- Thus, working memory contain information either supplied by user or infer by the system.

# The Structure of ES

**INFERENCE ENGINE**

- Knowledge processor which is modeled after the expert reasoning power.
- Processor in an expert system that matches the facts contained in the working memory with the domain knowledge contained in the knowledge base, to draw conclusion about the problems.
- It taps the knowledge base and working memory to derive new information and solve problems

# The Structure of ES

**THE USER INTERFACE**

- The user communicates with the expert system through the user interface.
- It allows the user to query the system, supply information and receive advice.
- The aims are to provide the same form of communication facilities provided by the expert.
- But normally has less capability of understanding natural language and general knowledge.

# The Structure of ES

**THE EXPLANATION FACILITY**

- A trademark of expert systems: ability to explain their reasoning.
- An additional component of expert system.
- ES can provide explanation on:
  - **WHY** it is asking the question
  - **HOW** it reached some conclusion.

# The Structure of ES

Explaining WHY

- Example:
  - MM : Will the car not start?
  - Person : WHY
  - MM : If I know that the car won't start then I usually assume the problem is the electrical system.
- Expert responds with what they might conclude from the answer.
- ES respond to a WHY query by displaying the rule it is currently pursuing.

# The Structure of ES

Explaining HOW

- Besides giving final results, expert system can explain how it arrived at a result.
- Example:
  - MM : The battery is bad
  - Person : HOW
  - MM : Since your car won't start, I assumed there was a problem with the electrical system. I found the battery voltage was below 10, I knew the battery was bad.
- ES respond by tracing back through the rules that fire the conclusion.
- This tracing is a map of the system line of reasoning.

# Characteristics of Expert Systems

1. High-level expertise.
   - The most useful characteristic of an expert system.
   - This expertise can represent the best thinking of top experts in the field, leading to problem solutions that are imaginative, accurate, and efficient.
2. Adequate response time.
   - The system must also perform in a reasonable amount of time, comparable to or better than the time required by an expert to solve a problem.

# Characteristics of Expert Systems

3. Permits Inexact Reasoning.
   - These types of applications are characterized by information that is uncertain, ambiguous, or unavailable and by domain knowledge that is inherently inexact.
4. Good Reliability.
   - The system must be reliable and not prone to crashes because it will not be used

# Characteristics of Expert Systems

5. Comprehensibility.
   - The system should be able to explain the steps of its reasoning while executing so that it is understandable.
   - The systems should have an explanation capability in the same way that human experts are suppose to be able to explain their reasoning.
6. Flexibility.
   - Because of the large amount of knowledge that an expert system may have, it is important to have an efficient mechanism for modifying the knowledge base.

# Characteristics of Expert Systems

7. Symbolic Reasoning.

- Expert systems represent knowledge symbolically as sets of symbols that stand for problems concepts.
- These symbols can be combined to express relationship between them. When these relationship are represented in a program they are called symbol structures.
- For example,
  - Assert: Ahmad has a fever
- Rule: IF person has fever THEN take panadol

  Conclusion: Ahmad takes panadol

# Characteristics of Expert Systems

8. Reasons Heuristically
   - Experts are adapt at drawing on their experiences to help them efficiently solved some current problem.
   - Typical heuristics used by experts:
   - I always check the electrical first.
   - People rarely get a cold during the summer
   - If I suspect cancer, then I always check the family history.
9. Makes Mistakes
   - Expert systems can make mistakes.
   - Since the knowledge of expert have to be captured as close as possible in expert system, like its human counterpart, it can make mistakes.

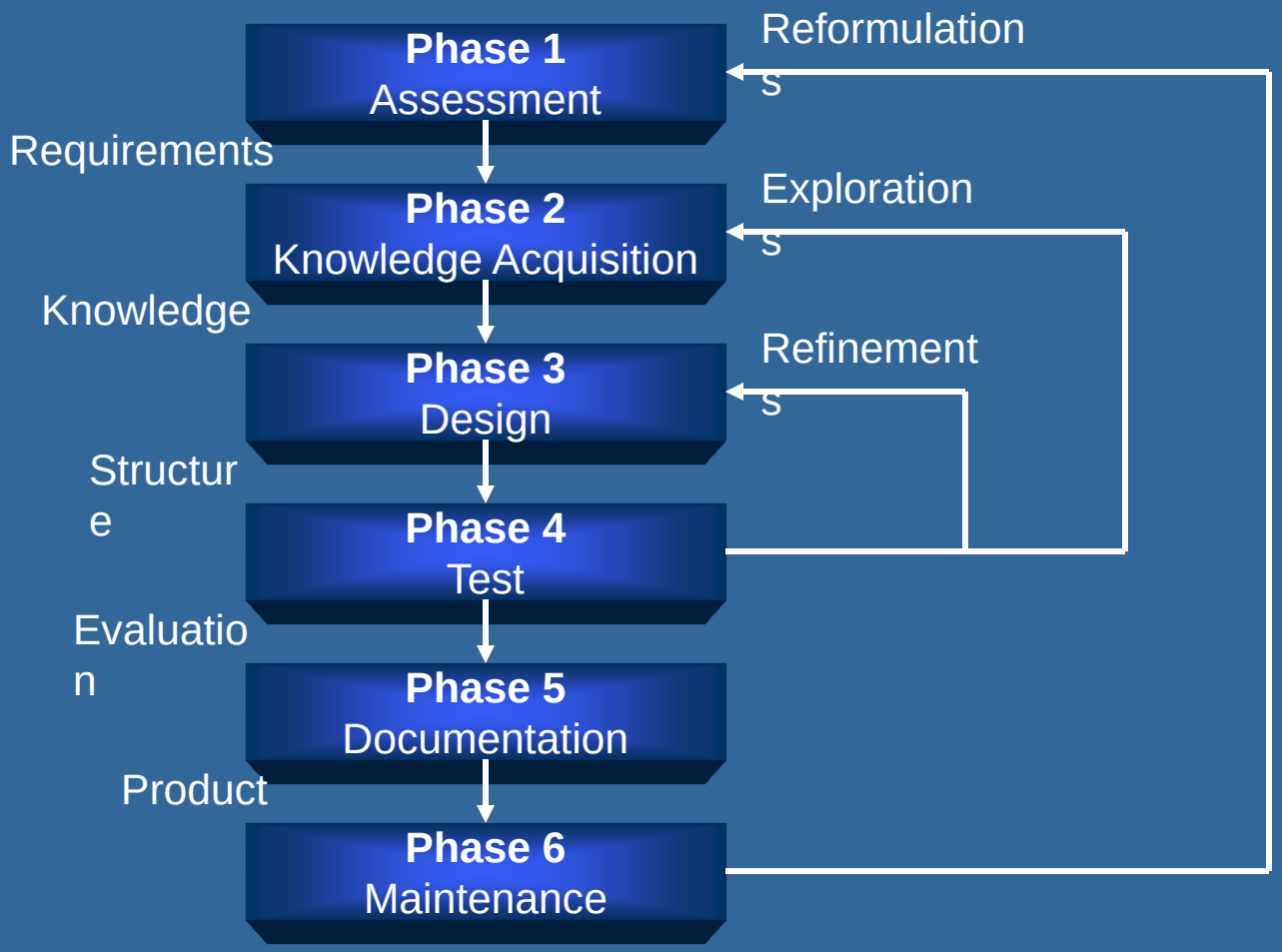
# Characteristics of Expert Systems

10. Thrives on Reasonable Complexity
    - The problem should be reasonably complex, not too easy or too difficult.
11. Focuses Expertise
    - Most experts are skillful at solving problems within their narrow area of expertise, but have limited ability outside this area.

# ES Development Life Cycles (ESDLC)

- ESDLC contains the following phases:
  1. Assessment
  2. Knowledge Acquisition
  3. Design
  4. Testing
  5. Documentation
  6. Maintenance

# ES Development Life Cycles



# ES Development Life Cycles

1. Assessment
   - Determine feasibility & justification of the problem
   - Define overall goal and scope of the project
   - Resources requirement
   - Sources of knowledge

# ES Development Life Cycles

2. Knowledge Acquisition
   - Acquire the knowledge of the problem
   - Involves meetings with expert
   - Bottleneck in ES development

# ES Development Life Cycles

3. Design
   - Selecting knowledge representations approach and problem solving strategies
   - Defined overall structure and organization of system knowledge
   - Selection of software tools
   - Built initial prototype
   - Iterative process

# ES Development Life Cycles

4. Testing
   - Continual process throughout the project
   - Testing and modifying system knowledge
   - Study the acceptability of the system by end user
   - Work closely with domain expert that guide the growth of the knowledge and end user that guide in user interface design

# ES Development Life Cycles

5. Documentation
   - Compile all the projects information into a document for the user and developers of the system such as:
     - User manual
     - diagrams
     - Knowledge dictionary

# ES Development Life Cycles

6. Maintenance
   - Refined and update system knowledge to meet current needs

# Participants in ES Development

- The main participants in the process of building an expert system are:
  a. the domain expert
  b. the knowledge engineer
  c. the user.

# Participants in ES Development

- THE DOMAIN EXPERT
  - Is a person who has the special knowledge, judgment, experience, skills and methods, to give advice and solve problems in a manner superior to others.
  - Although an expert system usually models one or more experts, it may also contain expertise from other sources such as books and journal articles.
  - Qualifications needed by the Domain Expert:
    - Has expert knowledge
    - Has efficient problem-solving skills
    - Can communicate the knowledge
    - Can devote time
    - Must be cooperative

# Participants in ES Development

- If you call someone an “expert” for a project, treat that person like one. Even if the person doesn’t know everything about the domain, the person knows more than you.

  - Patrick E. Dessert

# Participants in ES Development

- THE KNOWLEDGE ENGINEER
  - A person who designs, builds and tests an expert systems.
  - Qualifications needed by Knowledge Engineer:
    - Has knowledge engineering skills (art of building expert system)
    - Has good communications skills
    - Can match problems to software
    - has expert system programming skills

# Participants in ES Development

- A KNOWLEDGE ENGINEER
  - I have been working as knowledge engineer for a software house for two years. Each project is different. The job is challenging and requires creative thinking and strong communication skills. I started as junior knowledge engineer at a salary of $30,500. I am now a lead engineer with a salary of $40,700 plus a nice annual bonus
    - Christine Melekian

# Participants in ES Development

- THE USER
  - Is a person who uses the expert system once it is developed.
  - Can aid in knowledge acquisition (giving broad understanding of the problems)
  - Can aid in system development

# Selected Business Expert Systems and Functions

| System | Developer | Business Function | Activity |
|---|---|---|---|
| AS/ASO | Arthur Andersen | Accounts Receivable | Aid auditing procedures |
| Authorizers Assistant | American Express | Consumer Credit | Evaluate credit records to protect against credit card fraud |
| Helpdesk advisor | Publix Supermarkets | Retailing | Handle problem calls from store managers |

# Selected Business Expert Systems and Functions

| System | Developer | Business Function | Activity |
|---|---|---|---|
| Intelligent Secretary | Nippon T & T | Personnel | Coordinate schedules of company personnel |
| Mortgage loan Analyzer | Arthur Andersen | Banking | Help loan officer make final decisions on home mortgage loan |
| Direct Labor Mgmt System (DLMSISIS) | Ford Motor Company | Manufacturing | Improve efficiency in all phases of the production process |

# Selected Business Expert Systems and Functions

| System | Developer | Business Function | Activity |
|---|---|---|---|
| Inspector | | Banking | Monitor Worldwide foreign exchange trading to identify irregular activities |
| Prohibited Transaction Exemption (TPE) Analyst | | Law | Help attorney evaluate transactions subject to Employee Retirement Income security Act |
| Personnel Policy Expert | | Personnel | Help devise employee policies & write employee handbooks; |

# When to Use Expert Systems

- Provide a high potential payoff or significantly reduced downside risk
- Capture and preserve irreplaceable human expertise
- Provide expertise needed at a number of locations at the same time or in a hostile environment that is dangerous to human health

# When to Use Expert Systems

- Provide expertise that is expensive or rare
- Develop a solution faster than human experts can
- Provide expertise needed for training and development to share the wisdom of human experts with a large number of people

# Justifying the Problem Domain

- The first step toward successful system is to pick the right problem and justify its selection.
- Selecting the right problem should be the first consideration in ES development.
- This step entails identifying the domain expert, the user and the payoff from the system

# Justifying the Problem Domain

- Key Domain Characteristics:
  - A narrow, well defined focus
  - Moderate solution time
  - Symbolic knowledge and reasoning
  - A stable domain
  - Size of the knowledge base (100 rules for first-time domain)
  - Available test cases
  - Complexity of the domain
  - Degree of uncertainty or fuzziness
  - Demonstration of worth
  - Scarce expertise
  - Appropriate depth of required knowledge

# MYCIN: A medical expert system

- Developed at Stanford University in the mid 1970's.
- The first large expert system that perform at the level of human expert and use as benchmark by expert system developers.
- Provide consultative advise about bacteremia and meningitis.
- Bacteremia is an infections that involve bacteria in the blood.

# MYCIN: A medical expert system

- Meningitis is an infection which is an inflammation of the membranes that envelop the brain and spinal cord.
- Can be fatal, thus need quick response, but positive identification normally takes 24 - 48 hours.
- Normally doctors must begin treatment in the absence of lab results.
- Very complex and doctor need advice of an expert of bacteremia and meningitis.

# How MYCIN works?

- MYCIN begin by initiating a dialogue.
- Physician response to the questions
- MYCIN provides:
    a. diagnosis
    b. prescription

# How MYCIN reasons?

- Laboratory results of body fluid analyses
- Symptoms that patient is displaying
- Characteristics of the patient such as age, sex etc.

# MYCIN

MYCIN consultative proceeds in 2 phases:

- Diagnosis is made to identify the most likely infection organisms
- Prescribe one or more drugs (antibiotics)

# MYCIN: Example of a rule

**IF** the stain of the organism is gram-positive
**AND** the morphology of the organism is coccus,
**AND** the growth conformation of the organism is clumps,
**THEN**
there is suggestive evidence (0.7) that the identity of the organism is staphyloccus

# A consultation With MYCIN

1. Please enter information about the patient.

| Name | Age | Sex | Race |
|---|---|---|---|
| Sally | 42 years | Female | Melayu |

2. Are there any positive cultures obtained from SALLY?

*No*

3. Are there any pending cultures of SALLY?

Yes

4. Site: date collected: stain examined: method

| CSF | 3-Jun-75 | Yes | N/A |
|---|---|---|---|

5. Stain of smear:

(type NONE if no organism was seen on the smear)

None

(Unable to reach conclusion from lab test, like physician continue asking questions.)

# A consultation With MYCIN (cont..)

6. Has Sally recently had symptoms of persistent headache or other abnormal neurologic symptoms(dizziness, lethargy etc.)

   Yes

7. Has SALLY recently had objective evidence of abnormal neurologic signs documented by physician observation of examination?

   Yes

Questions 6 and 7 traditional approach to diagnose by symptoms.

Conclude from the questions by giving first conclusion.

**Conclusion:** The CSF cultures will be considered to be associated with **MENINGITIS.**

# A consultation With MYCIN (cont..)

The following questions will identify particular organism that cause the infections.

8. Is the meningitis a hospital-acquired infection?

Yes

9. Is SALLY clinical history consistent with EPIGLOTTITIS?

No

10. Is Sally clinical history consistent with OTITIS-MEDIA?

No

11. Has the patient ever been to an area that is endemic for coccidiomycoses?

Unknown

12. Is Sally a burn patient?

Yes (Why)

**Conclusion:** The type of infection may be BACTERIAL.

# A consultation With MYCIN (cont..)

The final phase, prescription of antibiotics.

13. Does SALLY have clinically significant allergic reaction to any antimicrobial agent?

    No

14. Is Sally pregnant of breast feeding?

    No

15. Do you have reason to suspect that SALLY may have impaired renal functions?

    No

16. SALLY weight in kilograms?

    51.4

# A consultation With MYCIN

My preferred therapy recommendation is as follows:

Give the following combination:

1. ETHAMBUTAL

   Dose: 1.28g (13.0 100mg tablets) q24h PO for 60 days

   then 770 mg (7.5 100 mg tablets) q24h PO.

   Comments: periodic vision screening tests are recommended for optic neuritis.

2. INH

   Dose: 513 mg (5.0 100mg-tablets) q24h PO

3. RIFAMPIN

   Dose: 600 mg PO q24h

   Comments: Administer dose on empty stomach.

# HOW GOOD AN EXPERT IS MYCIN?

- In one complex evaluation, 8 independent evaluators evaluate MYCIN with 9 others human diagnostician for 10 difficult cases of meningitis.

- The task used was the selection of drugs for cases of meningitis before causative agents had been identified.

- Two phases of the evaluation:
  a. MCYIN and 9 human experts evaluate 10 cases
  b. Each of them prescribe medications

# HOW GOOD AN EXPERT IS MYCIN?

Two evaluative criteria was used to see whether the prescriptions:

a. Would be effective against the actual bacteria after it was finally identified.

b. Adequately covered for other possible bacteria while avoiding over-prescribing.

# HOW GOOD AN EXPERT IS MYCIN?

**Results:**

Criteria 1: MYCIN and 3 other humans expert consistently prescribe therapy that would have been effective for all 10 cases.

Criteria 2: MYCIN received higher ratings. 65% correct in all the cases whereas human expert 42.5% to 62.5%.

# HOW GOOD AN EXPERT IS MYCIN?

MYCIN strengths is based on 4 factors:

a. MYCIN's knowledge base is extremely detail because acquired from the best human practitioners.

b. MYCIN do not overlook anything or forget any details. It considers every possibility.

c. MYCIN never jumps to conclusions of fails to ask for key pieces of information.

d. MYCIN is maintained at a major medical center and consequently, completely current.

MYCIN represents 50 man-years of effort.

Back to Main Menu

# Building Tools

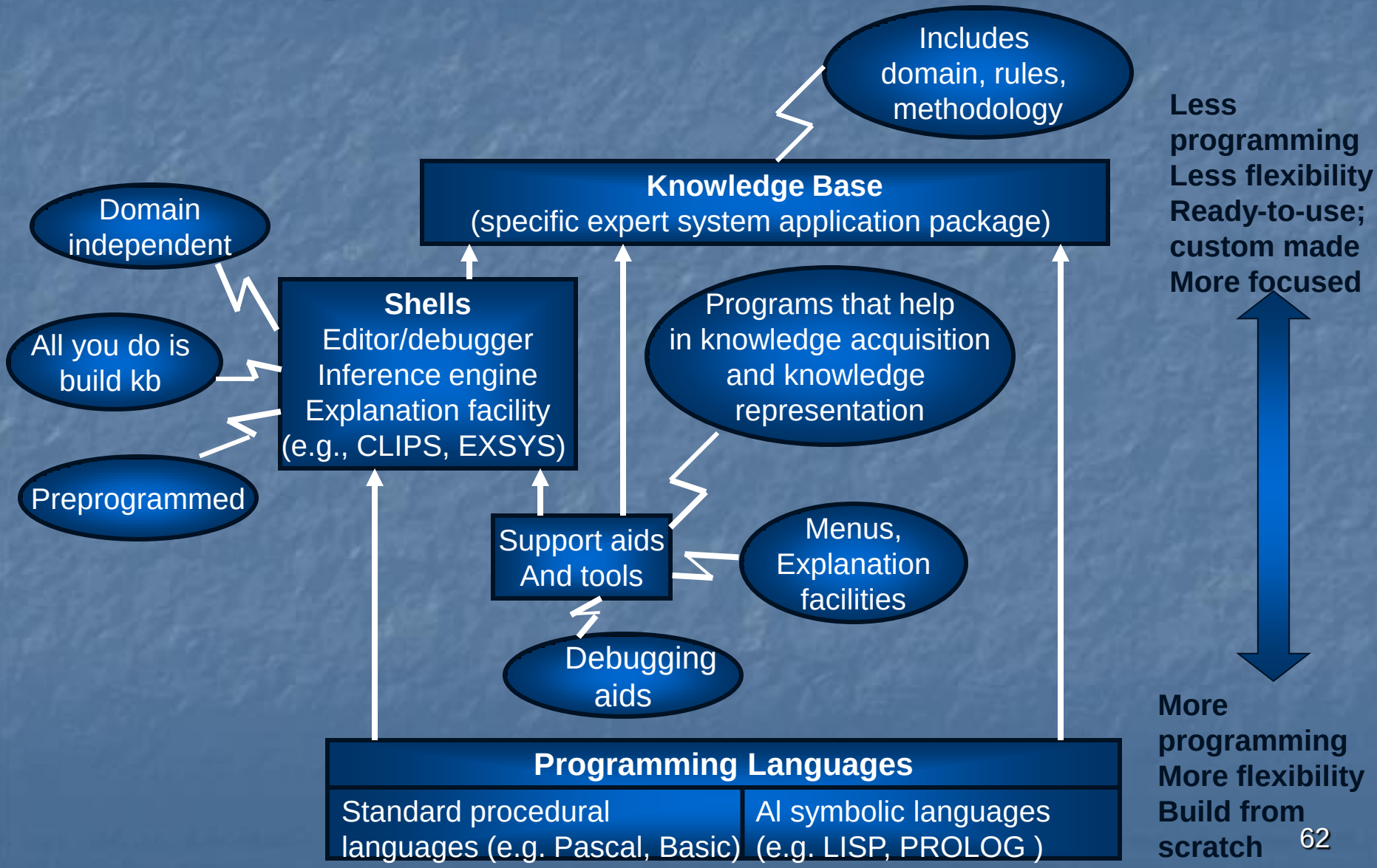
- Since mid-1970s, a wide choice of tools and approaches fro developing ES have become available.
- They range from high-level and AI programming language to shells to ready-to-use customized packages for industry and government.
- Which tools to adopt depend on:
  - The nature of the problem
  - The skill of the builder
  - The function it is expect to perform (either diagnoses or monitoring)

# Building Tools

- Several levels or categories of tools are available for building ES such as follows:
  - Programming languages
  - Support aids and tools
  - Specific ES packages
  - Shells
- The figure below illustrates the 4 levels (p344)

# Building Tools

- The figure below illustrates the 4 levels



# Programming Language

- The language written is important because it determines the efficiency and performance of the tool.
- ES can be programmed in a variety of languages: both standard or AI-oriented.
- Standard programming or algorithmic approach, is a “brute force” method in which standard procedural languages are used to develop the IF … THEN rules

# Programming Language

- Standard programming language are used for the following reasons:
  - Limitation of hardware operating system
  - Power and speed of the language
  - Incorporation of digital input/output devices in the system
  - Language execution time efficiency

# Programming Language

- AI programming are done through symbolic language such as LISP and Prolog.
- Although more restrictive and require more memory, they are effective the way they present rules and control their processing
- They process symbols instead of numbers to reach conclusion on a logical level of knowledge representation

# Programming Language

- Example of LISP programming language

```
(rule 43  (concerns (car auto mobilehome))
          (application_if (in vehicle frame))
          (antecedent_is
                    (if ((? entity) has (wheels and owner
                                        and roof… ))
          (production_is
                    (then      ((? entity? isa auto)
          (alternate_productions
                    (then      ((? entity? isa mobilehome)…
          (further _information
                    (top_down   (see transportation
status_symbol))
                    (bottom_up   (see wheels driver owner …))  )
          (confidence  *use function auto_confidence)
          (update_rule   (apply learning_function
                         (number  32 ))))))
```

# Programming Language

- Example of PROLOG programming language

```
>student (david).
>student (mary).
>student (john).
>student (ann).
>student (jerry).
>student (sue).
```

**FACTS**

```
Likes (Someone, accounting) :-
        concentrating (Someone, accounting).
```

**RULE**

```
>concentrating (david, mis).
>concentrating (mary, marketing).
>concentrating (mary, mis).
>concentrating (john, accounting).
>concentrating (ann, management).
>concentrating (ann, mis).
>concentrating (jerry, finance).
>concentrating (sue, accounting).
```

**FACTS**

# Support Aid and Tools

- Support aids automate the time consuming phase of acquisition, improve effectiveness of representation, ensure crisp human-machine interface and debugging aids that traces the reasoning.
- Explanation facilities show how the system arrives at a particular solution
- Editing facility ensures that the syntax is correctly represented in the knowledge base

# Specific Expert System packages

- The easiest product to use from user's  of view
- Specific ready-to-use program that advises a specific user in a specific industry to address a specific problem domain
- For example, a consultation system that advises student on elective courses to take.
  - The system essentially plugs in the vital variable, matches them against established criteria and determines the courses to take.

# Shells

- A shell provides a basic architecture for building ES.

- Shells perform 3 different functions:
  a. Assists in building the knowledge base by allowing the developer to insert knowledge into knowledge representation structures.
  b. Provides methods of inference or deduction that reason on the basis of information in the knowledge base and new facts input by the user.
  c. Provides an interface that allows the user to set up reasoning task and query the system about its reasoning strategy.

# Shells

- The main 3 components:
  a. The knowledge base
  b. Inference engine
  c. User interface

# Shells

- Main components of a shell