Intelligent Control Systems (0640734)

Lecture (2)

Intelligent Systems and Applied Artificial Intelligence.

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What is Intelligence?

According to the Oxford and Penguin English Dictionaries the word "intelligence" can be defined as follows:

- ability to understand
- reason
- perceive
- quickness in learning
- mental alertness
- ability to grasp relationships
- clever
- information
- news

One way to understand “intelligence” is by looking at our own capabilities, which means that humans are able to:

- think
- understand
- recognize
- perceive
- generalize
- adapt
- learn
- make decisions
- solve daily problems

What is Artificial Intelligence (AI)?

- AI is the branch of computer science that deals with ways of representing knowledge using symbols rather than numbers and with rules-of-thumb, or heuristic, methods for processing information.
- AI is a study about inventing machines/computers that capable of mimicking human/animal intelligent behavior.
- The ultimate objective is to develop a **system that can think and act rationally like humans**.

AI Advantages Over Natural Intelligence:

- More permanent
- Ease of duplication and dissemination
- Less expensive
- Consistent and thorough
- Can be documented
- Can execute certain tasks much faster than a human can
- Can perform certain tasks better than many or even most people

How Artificial Intelligence Differs from Conventional Computing:

Conventional Computing :

- Based on an **Algorithm** (clearly defined, step-by-step procedure)
- Mathematical Formula or Sequential Procedure
- Converted into a Computer Program
- Uses Data (Numbers, Letters, Words)
- Limited to Very Structured, Quantitative Applications

How Artificial Intelligence Differs from Conventional Computing:

AI Computing :

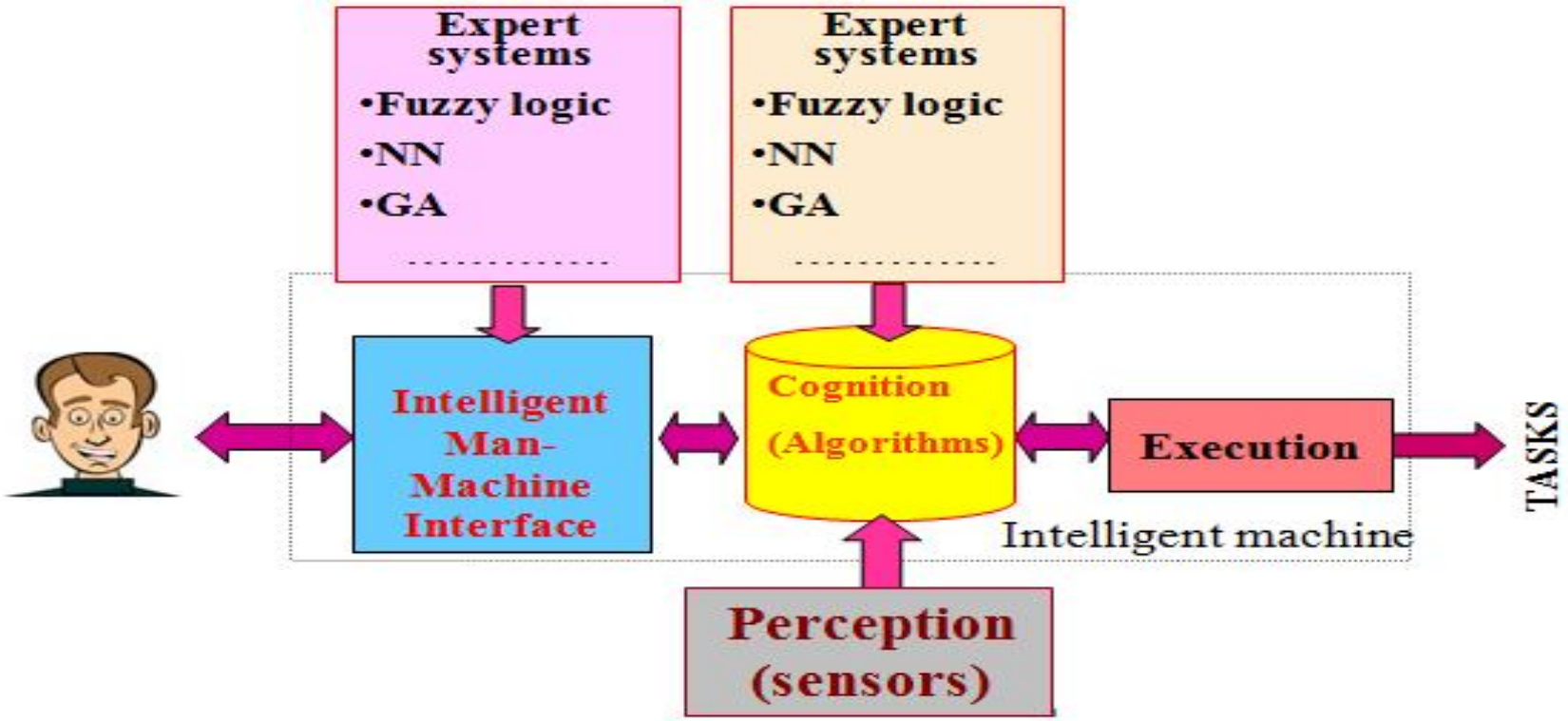
- Based on symbolic representation and manipulation.
- A symbol is a letter, word, or number represents objects, processes, and their relationships.
- Objects can be people, things, ideas, concepts, events, or statements of fact.
- Create a symbolic knowledge base.
- Uses various processes to manipulate the symbols to generate advice or a recommendation.
- AI reasons or infers with the knowledge base by search and pattern matching.
- Hunts for answers.

How Artificial Intelligence Differs from Conventional Computing:

Dimension	Artificial Intelligence	Conventional Programming
Processing	Primarily Symbolic	Primarily Algorithmic
Nature of Input	Can be Incomplete	Must be Complete
Search	Heuristic (Mostly)	Algorithms
Explanation	Provided	Usually Not Provided
Major Interest	Knowledge	Data, Information
Structure	Separation of Control from Knowledge	Control Integrated with Information (Data)
Nature of Output	Can be Incomplete	Must be Correct
Maintenance and Update	Easy Because of Modularity	Usually Difficult
Reasoning Capability	Limited, but Improving	None

Intelligent Systems Design: Conceptual Design

- **Expert System:** is a branch of AI that attempt to mimic human experts specifically in decision making process based on prior knowledge.
- **Expert System:** is a computer-based system that uses knowledge and facts, and apply an appropriate reasoning technique to solve problems in a given field (domain) that normally require the services of human experts.



Transferring Expertise:

Objective of an Expert System:

- To transfer expertise from an expert to a computer system and
- Then transfer to other humans (nonexperts)

Activities of an Expert System:

- Knowledge acquisition
- Knowledge representation
- Knowledge inferencing
- Knowledge transfer to the user

Knowledge is stored in a *knowledge base*

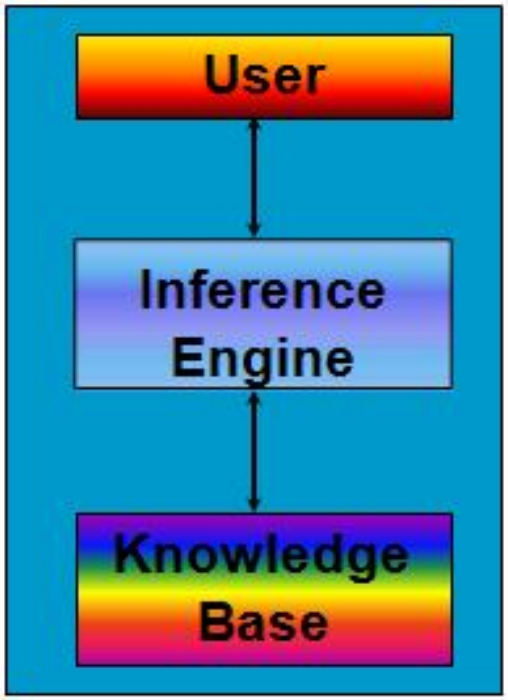
Differences between Intelligent and Expertise:

Expertise & intelligence are not the same things, where;

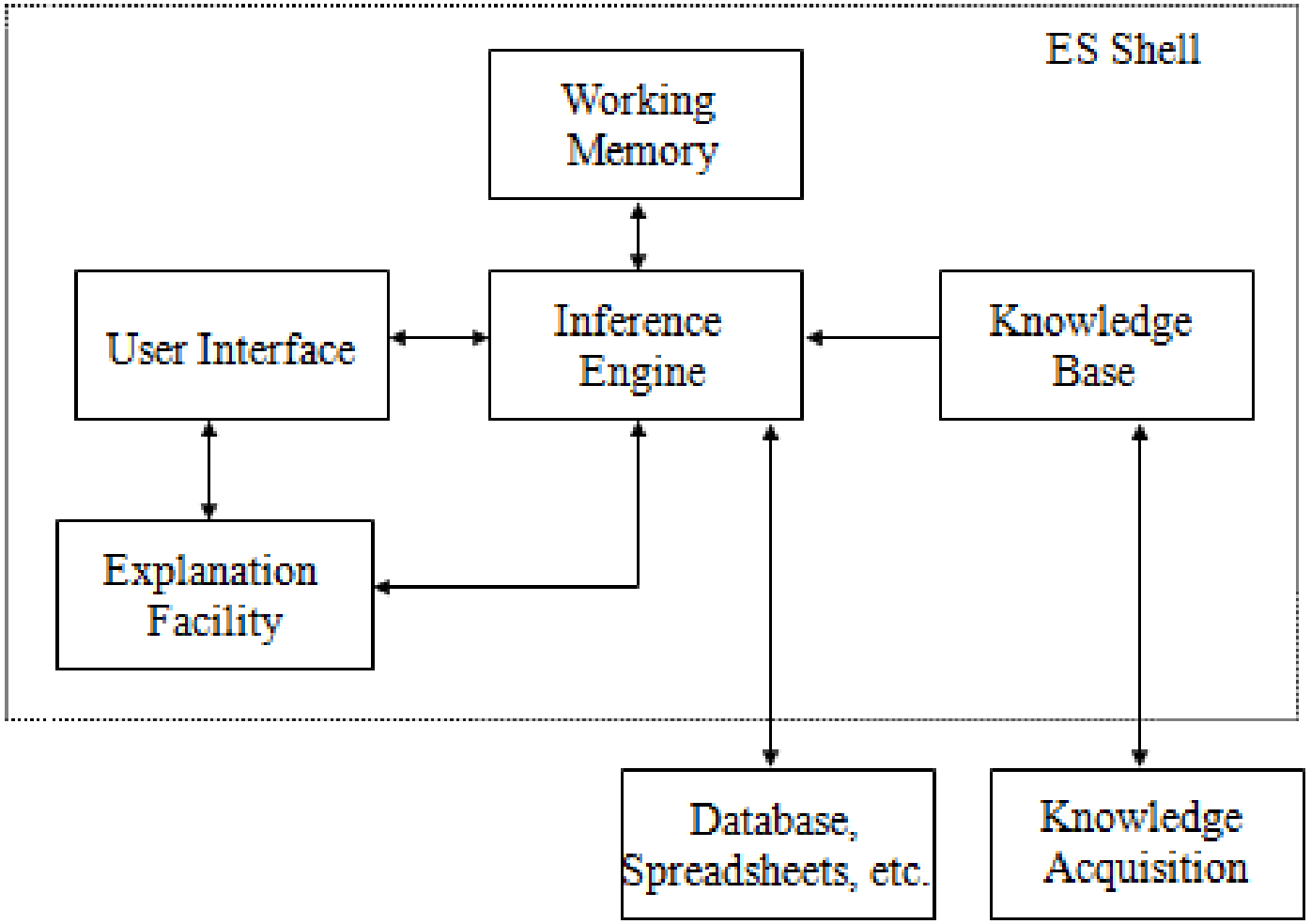
- Expertise requires long time to learn.
- Expertise is a large amount of knowledge (in some domain).
- Expertise is easily recalled.
- Expertise enables you to find solution much faster.
- Intelligence allows you to use your expertise (apply the knowledge).

ES Components:

1. **Knowledge Base:** The knowledge base contains the knowledge necessary for understanding, formulating, and solving problems.
2. **Inference Engine: Represents;**
   - ✓ The brain of the ES,
   - ✓ The control structure (rule interpreter)
   - ✓ Provides methodology for reasoning.
3. **User Interface:**
   - ✓ Language processor for friendly,
   - ✓ problem-oriented communication,
   - ✓ Menus and graphics, ….



Basic ES Structure:



Expert Systems Benefits:

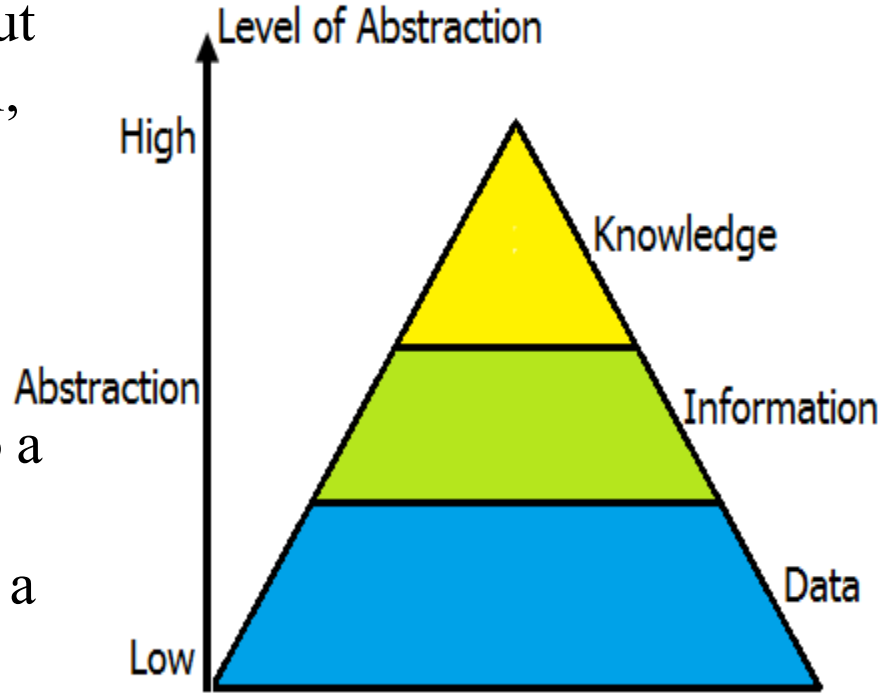
- Improved Decision Quality
- Increased Output and Productivity
- Decreased Decision Making Time
- Increased Process and Product Quality
- Capture Scarce Expertise
- Can Work with Incomplete or Uncertain Information
- Enhancement of Problem Solving and Decision Making
- Improved Decision Making Processes
- Knowledge Transfer to Remote Locations.

Types of Expert Systems:

1. **Ruled Based Expert System:** Represented as a series of rules.
2. **Frame-Based System:** Representation of the object-oriented programming approach.
3. **Hybrid System:** Include several knowledge representation approach.
4. **Model-Based System:** Structured around the model that stimulates the structure and function of the system under study.
5. **Real-Time Expert Systems:** dealing with real-time data acquired from sensors and generate the required control signals according to the given facts and fired rules.

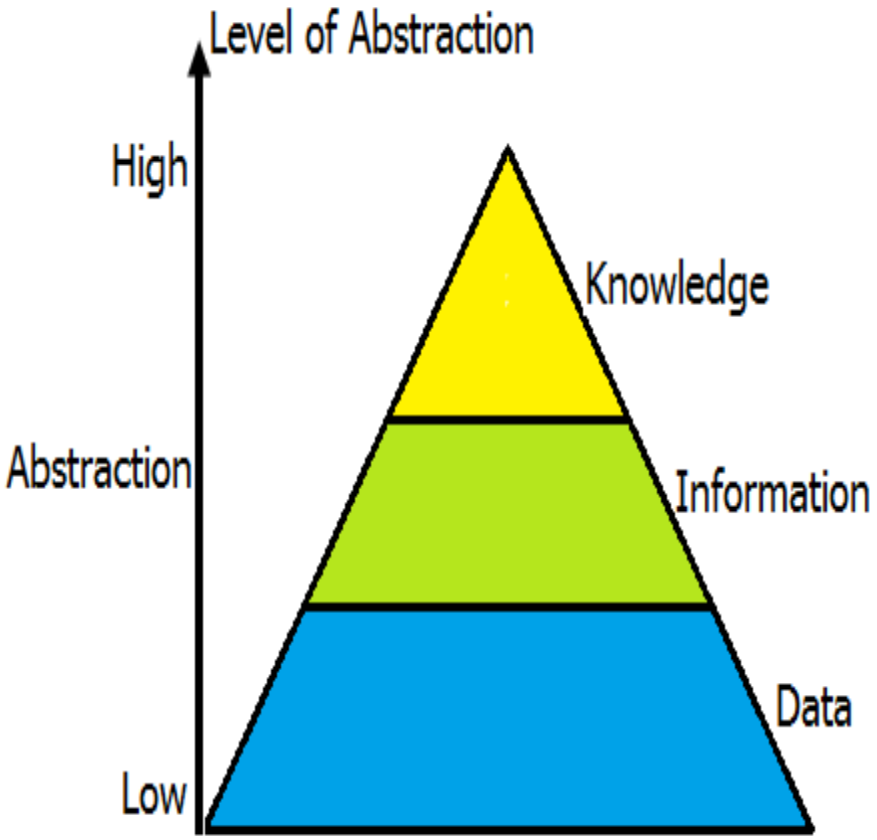
What is Data? Information? Knowledge?

- **DATA:** measurements or records about events. Can be numerical, alphabetical, images, sounds, etc.
- **INFORMATION:** analyzed and organized data such that we know its characteristics.
- **KNOWLEDGE:** information put into a specific context. It is a theoretical or practical understanding of a subject or a domain.



- Those who possess knowledge are called **Experts**.
- Anyone can be considered as an **expert** in a practical domain if he or she has deep knowledge and strong practical experience in that domain.

- Data, Information and Knowledge can be classified by levels of abstraction and quantity.
- Knowledge is the most abstract and exists in the smallest quantity.
- Knowledge itself can have levels of abstraction :
  - ✓ **Concrete:** knowledge about the specific problem,
  - ✓ **Domain specific:** class of problems, and
  - ✓ **Abstract:** many classes of problems.



Expert System Design:

- The process of building an Expert System is called **Knowledge Engineering**.
- It consists of three stages :
  1. **Knowledge acquisition** : the process of getting the knowledge from experts
  2. **Knowledge representation** : selecting the most appropriate structures to represent the knowledge
  3. **Knowledge validation** :testing that the knowledge of ES is correct and complete

Knowledge Representation Techniques:

- **Knowledge Representation:** Able to understand the concept of expert system.
- The **rule** is the most commonly used type of knowledge representation in AI.
- Any rule consists of two parts: the **IF** part, called the **antecedent** (or **condition**) and the **THEN** part called the **consequent** (or **action**).
- A rule provides some description of how to solve a problem.
- Rules are relatively easy to create and understand.
- Any rule consists of two parts: the IF part, called the **antecedent** or **condition,** and the THEN part called the c**onclusion** or **action**.

Knowledge Representation Techniques: Rules

Rules can represent relations, recommendations, directives, strategies and heuristics:

- **Relation:**

  IF the 'traffic light' is red **THEN** the action is stop

- **Recommendation:**

  IF the sea is very deep **AND** the sky is cloudy **AND** the forecast is danger **THEN** the advice is 'do not go to the sea'

- **Directive:**

  IF eat too much raya cakes, rendang **AND** the stomach is always aching **THEN** the action is 'fasting in Syawal'

❑ Strategy

IF the car is dead

THEN the action is ‘check the fuel tank’;

Step1 is complete

IF step1 is complete **AND** the ‘fuel tank’ is full

THEN the action is ‘check the battery’;

Step2 is complete

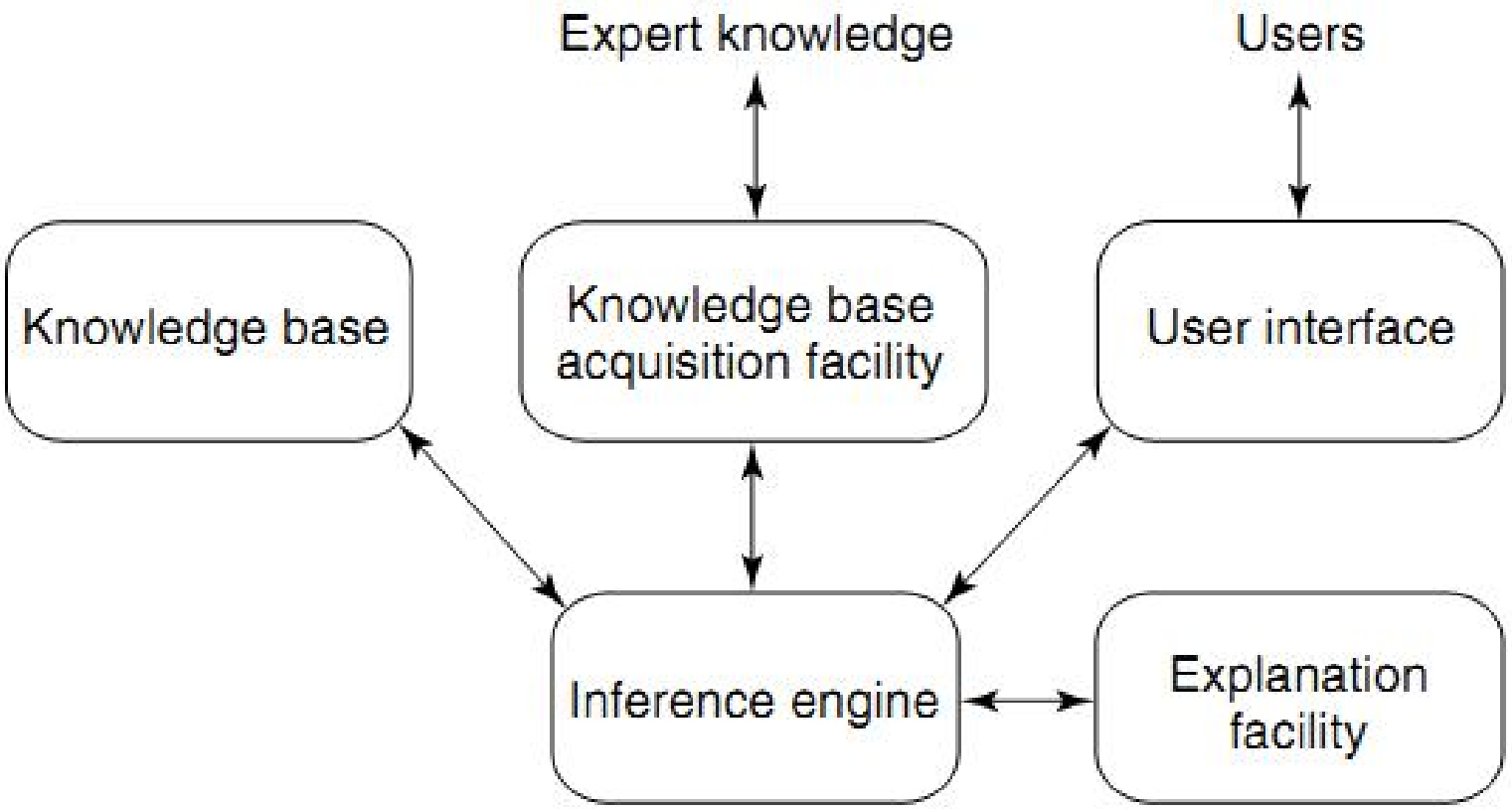
❑ Heuristic

IF the spill is liquid **AND** the ‘spill pH’ < 6

AND the ‘spill smell’ is vinegar

THEN the ‘spill material’ is ‘acetic acid’

Rule-Based System: Basic Structure



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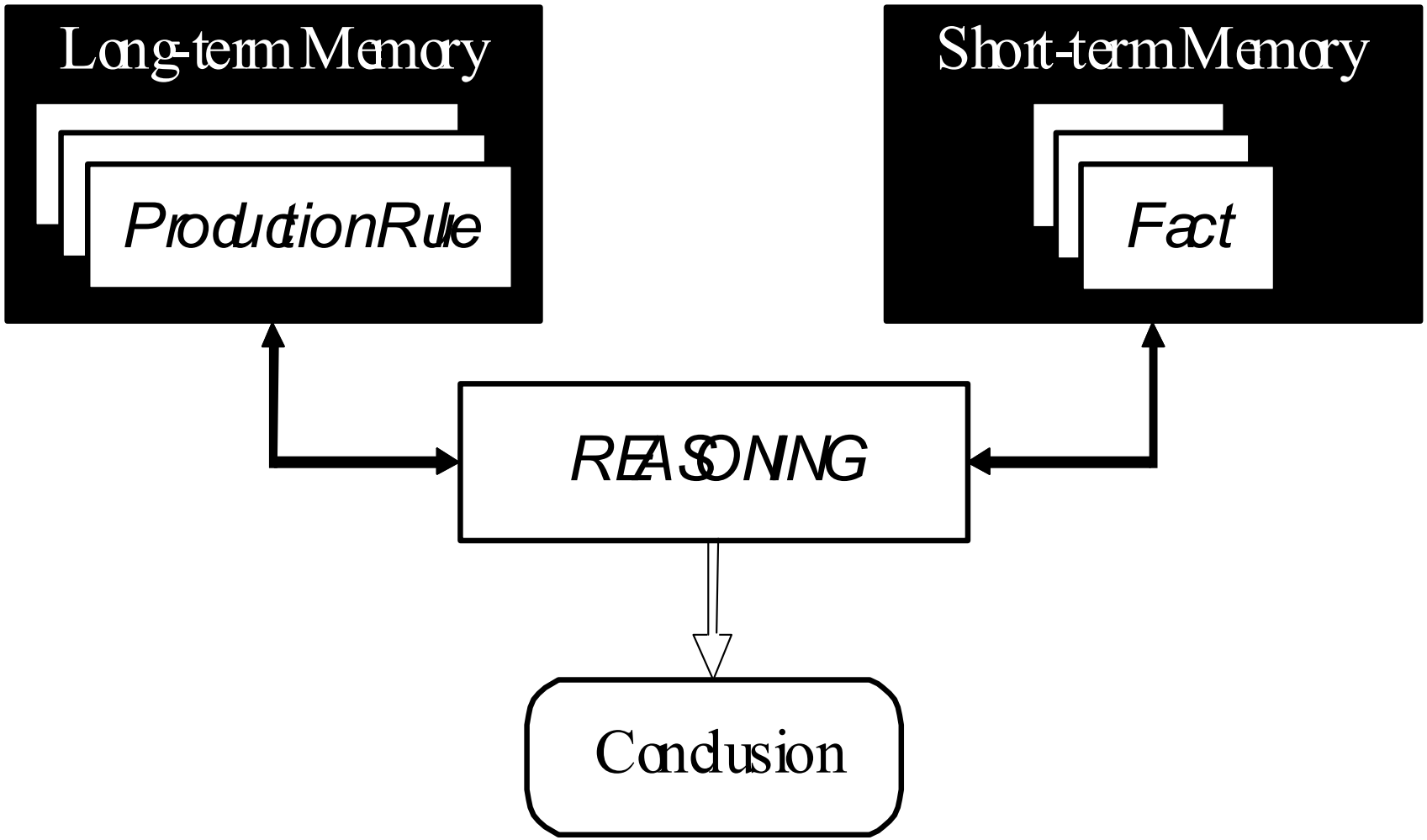
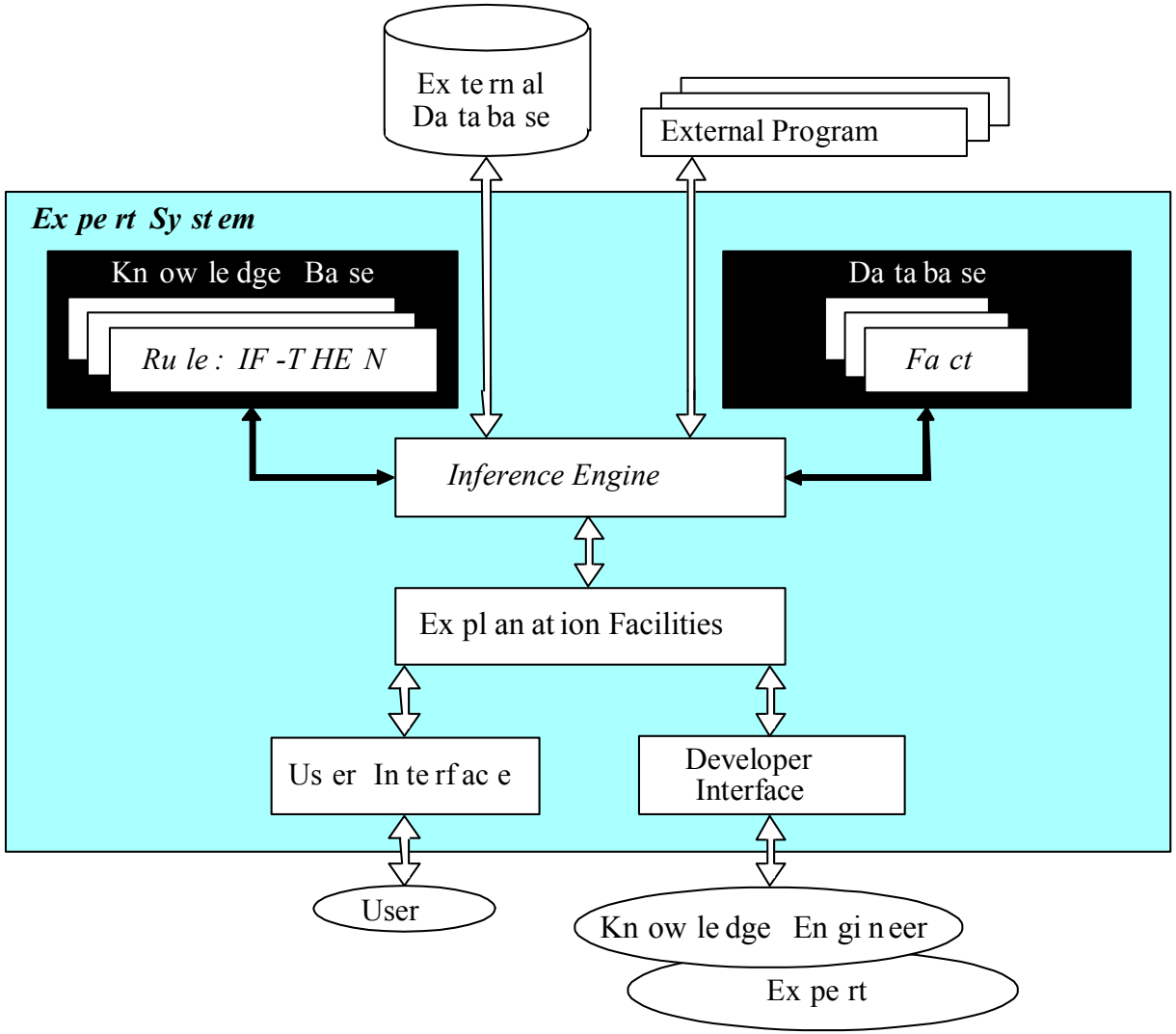


Rule-Based System: Basic Structure

- The **knowledge base** contains the domain knowledge useful for problem solving.
  - The knowledge is represented as a set of rules.
  - Each rule specifies a relation, recommendation, directive, strategy or heuristic.
  - Each rule has the IF (condition) THEN (action) structure.
  - When the condition part of a rule is satisfied, the rule is said to ***fire*** and the action part is executed.
- The **database** includes a set of facts used to match against the IF (condition) parts of rules stored in the knowledge base.
- The **inference engine** carries out the reasoning whereby the expert system reaches a solution. It links the rules given in the knowledge base with the facts provided in the database.

Rule-Based System: Basic Structure



Comparison of Expert Systems with Conventional Systems and Human Experts

Human Experts	*Expert Systems*	*Conventional Programs*
Use knowledge in the form of rules of thumb or heuristics to solve problems in a narrow domain.	Process knowledge expressed in the form of rules and use symbolic reasoning to solve problems in a *narrow domain*.	Process data and use algorithms, a series of well-defined operations, to solve general numerical problems.
In a human brain, knowledge exists in a compiled form.	Provide a *clear separation of knowledge from its processing*.	Do not separate knowledge from the control structure to process this knowledge.
Capable of explaining a line of reasoning and providing the details.	*Trace the rules fired* during a problem-solving session and *explain how* a particular conclusion was reached and *why* specific data was needed.	Do not explain how a particular result was obtained and why input data was needed.

Comparison of Expert Systems with Conventional Systems and Human Experts

Human Experts	*Expert Systems*	*Conventional Programs*
Use inexact reasoning and can deal with incomplete, uncertain and fuzzy information.	Permit *inexact reasoning* and can deal with incomplete, uncertain and fuzzy data.	Work only on problems where data is complete and exact.
Can make mistakes when information is incomplete or fuzzy.	*Can make mistakes* when data is incomplete or fuzzy.	Provide no solution at all, or a wrong one, when data is incomplete or fuzzy.
Enhance the quality of problem solving via years of learning and practical training. This process is slow, inefficient and expensive.	Enhance the quality of problem solving by adding new rules or adjusting old ones in the knowledge base. When new knowledge is acquired, *changes are easy* to accomplish.	Enhance the quality of problem solving by changing the program code, which affects both the knowledge and its processing, making changes difficult.

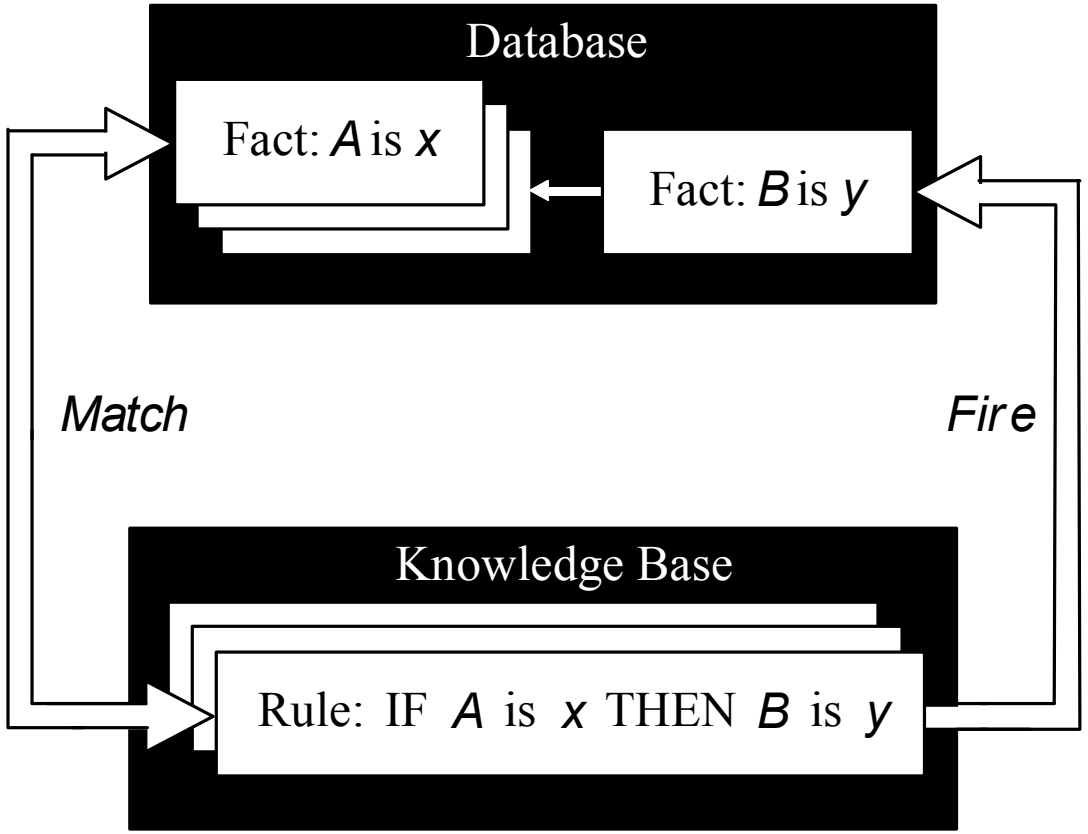
Chaining Methods:

Chaining: indicates how an expert system applies the rules to reach a conclusion.

Forward Chaining:

In rule-based system;

- The inference engine compares each rule stored in the knowledge base with facts contained in the database.
- When the IF (condition) part of the rule matches a fact, the rule is fired and its THEN (action) part is executed.

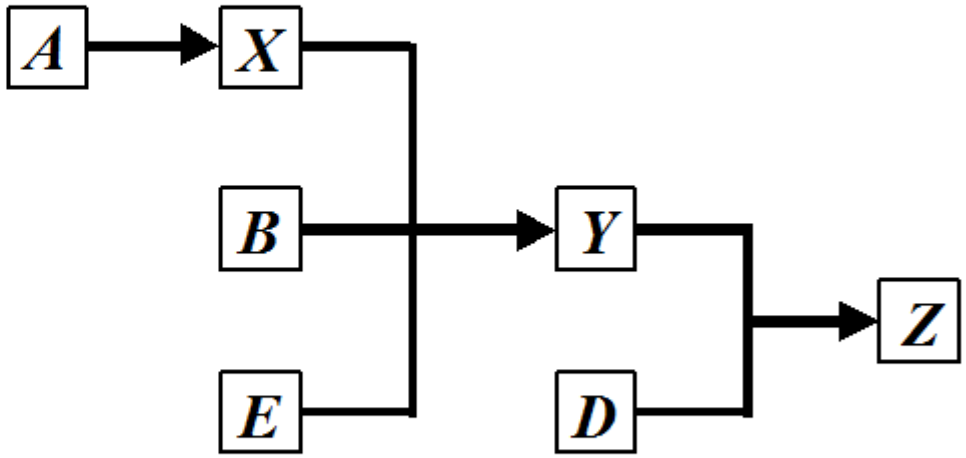


Forward Chaining: An Example:

Rule 1: IF *Y* is true
AND *D* is true
THEN *Z* is true

Rule 2: IF *X* is true
AND *B* is true
AND *E* is true
THEN *Y* is true

Rule 3: IF *A* is true
THEN *X* is true



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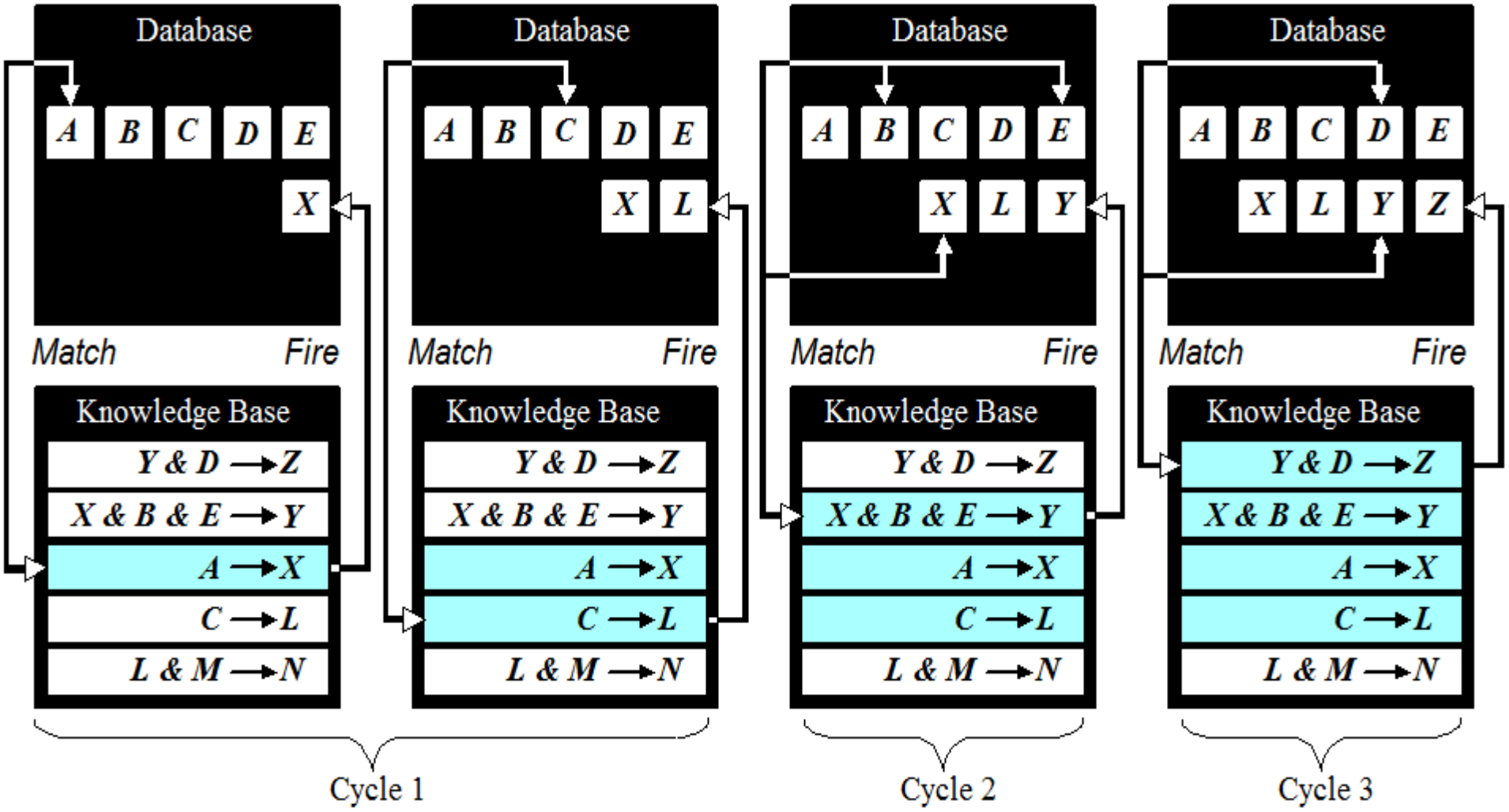
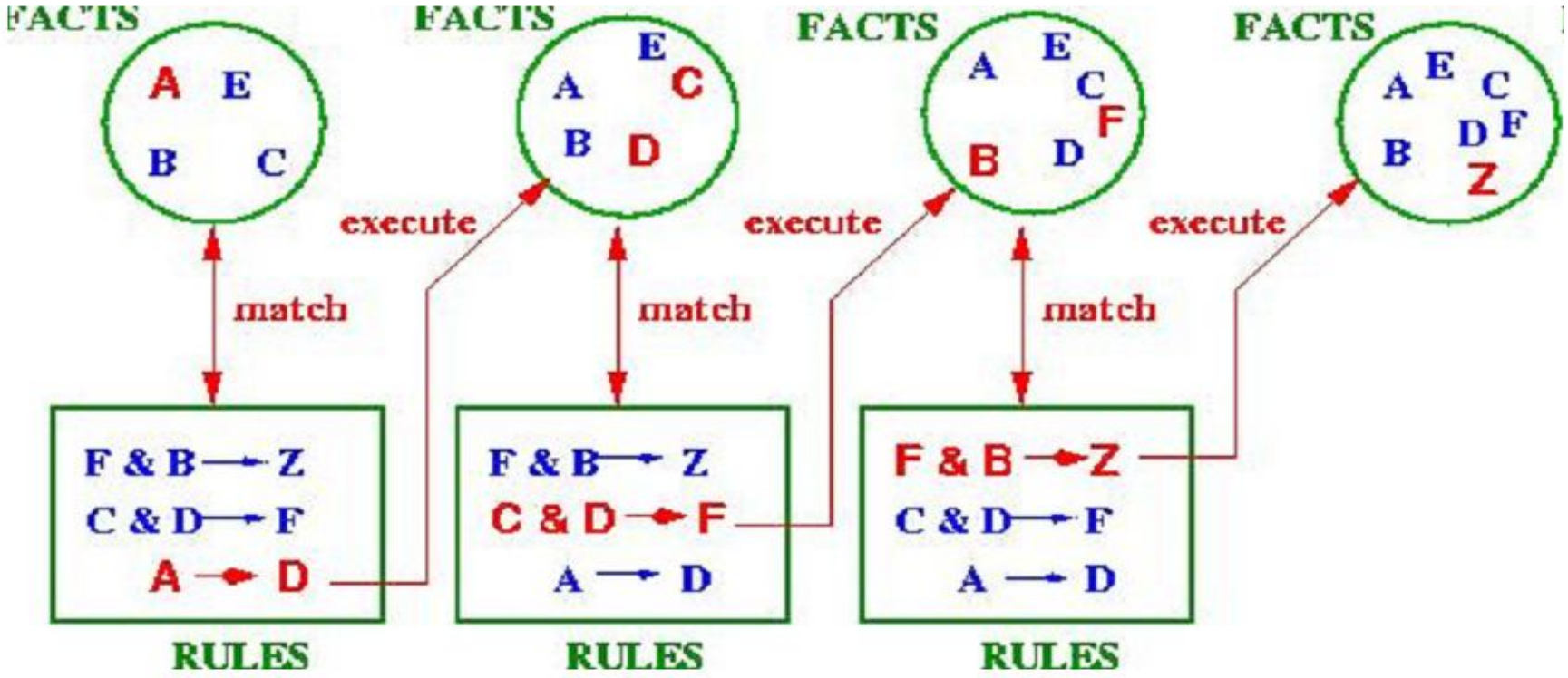


Forward Chaining: An Example:

Goal state: Z
Termination condition: stop if Z is derived or no further rule can be applied



Source: Kerber (2004), http://www.cs.bham.ac.uk/~mmk/Teaching/AI/l2.html

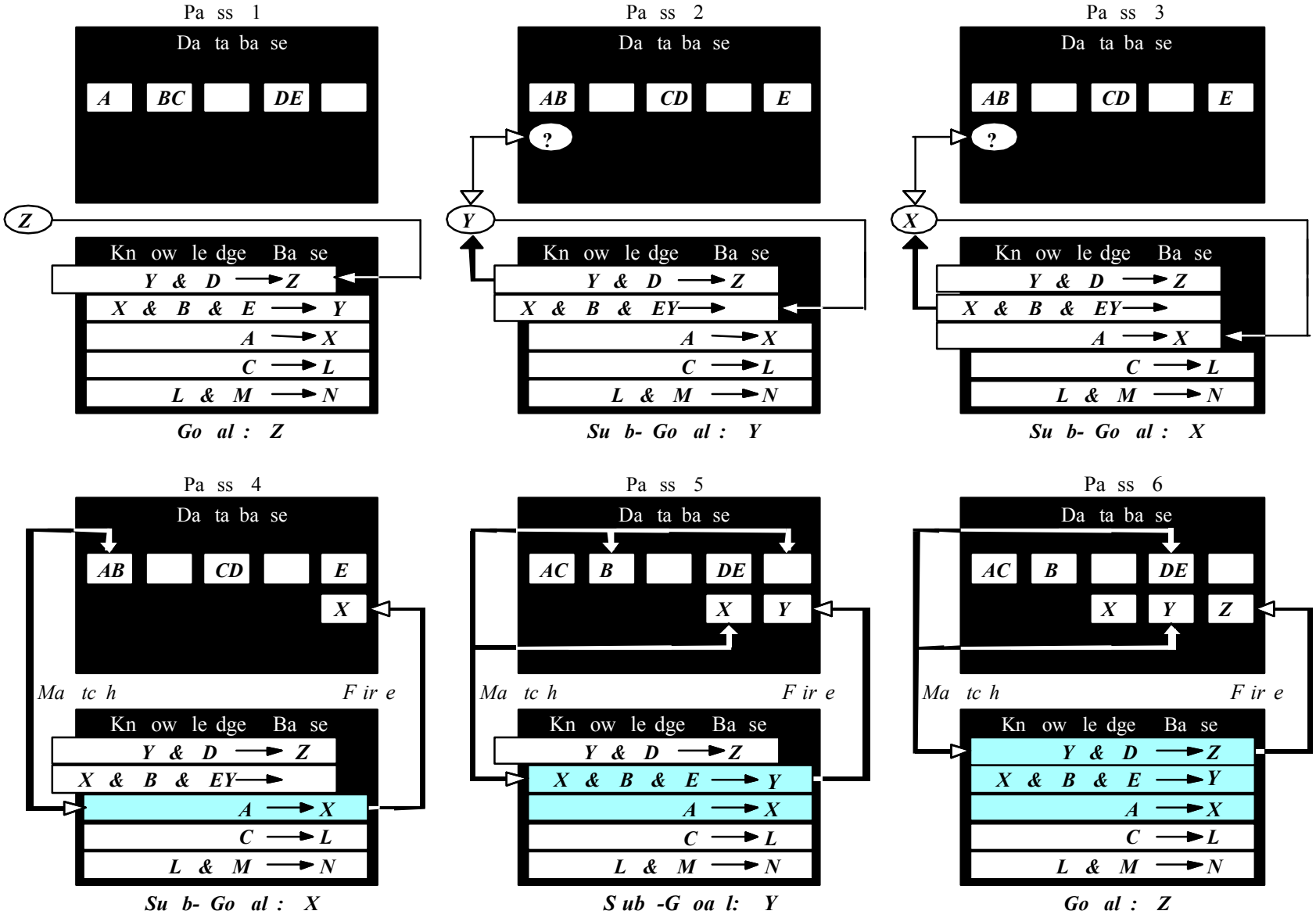
Forward Chaining: Remarks

- Forward chaining is a data driven reasoning.
- It is a technique for gathering information and then inferring from it whatever can be inferred.
- However, in forward chaining, many rules may be executed that have nothing to do with the established goal.
- Therefore, if our goal is to infer only one particular fact, the forward chaining inference technique would not be efficient.

Backward Chaining: (Goal-driven reasoning)

- The system has the goal and the inference engine attempts to find the evidence to prove it.
- The knowledge base is explored to find rules that might have the desired solution. Such rules must have the goal in their THEN (action) parts.
- If such a rule is found and its IF (condition) part matches data in the database, then the rule is fired and the goal is proved.
- The inference engine puts aside the rule it is working with (the rule is said to ***stack***) and sets up a new goal (subgoal) to prove the IF part of this rule.
- Then the knowledge base is searched again for rules that can prove the subgoal.
- The inference engine repeats the process of stacking the rules until no rules are found in the knowledge base to prove the current subgoal.

Backward Chaining: An Example:



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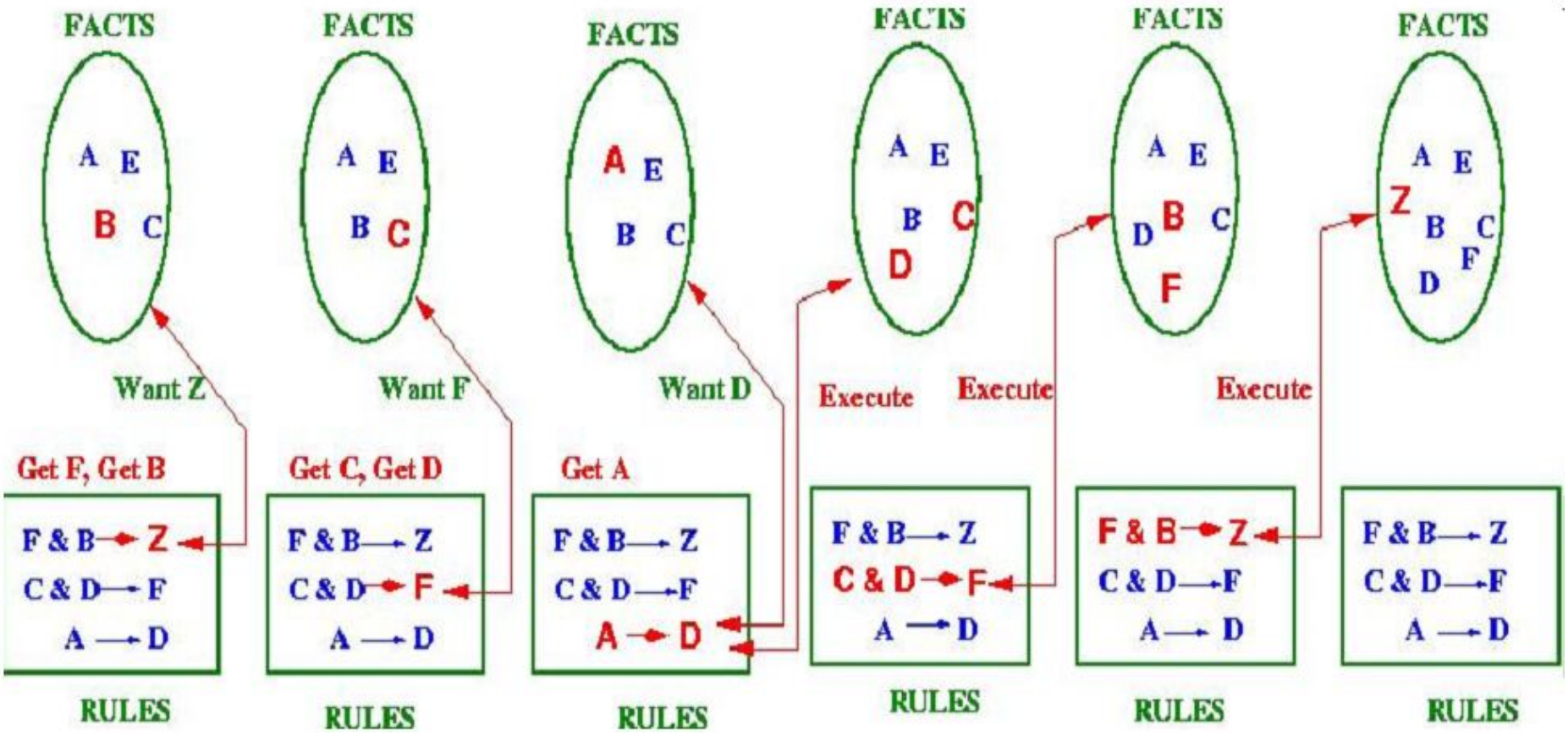

Choosing Chaining Technique:

- If an expert first needs to gather some information and then tries to infer from it whatever can be inferred, choose the forward chaining inference engine.
- However, if your expert begins with a hypothetical solution and then attempts to find facts to prove it, choose the backward chaining inference engine.

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