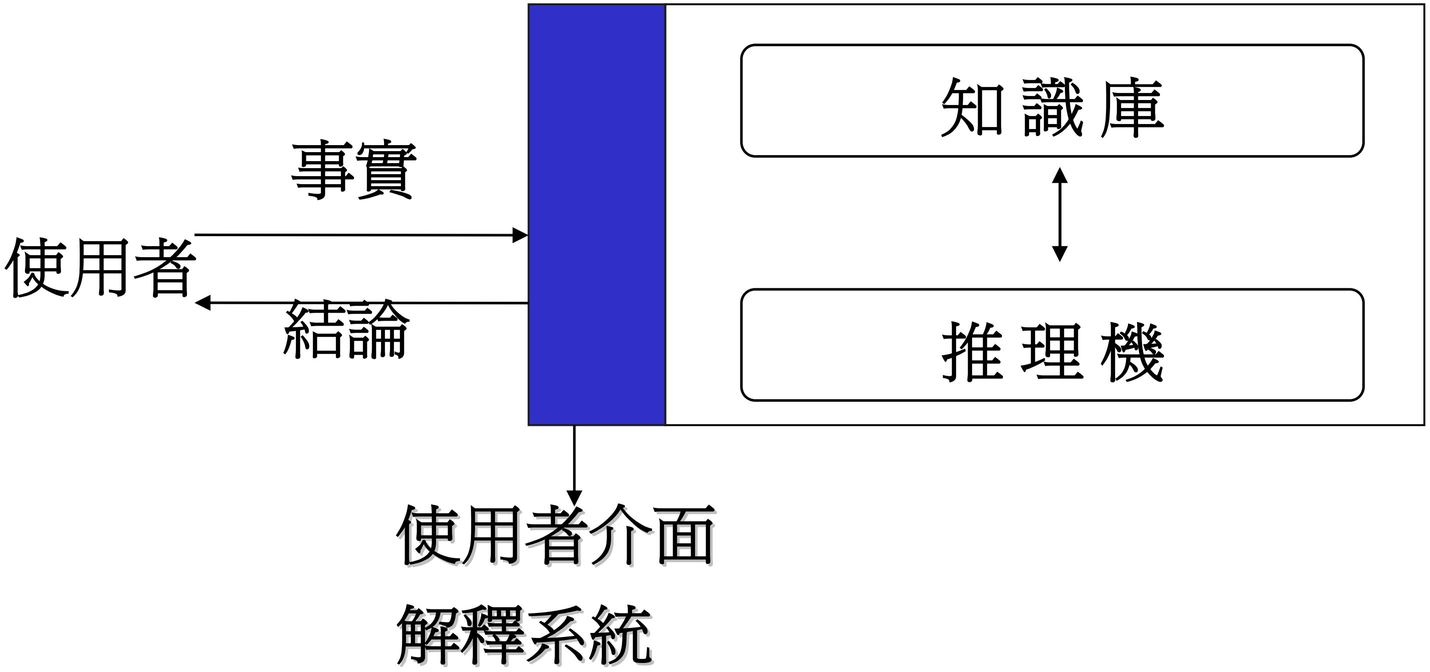
CHAPTER 1

人工智慧與專家系統簡介

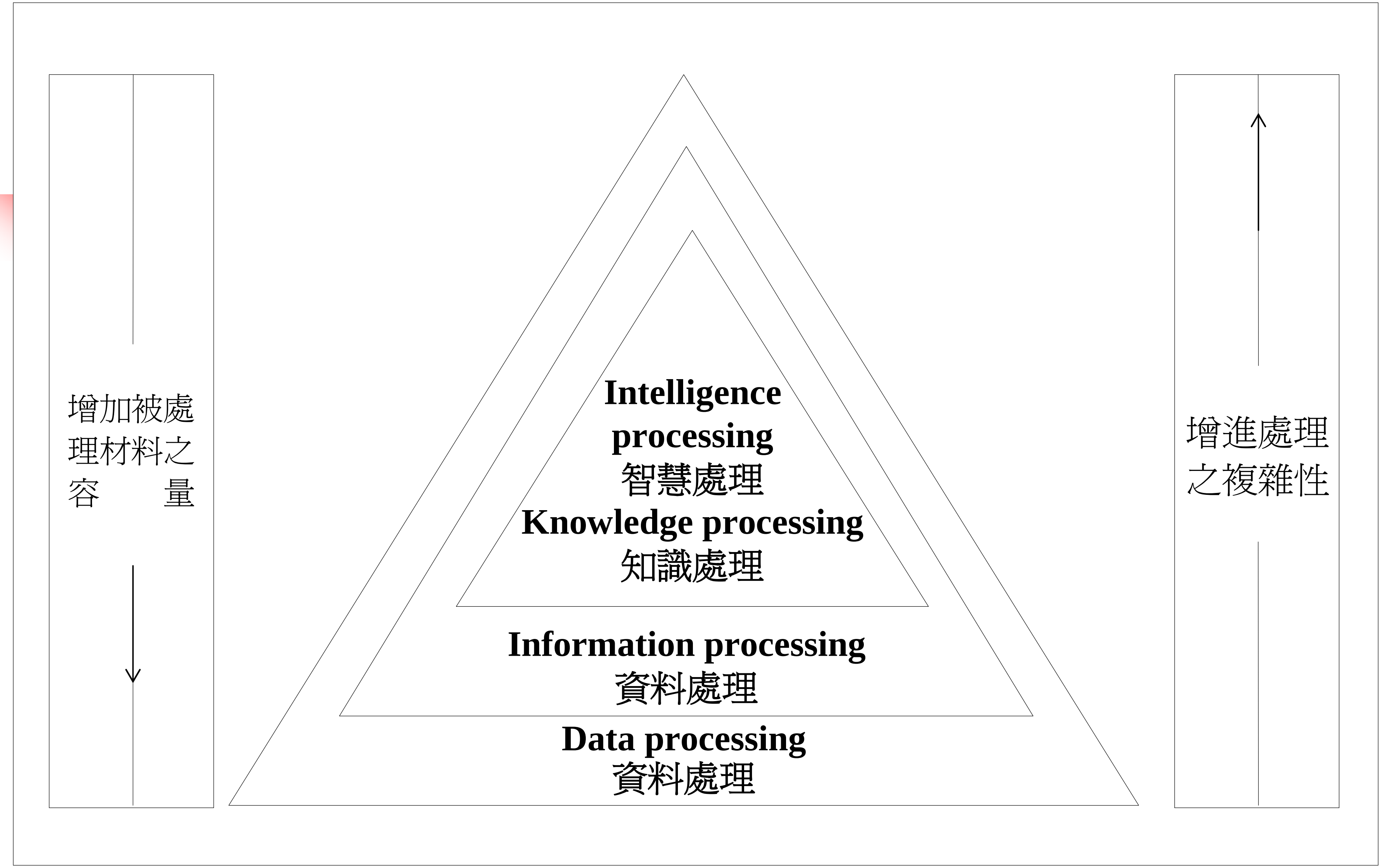
What is an expert system ?

An intelligent computer program that uses knowledge and inference procedure to solve problems.



參與成員

- Users
- Experts
  - An expert’s knowledge is specific to one problem domain, as opposed to knowledge about general problem-solving techniques
  - The expert’s knowledge about specific problems is called the knowledge domain of the expert.
- Knowledge Engineers



增加被處理材料之容　　量

Intelligence processing

智慧處理

Knowledge processing

知識處理

Information processing

資料處理

Data processing

資料處理

增進處理之複雜性

電腦處理之演進空間

Different Views of Technology

- Manager：

  What can I use it for ?
- Technologist：

  How can I best implement it ?
- Researcher：

  How can I extend it ?
- Consumers：

  How will it help me ?

  Is it worth the trouble and expense ?

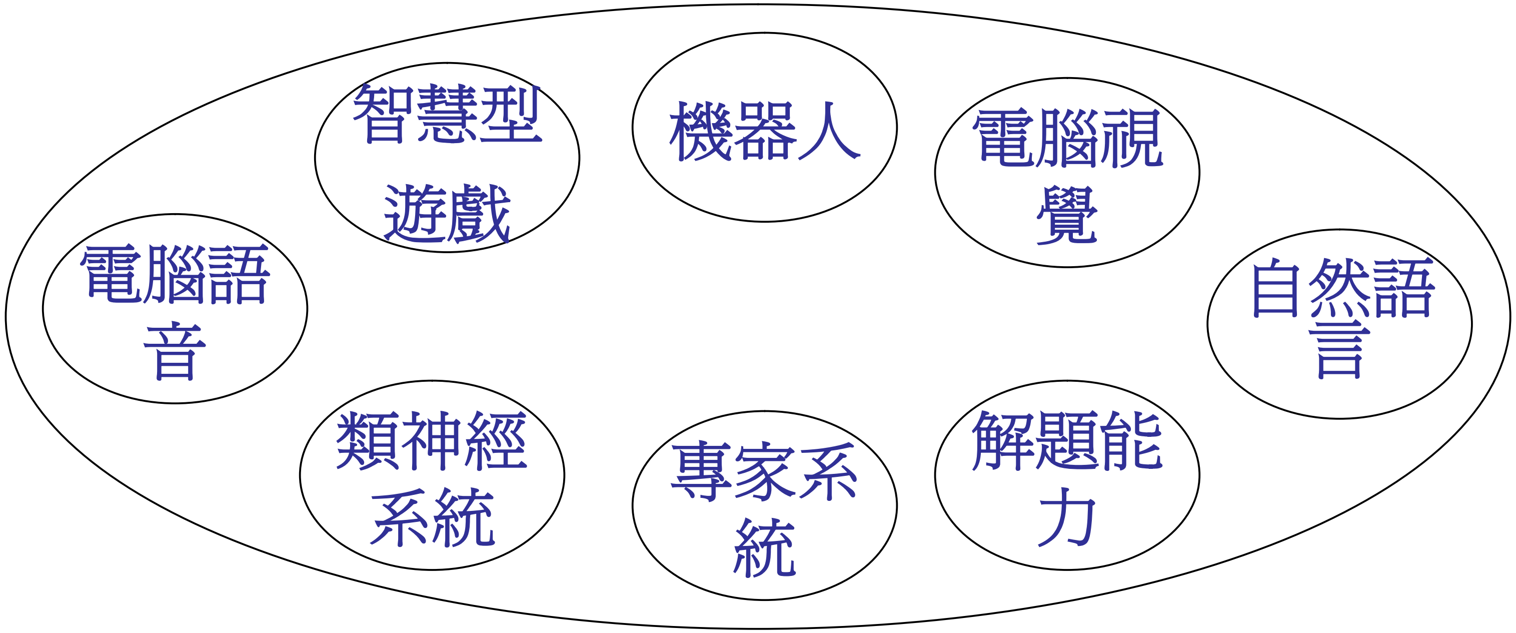
  How reliable is it ?

Basic Concepts

- Professor Edward Feigenbaum of Stamford Univ., defined an expert system as “an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions”.
- A program that emulates the decision-making ability of a human expert.

Artificial Intelligence (AI)

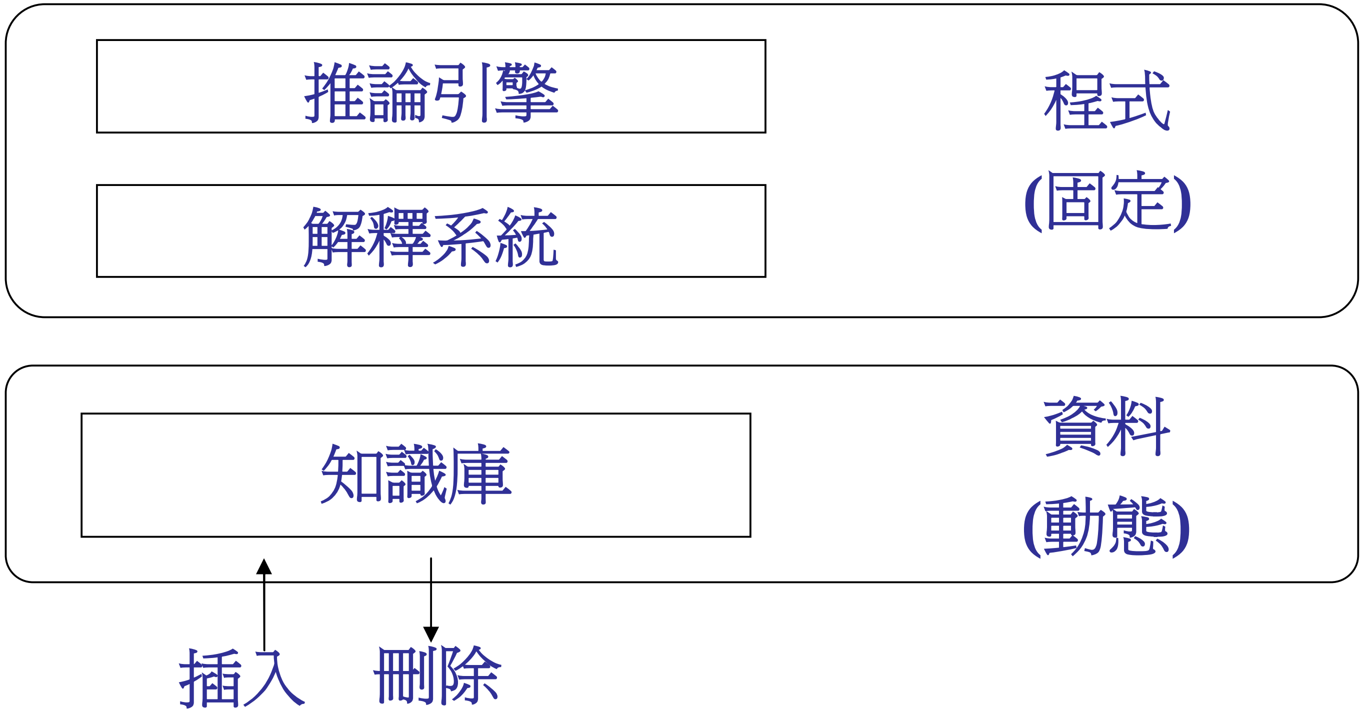
- The study of the computation that makes it possible to perceive, reason,and act.



Expert Systems and AI

- Expert system is a branch of AI that makes extensive use of specialized knowledge to solve problems at the level of a human expert by restricting the problem domain.
- The terms “expert system”, “knowledge-based system”, or “knowledge-based expert system” are used to represent the same thing.

Knowledge-based Systems V.S. Conventional programs



- **Can be easily examined for correctness, consistency, and completeness.**

Knowledge-based Systems V.S. Conventional programs

CONVENTIONAL SOFTWARE DEVELOPMENT……2000 LINES / YEAR

EXPERT LISP PROGRAMMERS CAN PRODUCE THE EQUILIVANT OF ….100,000 LINES/YEAR

Advantages of expert systems

- Increased availability

A person $\xrightarrow{\text{20 years}}$ An expert

A computer $\xrightarrow{\text{40 years}}$ Many experts

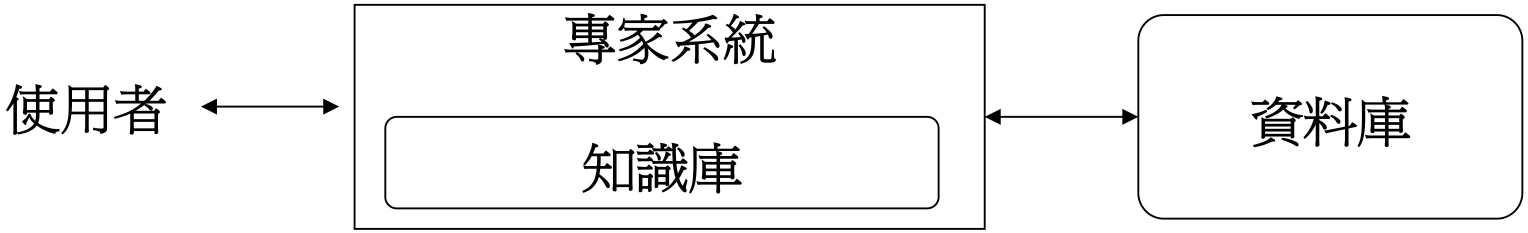
- Reduced cost (the cost of providing expertise)
- Reduced danger
- Knowledge integration
- Permanence -- no complaint never get tired
- Multiple expertise

- Fast response
- Increase reliability

  Second opinion to an expert

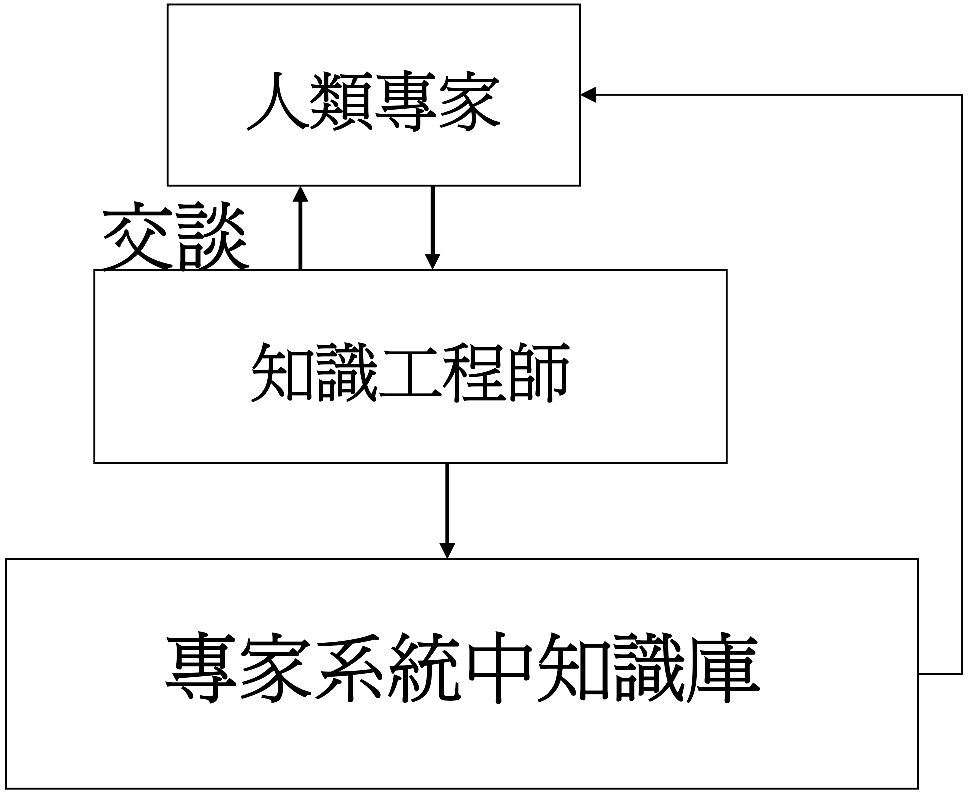
  Break a tie when no agreement is available from multiple experts.
- Intelligent tutor

  Consultation and explanation
- Intelligent database

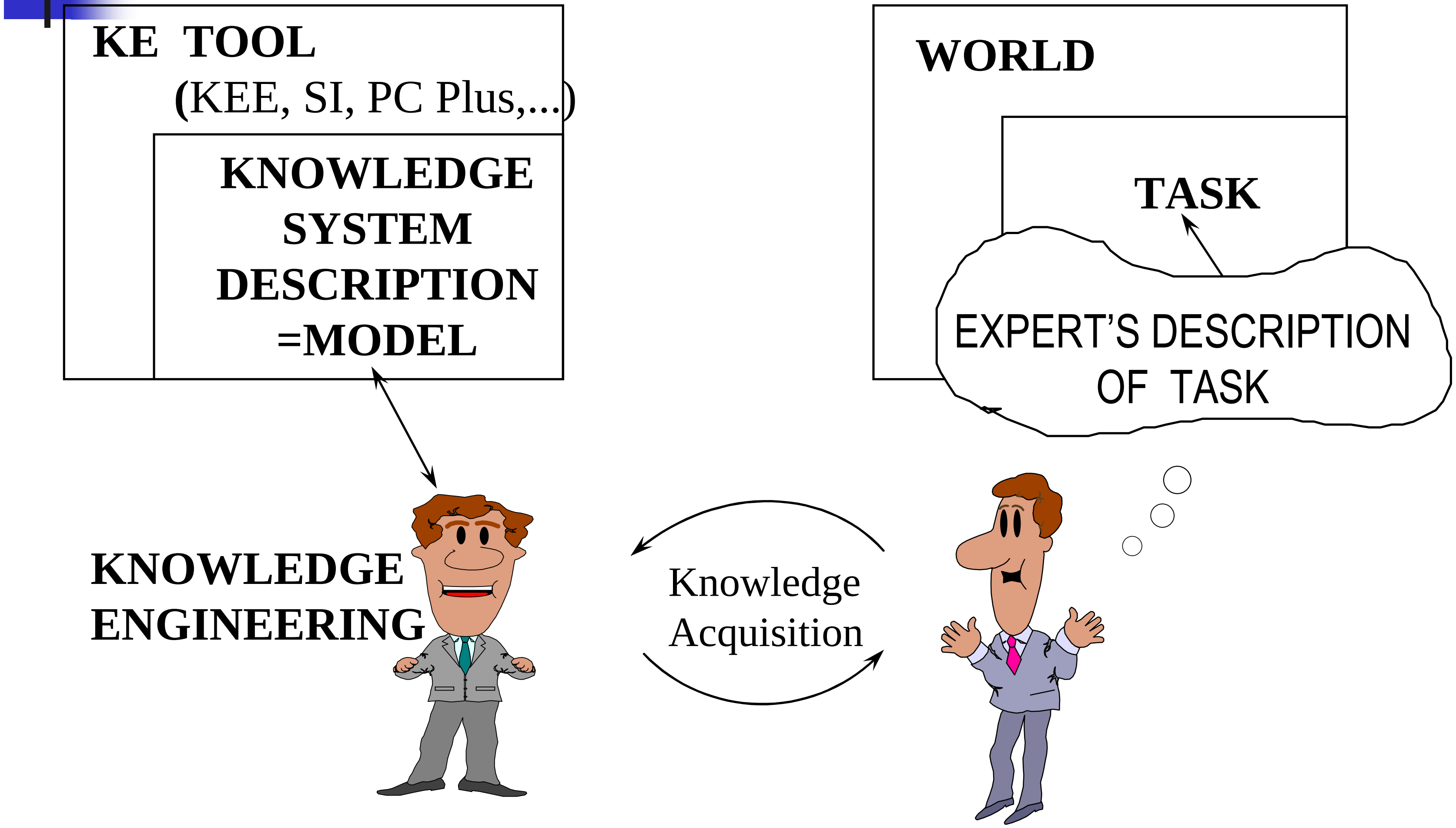


Knowledge Engineering

- The process of building an expert system



Knowledge acquisition is the bottleneck for building knowledge-based systems.



KE TOOL

(KEE, SI, PC Plus,...)

KNOWLEDGE SYSTEM DESCRIPTION =MODEL

WORLD

TASK

EXPERT'S DESCRIPTION OF TASK

KNOWLEDGE ENGINEERING

Knowledge Acquisition

Three approaches of Knowledge acquisition

- By a knowledge engineer (知識工程師)
- By a knowledge acquisition tool
- By machine learning (機器學習) approaches

  e.g.,learn rules by example, through rule induction, in which the system create rules from tables of data.

Limitations of Expert Systems

- Lack of causal knowledge (因果的知識) -the expert system do not really have an understanding of the underlying causes and effects in a system.
- Cannot generalize their knowledge by using analogy to reason about new situations the way people can (limited to the problem domain).
- Building is very time-consuming
- It is much easier to program expert system with shallow knowledge (淺層知識).

Shallow & Deep Knowledge

- Shallow Knowledge (淺層知識):
  - **based on empirical and heuristic knowledge**
  - **Algorithm：guaranteed to have a solution**
  - **Heuristic：no guarantee**
- Deep Knowledge (深層知識- Causal Knowledge)：
  - **based on the basic structure, function, and behavior of objects**
- Example：
  - Prescribe an aspirin for a person’s headache (shallow)
  - Programming of a causal model of a human body (deep)

Characteristics of an Expert System

- High performance
- Adequate response time
- Good reliability
- Understandable
  - **rather than being just a black box**
  - **convince the user**
  - **confirm the knowledge**
- Flexibility
  - **adding, changing, and deleting**
  - **grow incrementally**
  - **rapid prototyping**

Explanation Facility

1. **List all the facts that made the latest rule execute**
2. **List all the reasons for and against a particular hypothesis**
3. **List all the hypotheses that may explain the observed evidence**
4. **Explain all the consequences of a hypothesis**
5. **Give a prediction of what will occur if the hypothesis is true**
6. **Justify the questions that the program asks of the user for further information**
7. **Justify the knowledge of the program**

History of AI & Expert Systems

?	**Cognitive Science** The study of how humans process information
1943	**A.I.**
1957	**GPS （General Problem Solver）**
1958	**LISP**
1965	**Dendral（The first expert system）**
1970	**PROLOG**
1971	**Hearsay 1 for speech recognition**
1973	**MYCIN**
1975	**Frames , knowledge representation (Minsky)**
1976	**PROSPECTOR** · **Mineral deposit** · **Worth $100 millions**

1978 XCON / R1

- **Configuration of a computer system**
- **Fifteen times faster**
- **98% accuracy (humans：70%)**

1979 Rete Algorithm for fast pattern match

1980 Symbolic LISP Machine

1982 Japanese Fifth Generation project to develop intelligent computer

1983 KEE (Knowledge Engineering Tool)

1985 CLIPS

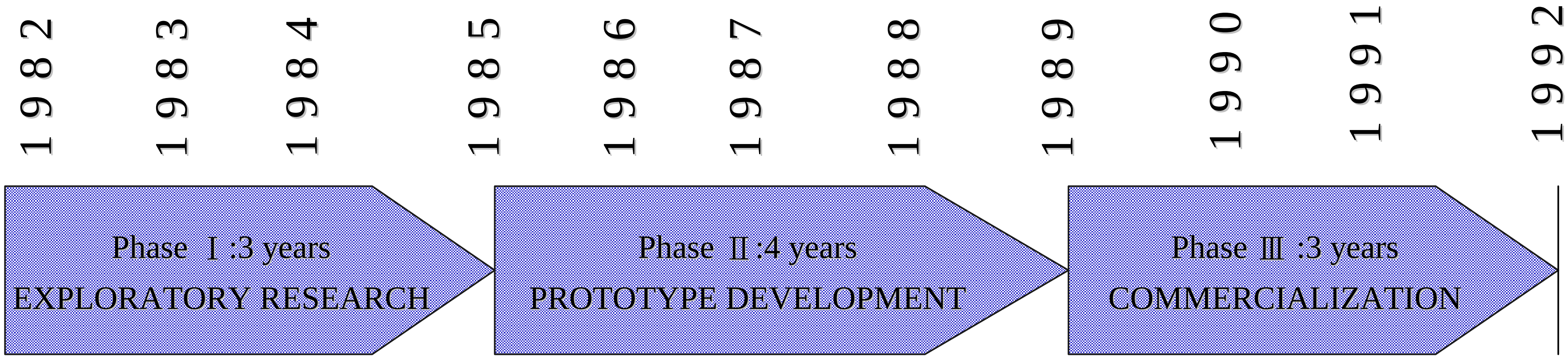
- **By NASA**
- **Written in C language**
- **Match rules by Rete algorithm**

2001 DRAMA

- **By National Chiao Tung University, Taiwan**
- **Written in C language**
- **Providing Web-based interface**

Japan’s Fifth-Generation computer project

Announced in 1981



Goal:
High-performance
personal PROLOG
machine

$50 million budgeted
for 1982-1984
$450 million budgeted
for 1985-1991

Goal:
VLSI design
Automatic Programming

Responses as of 1985
United States:Microelectronics & Computer Technology Corp (MCC)
common Market:ESPRIT (50year program budgeted at $1.3 billion)
Great Britain: Alvoy Programme

General Problem Solver

- Human knowledge expressed by IF-Then rules

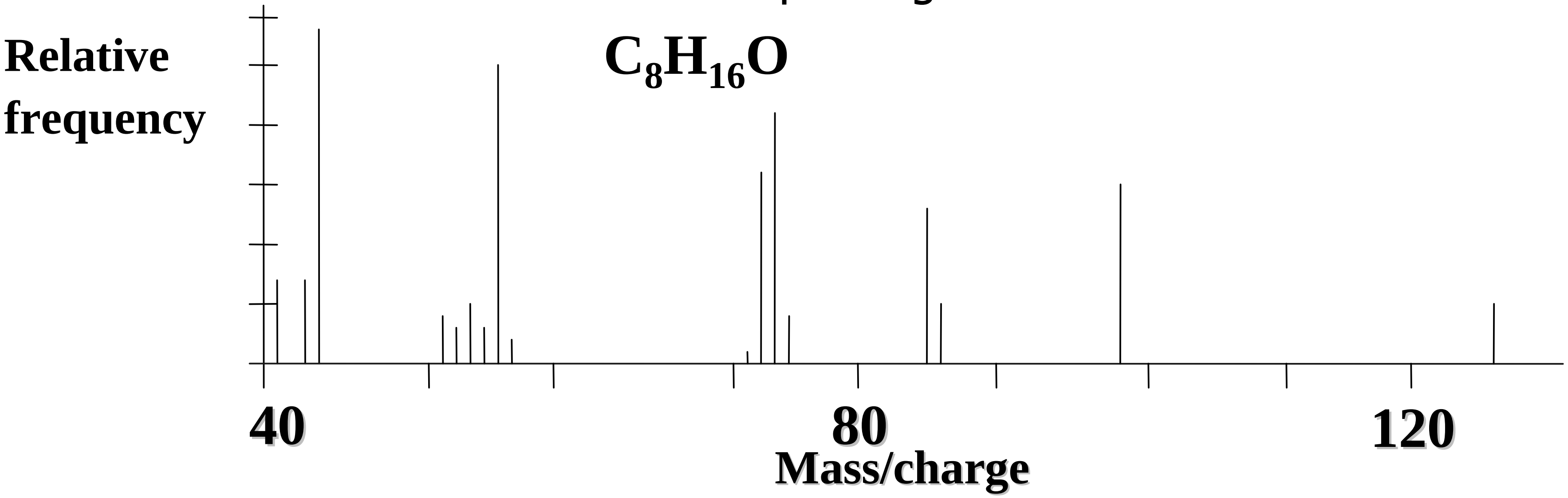
  Long term memory (rules)
- Short term memory (working memory)
- Cognitive Processors (inference engine)
- Conflict Resolution

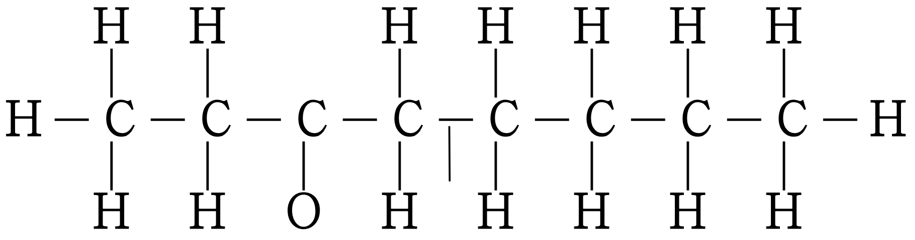
  e.g. IF there is a fire THEN leave

  IF my clothes are burning THEN put out the fire
- Relied little on domain knowledge and more on powerful reasoning
- A basis of modern rule-based expert systems

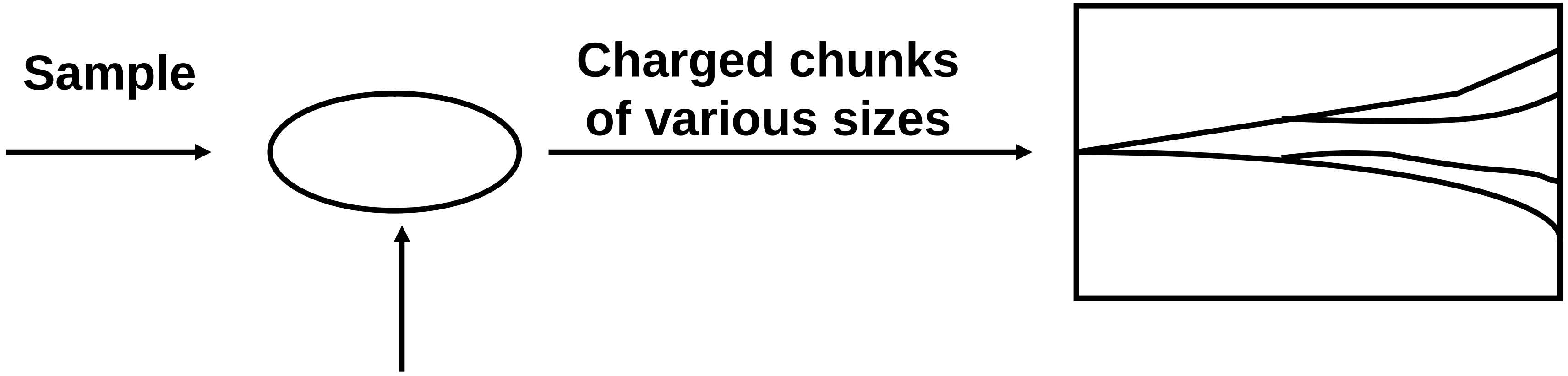
Dendral-The first expert system

- Domain Knowledge plays the main role
- Chemical Formula + Mass Spectrogram→ Chemical Structure





Generation of Spectrogram



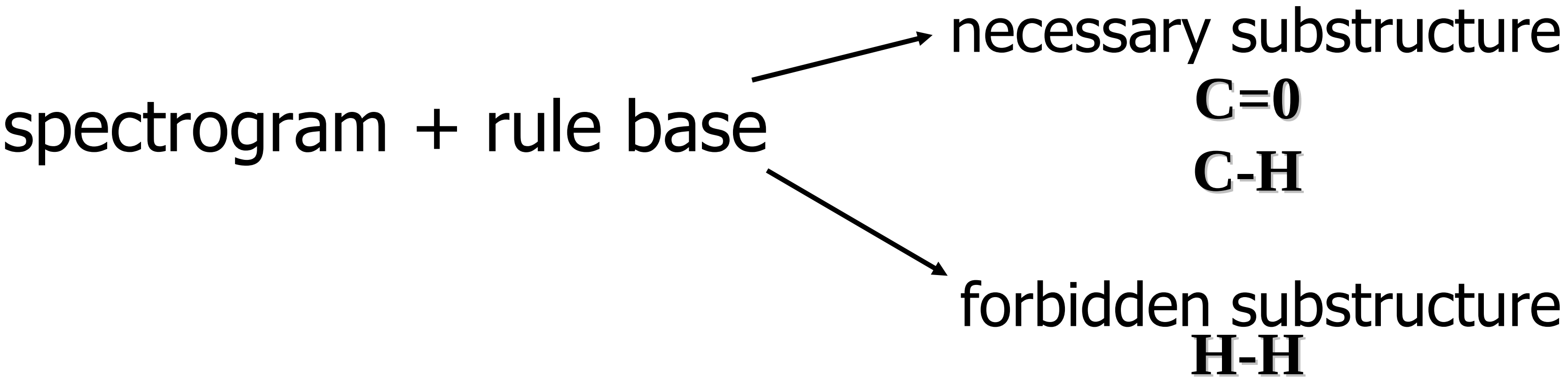
Sample

Charged chunks of various sizes

Bombarded by high energy electronics

Rules in Dendral

- Reduce the number of possibilities



spectrogram + rule base

necessary substructure

C=0

C-H

forbidden substructure

H-H

Rule:

IF high peak at 71,43,86 and any peak at 58
THEN C=O is necessary

- **Thousands of possibility → tens of possibility**

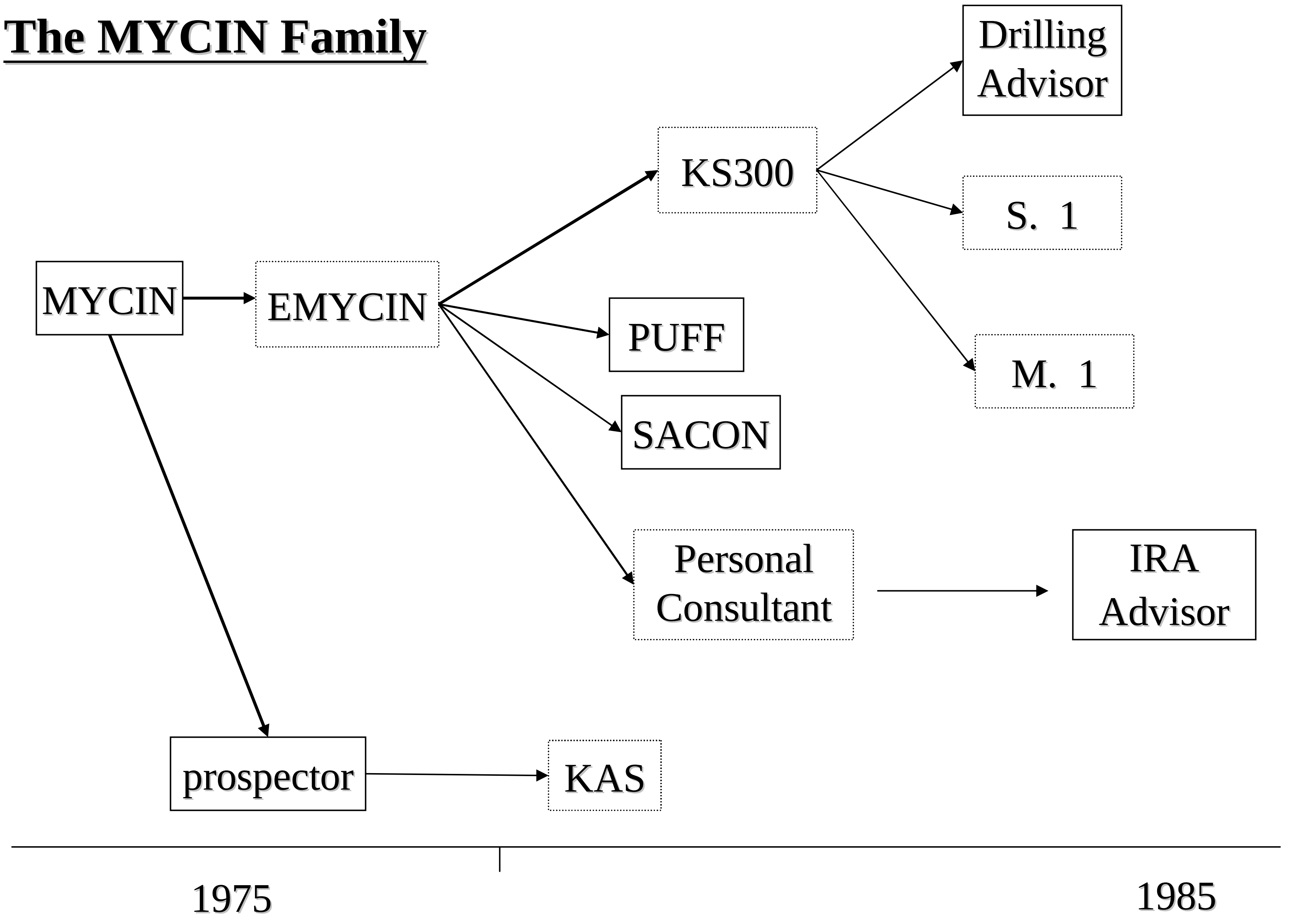
Generator and Tester

- **Generator**：
  - Generate possible structure
  - Produce a synthetic mass spectrogram by simulation
- **Tester**：
  - Compare the real mass spectrogram with those produced by the generator

MYCIN

- For bacterial infection diagnosis
- Explanation facility
- Automatic acquisition of knowledge
- Intelligent tutoring
- Feasibility of SHELL(EMYCIN)
- Separate the knowledge base from the inference engine
- Backward Chaining

The MYCIN Family



Example of MYCIN

- What is the patient’s name?
  - John Doe.
- Male or female?
  - Male.
- Age?
  - He is 55.
- Have you obtained positive cultures indicating general type?
  - Yes.
- What type of infection is it?
  - Primary bacteria.
- When did symptoms first appear?
  - May 5.
- Let’s call the most recent positive culture C1. From what site was C1 taken?
  - From the blood.

- **When?**
  - **May 9.**
- **Let's call the first significant organism from this culture U1. Do you know the identity of U1?**
  - **No.**
- **Is U1 a rod or a coccus or something else?**
  - **Rod.**
- **What is the gram stain of U1?**
  - **Gram-negative.**
- **Have there been positive cultures from sites that are not associated with the infections about which you are seeking advice?**
  - **No.**
- **Did U1 grow aerobically?**
  - **Yes.**

- When it is satisfied that it has a reasonably good grasp of the situation, MYCIN announces its diagnosis;
- My recommendation will be based on the opinion that the identity of U1 may be

  1. Pseudomonas-aeruginosa
  2. Klebsiella-pneumoniae
  3. E. coli
  4. Bacteroides-fragilis
  5. Enterobacter
  6. Proteus-nonmirabilis.

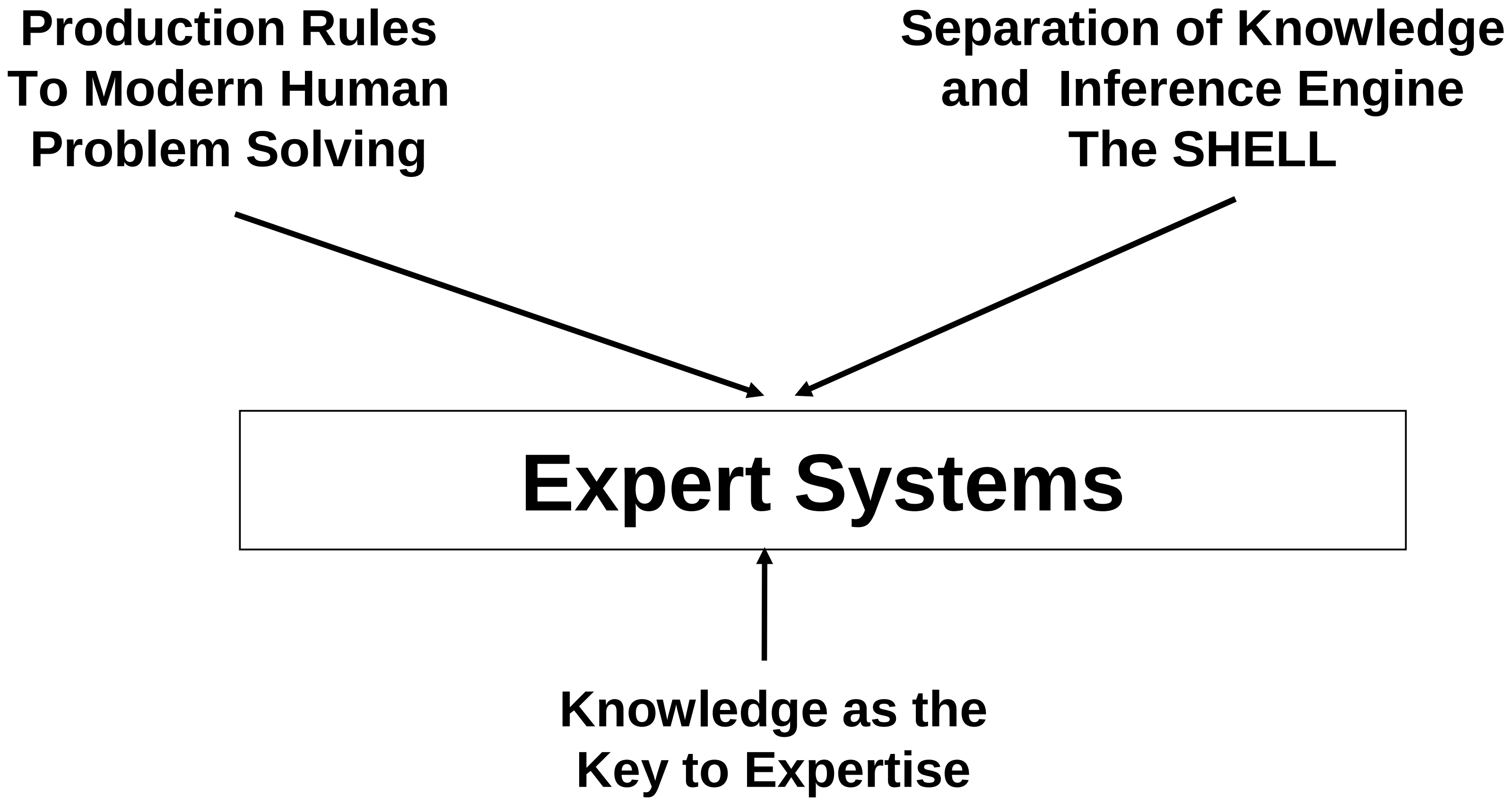
  After asking a few more questions about the patient, MYCIN announces its recommendation：
- On a scale of 0 to 4, where higher numbers indicate greater severity, how would you rate the patient’s degree of sickness?
  - 3.
- Does the patient have a clinically significant allergic reaction to any antimicrobial agent?
  - No.

- How much does the patient weigh?
  - 70 kilograms.
- My first recommendation is as follows：to cover for items 1,2,3,5, and 6, give gentamycin using a dose of 119 mg (1.7 mg/kg) q8h IV [or IM] for 10 days. Modify dose in renal failure. Also, to cover for item 4, give clindamycin using a dose of 595 mg (8.5 mg/kg) q6h IV [or IM] for 14 days. If diarrhea or other gastrointestinal symptoms develop, check for pseudomembranous colitis.
- MYCIN's pool of knowledge consists of approximately 500 antecedent-consequent rules, which give MYCIN the ability to recognize about 100 causes of bacterial infections. The following rules is typical：
  - M88: IF   ?x's type is primary bacteremia

    the suspected entry point of ?x is the gastrointestinal tract

    THYEN   there is evidence that ?x is bacteroides

Tendency



Production Rules
To Modern Human
Problem Solving

Separation of Knowledge
and Inference Engine
The SHELL

Expert Systems

Knowledge as the
Key to Expertise

專家系統的分類

- 解釋系統: 從觀察的資料中分析推論如 **DENTRAL**
- 預測系統:氣象預報、石油市場預測如 **PROSPECTOR**
- 診斷系統: **MYCIN**、**PUFF**
- 設計系統: **XCON**
- 監督系統: 核能廠
- 偵錯系統: 程式偵錯、電話線路偵錯

領　域	系　統	說　　明	研究與開發機構
化學工業	DENDRAL	解釋大型光譜測度儀所產生之資料，並決定分子結構及其原子成分	HPP，史丹福大學
教育用	GUIDON	實驗中之智慧型電腦輔函教學(CAI)，它可就一系列的技術問題提出問題並糾正答案，以教導學生。	HPP，史丹福大學
醫學用	MYCIN	一種已使用中之醫學專家系統可診斷腦膜炎及血液傳染症	HPP，史丹福大學
醫學用	PUFF	一種使用中的醫用專家系統，可用以分析病者的病況資料，以辨認出病者可能的肺部病症。	HPP，史丹福大學

領域	系統	說明	研究與開發機構
電腦系統	R1/XCON	用於配置 VAX 系統的專家系統，	卡耐基·梅隆大學及迪吉多公司
電腦系統	XSEL/XCON	XSEL/XCON 之擴展，協助選擇合適的電腦系統	迪吉多公司
通用工具	EMYCIN	係衍自 MYCIN 的推論系統，它可應用於許多領域；已用於建立 PUFF，SACON 等系統	HPP，史丹福大學
通用工具	OPS	一種前向推論引擎，可應用於許多領域；現已用於 R1 及 AIRPLAN	卡耐基．梅隆大學
通用工具	TEIRESIAS	知識擷取系統	HPP，史丹福大學
資源探勘	PROSPECTOR	用以評估在礦物儲藏地點的專家系統，	SRI International Co.,

When should expert systems be employed to solve problems?

1. Difficult problems (can the problem be effectively solved by conventional programming?)

   (NP-hard, NP-complete, undecidable)

2. In the domain with mainly heuristics and uncertainties.

   (experienced knowledge)

3. Dangerous environments.

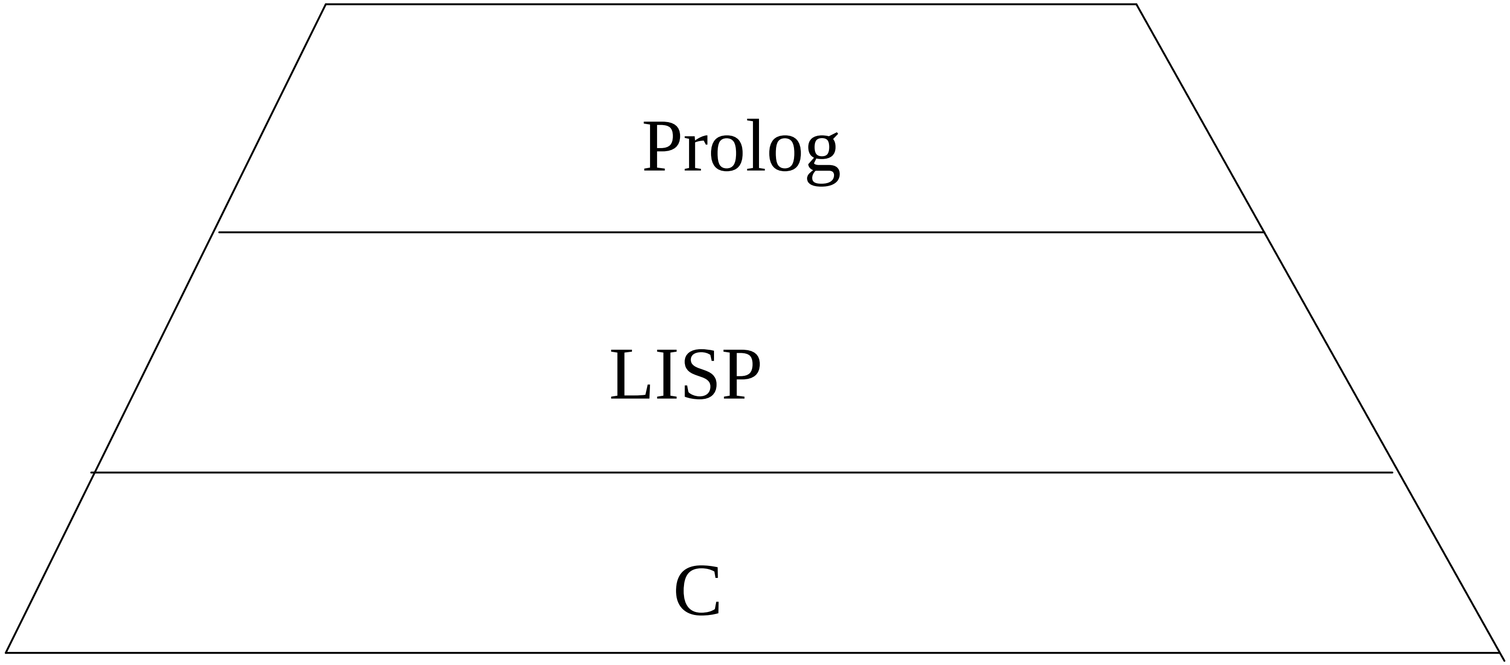
4. Previous knowledge that might be lost.

Expert System Language	Procedural Language
represent knowledge	represent data
(data and knowledge abstraction)	(data abstraction)
data and inference separate	data and algorithm interwoven
less rigid control	rigid control of execution sequence
knowledge intensive	less knowledge intensive
more special applications	more general applications

Languages, Shells, and Tools

- **Language**：LISP, Prolog, C

  A translator of commands written in a specific syntax



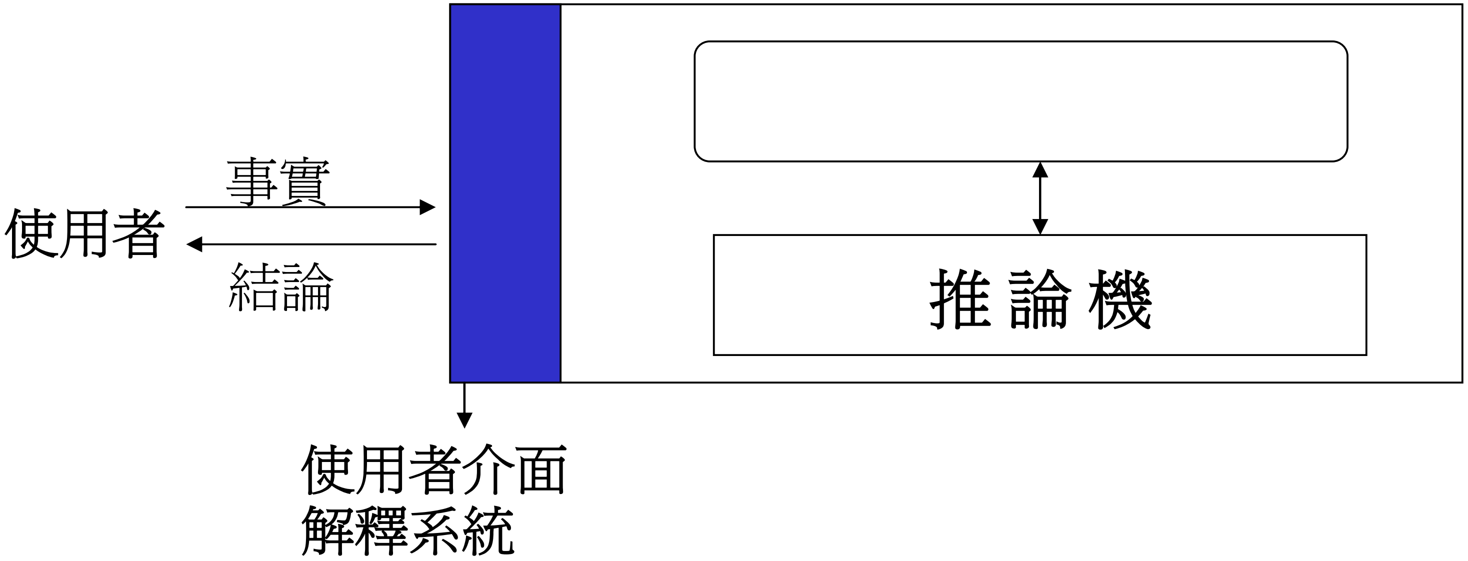
- Tool: Language ＋ Utilities

  (Editor, debuggers)

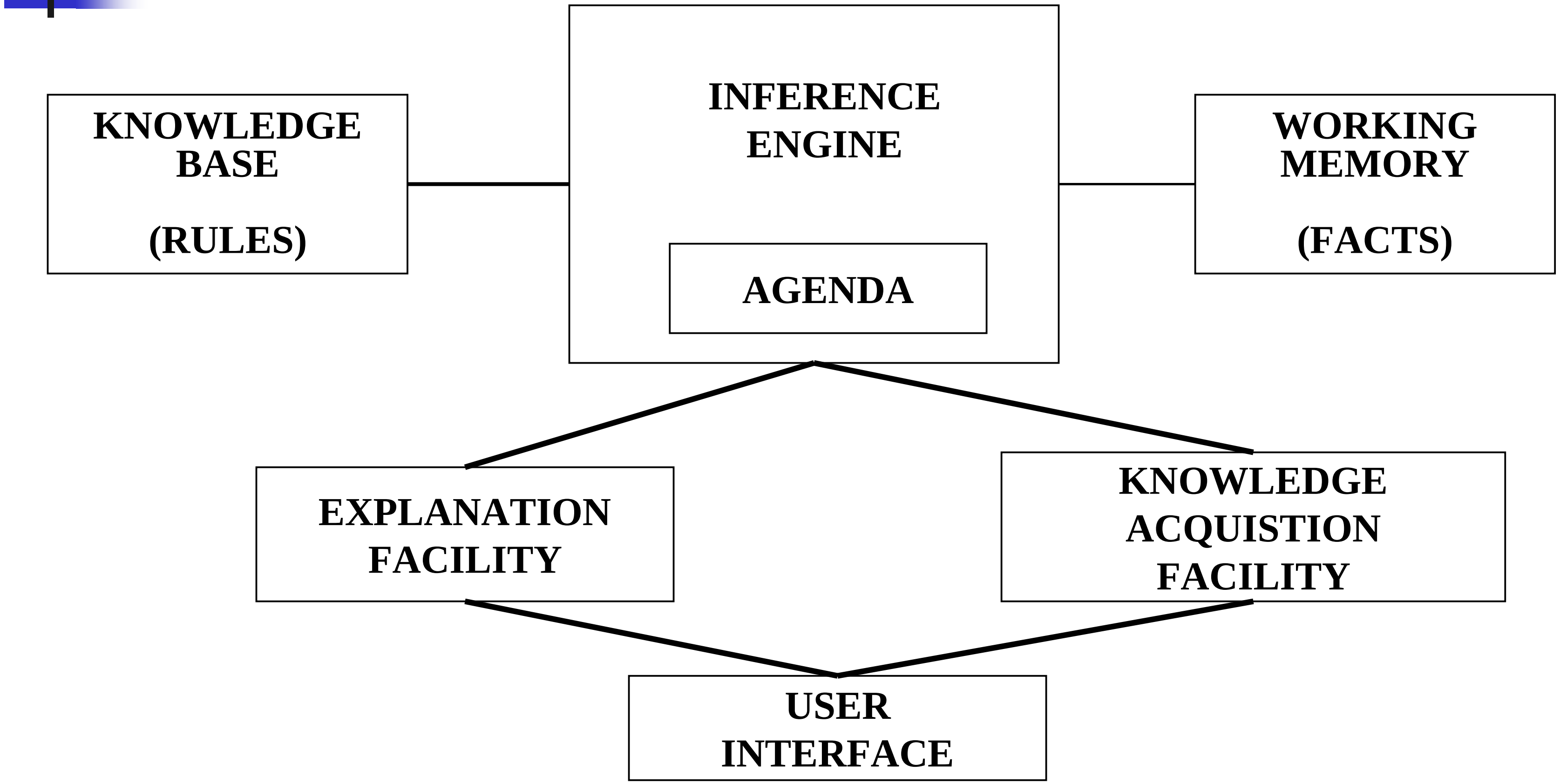
- Shell: knowledge base is empty

  (waiting for input expertise)

  PCPlus, CLIPS, KEE, ART, ...



Components of an Expert System



KNOWLEDGE BASE

(RULES)

INFERENCE ENGINE

AGENDA

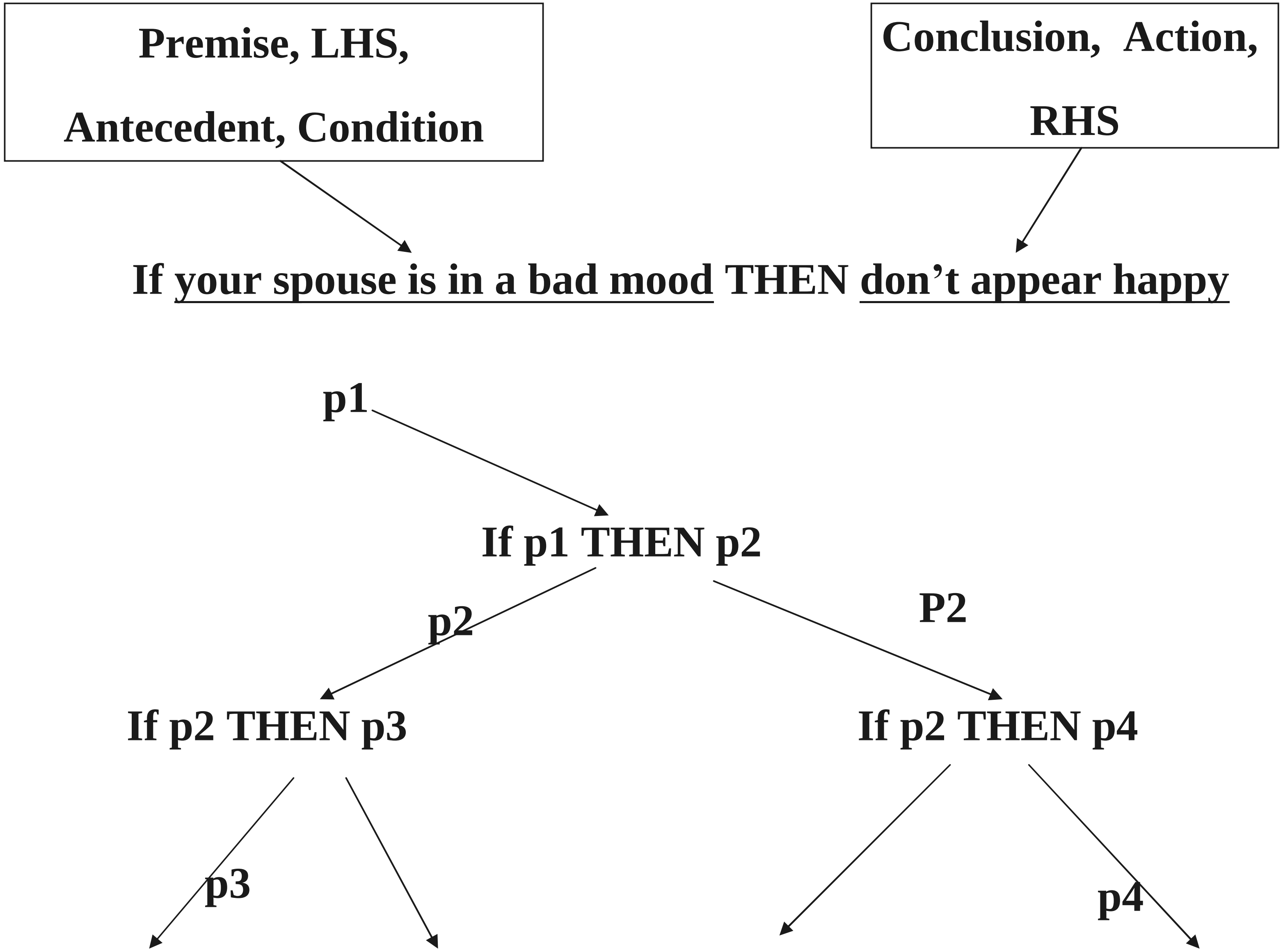
WORKING MEMORY

(FACTS)

EXPLANATION FACILITY

KNOWLEDGE ACQUISTION FACILITY

USER INTERFACE



Premise, LHS,

Antecedent, Condition

Conclusion, Action,

RHS

If your spouse is in a bad mood THEN don’t appear happy

p1

If p1 THEN p2

p2

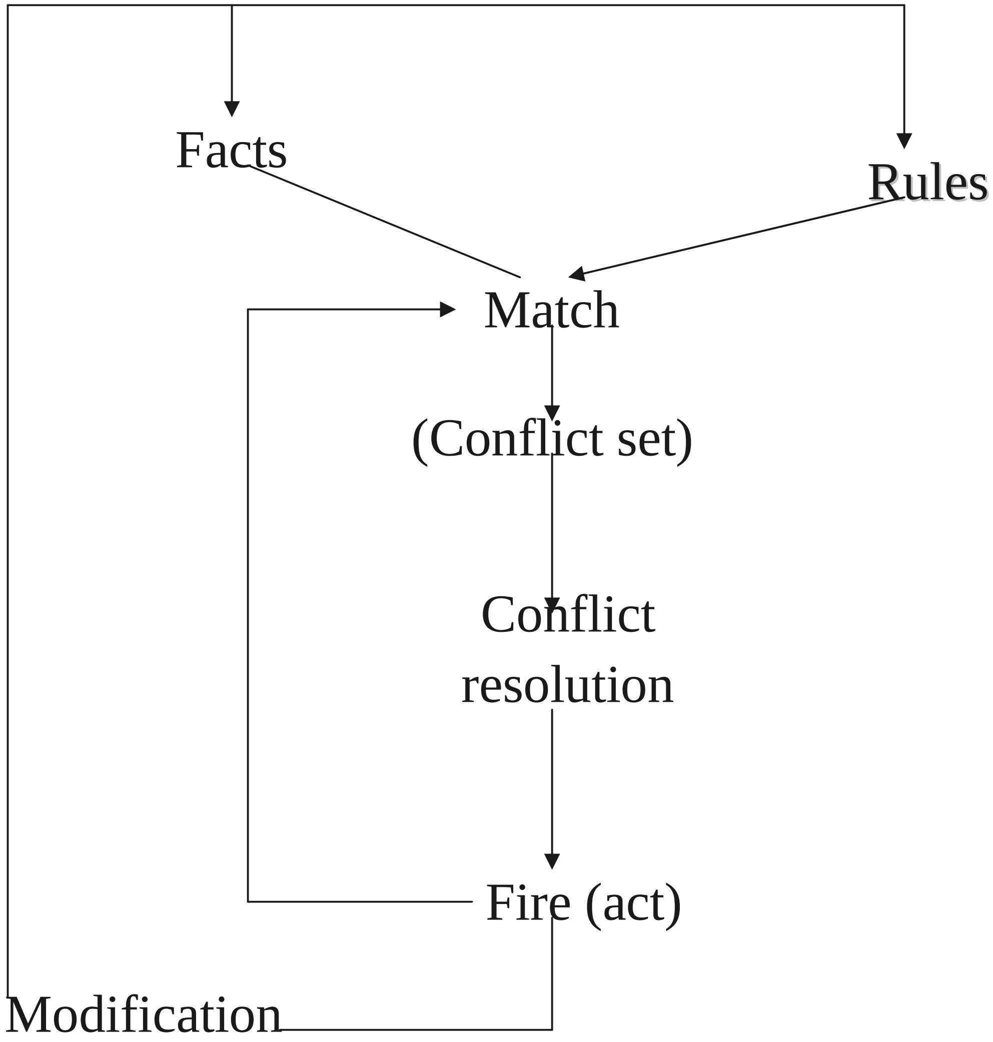
P2

If p2 THEN p3

If p2 THEN p4

p3

p4



Facts

Rules

Match

(Conflict set)

Conflict resolution

Fire (act)

Modification

Advantages of rule-based systems

- Modular nature: easy to increase knowledge
- Similar to human cognitive process
- Explanation facilities（解釋能力）
    - If A and B THEN C
    - If C and D THEN E
    - Why (E)?   :because Explain (C) and Explain(D)
    - Why (D)? :D is an input fact.
    - Why (C)? : :because Explain (A) and Explain(B)

Illustrative example

- Rule 1: If h-fever and r-spot THEN Danger-fever
- Rule 2:If temperature > 38 THEN h-fever = true
- Why danger fever?
- According rule 1:
  - Because Explain(h-fever) and Explain(r-spot)

Classification of Expert Systems

- Knowledge representation
- Forward or backward chaining
- Support of uncertainty
- Hypothetical reasoning
- Explanation facilities
- Applications

Procedural paradigms

- Procedural (sequential) languages
  - Imperative
    - ADA,PASCAL ,C
  - Functional
    - LISP, APL

Nonprocedural paradigms

- Nonprocedural languages
  - Declarative
    - Object-oriented: SMALLTALK
    - Logic: PROLOG
    - Rule-based: CLIPS, ART, OPS5
    - Frame-based: KEE
  - Nondeclarative
    - Induction-based: RULEMASTER, ANS

Functional programming

- Idea: Combine simple functions to yield more powerful functions (bottom-up design)
- Referentially transparent
  - Data objects
  - Primitive functions
  - Functional forms
  - Application operations
  - Naming procedures
- LISP- leading AI language

Logic programming

- GPS was designed to solve any kind of logic problem (puzzles, Tower of Hanoi, Missionaries and Cannibals, cryptarithmetic)
- PROLOG is more than just a language
  - An interpreter or inference engine
  - A database (facts and rules)
  - A form of pattern matching called unification
  - A backtracking mechanism
- Turbo PROLOG

Characteristic	Conventional Program	Expert System
Control by …	Statement order	Inference engine
Control and data	Implicit integration	Explicit separation
Control Strength	Strong	Weak
Solution by …	Algorithm	Rules and inference
Solution search	Small or none	Large
Problem solving	Algorithm is correct	Rules
Input	Assumed correct	Incomplete, incorrect
Unexpected input	Difficult to deal with	Very responsive
Output	Always correct	Varies with problem
Explanation	None	Usually
Applications	Numeric, file, and text	Symbolic reasoning
Execution	Generally sequential	Opportunistic rules
Program design	Structured design	Little or no structure
Modifiability	Difficult	Reasonable
Expansion	Done in major jumps	Incremental

Artificial Neural Systems

- ANS based on how the brain processes information
- Connectionist (neural network) models are attracting interest as useful tools for AI.
- The “perceptron model” is the simplest, and quite suitable for implementing classification systems
- Two main disadvantages:
  - It is very time-consuming when the training set is large
  - It is only suitable for a linearly separable training set

專家系統的發展程序(1/2)

- 問題分析
  - 選擇合適的領域
  - 是否有合適之專家
  - 可行性考慮
  - 發展計畫
- 知識擷取與知識表示
  - 專家與知識工程師的溝通
  - 知識擷取工具

專家系統的發展程序(2/2)

- 雛型系統製作與系統評估
  - 學習專業領域之知識
  - 評估標準及方式之抉擇
  - 選擇建構工具
- 擴充增強知識庫
  - 擴充知識庫
  - 檢討知識庫結構
  - 改善使用者介面
- 實際應用

建構專家系統之基本需求

- 是否有專家可配合?
- 專家們合作的態度如何?
- 專家能否精確表達其知識?
- 專家們是否已有共識?
- 知識擷取的技巧是否足夠?
- 是否以傳統方式發展會更好?

習 題(1/2)

1. Identify a person other than yourself who is considered either an expert or very knowledgeable. Interview this expert and discuss how well this person's expertise would be modeled by an expert system in terms of each criterion in "advantages of Expert Systems"
   - Write ten nontrivial rules expressing the knowledge of the expert in the above problem.
   - Show that each of the ten rules gives the correct advice.

習 題(2/2)

2. Write a program that can solve cryptarithmetic problems. Show the result for the following problem, where D = 5.

$$\begin{array}{rr} & \text{DONALD} \\ + & \underline{\text{GERALD}} \\ & \text{ROBERT} \end{array}$$