Rule-Based Expert System
Forward & Backward Chaining

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Rule-based Expert Systems

- A rule-based expert system is an expert system which works as a production system in which rules encode expert knowledge.
- Most expert systems are rule-based.

- Alternatives are
- frame-based - knowledge is associated with the objects of interest and reasoning consists of confirming expectations for slot values. Such systems often include rules too.

Production rules

- A production rule consists of two parts: condition (antecedent) part and conclusion (action, consequent) part,
- i.e: IF (conditions) THEN (actions)

- **Example**

  IF Gauge is OK **AND [TEMPERATURE] > 120**

  THEN Cooling system is in the state of overheating

Advantages of rule-based expert systems

- ***Natural knowledge representation.***
  - An expert usually explains the problem-solving procedure with such expressions as this: “In such-and-such situation, I do so-and-so”.
  - These expressions can be represented quite naturally as IF-THEN production rules.

- ***Uniform structure.***
  - Production rules have the uniform IF-THEN structure.
  - Each rule is an independent piece of knowledge.
  - Every syntax of production rules enables them to be self-documented.

Advantages of rule-based expert systems

- ***Separation of knowledge from its processing.***
  - The structure of a rule-based expert system provides an effective separation of the knowledge base from the inference engine.
  - Thus possible to develop different applications using the same expert system shell.

- ***Dealing with incomplete and uncertain knowledge.***
  - Most rule-based expert systems are capable of representing and reasoning with incomplete and uncertain knowledge. Example: *fuzzy rule based system*

Disadvantages of rule-based expert systems

- ***Opaque relations between rules***
  - Although individual rules are relatively simple and self-documented, their logical interactions within the large set of rules may be opaque.
  - Rule-based systems make it difficult to observe how individual rules serve the overall strategy.

- ***Ineffective search strategy***
  - Inference engine applies an exhaustive search through all the rules during each cycle.
  - Large set of rules (over 100 rules) can be slow, and large rule-based systems can be unsuitable for real-time applications.

- ***Inability to learn***
  - Cannot automatically modify its existing rules or add new ones.
  - Knowledge engineer still responsible for revising / maintaining the system.

Rules Techniques

- Rule is a knowledge structure that relates some known information to other information that can be concluded or inferred to be known → *Procedural Knowledge*
- ***IF … THEN …ELSE***
- *Ex : IF the ball's color is blue*
  THEN I like the ball

  IF Today's time is after 10 am
  AND Today is weekday
  AND I am at home
  OR My boss called and said that I am late for work
  THEN I am late for work
  ELSE I am not late for work

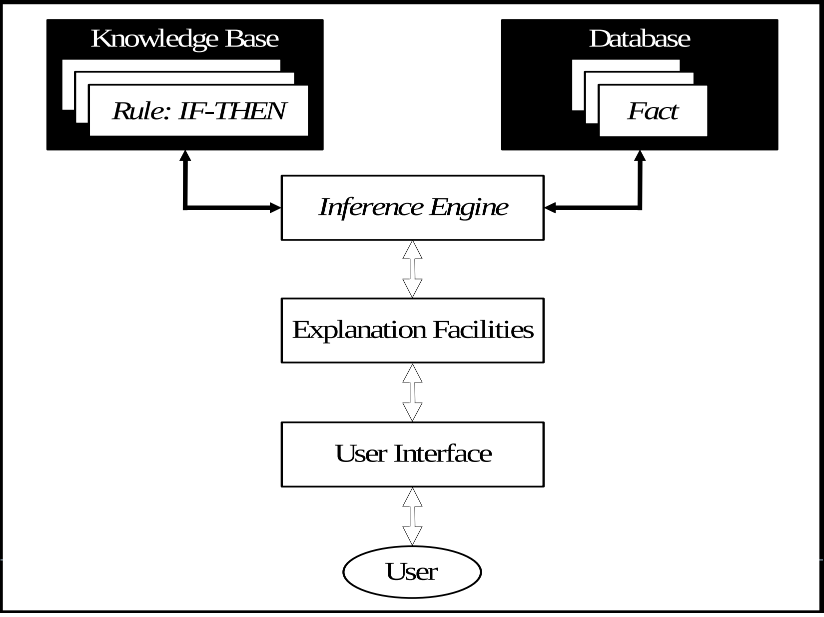
Rules Based System

- Use rules to encode the knowledge in the system
- General rule syntax :
  - if <antecedent> then <consequent>
    - if I put my hand on a hot iron,
    - then it will burn
    - if I want my car to stop,
    - then apply pressure to the brake
- Fact (or assertion) :
  - a statement that something is true
    - I put my hand on a hot iron
    - I want my car to stop

Components of a Rule Based Expert System

- A rule-based expert system contains :
  - Set of rules - stored in knowledge base
  - Working memory or database of facts
  - Rule interpreter - or inference engine
  - User interface
  - Explanation module
- These five components are ***essential*** for any rule based expert system

Basic structure of a rule-based expert system



Basic Components of a Rule Based Expert System

- The knowledge base:
  - Contains the domain knowledge useful for problem solving.
  - In a rule-based expert system, knowledge is represented as a set of rules.
  - Each rule specifies a relation, recommendation, directive, strategy or heuristic and 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

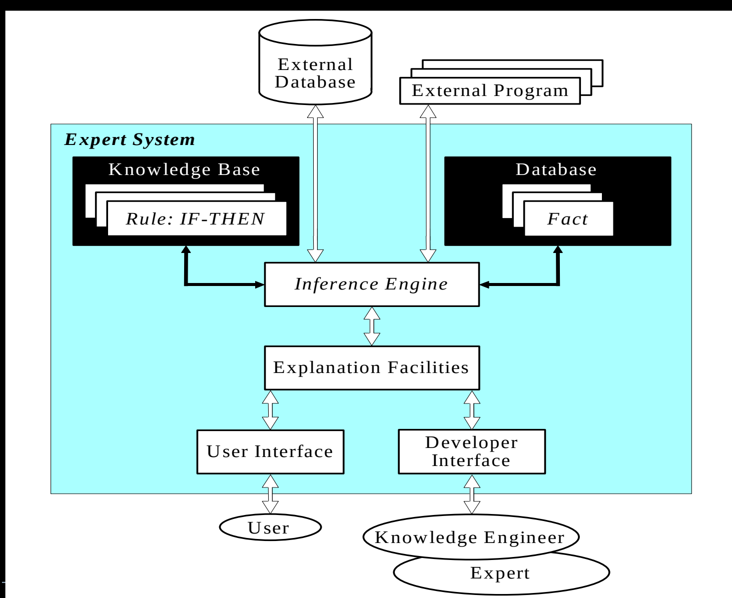
Basic Components of a Rule Based Expert System

- The inference engine:
  - Carries out the reasoning
  - Links the rules given in the knowledge base with the facts provided in the database
- The explanation facilities:
  - Enable the user to ask the expert system how a particular conclusion is reached and why a specific fact is needed.
  - An expert system must be able to explain its reasoning and justify its advice, analysis or conclusion.
- The user interface:
  - Means of communication between a user seeking a solution to the problem and an expert system.

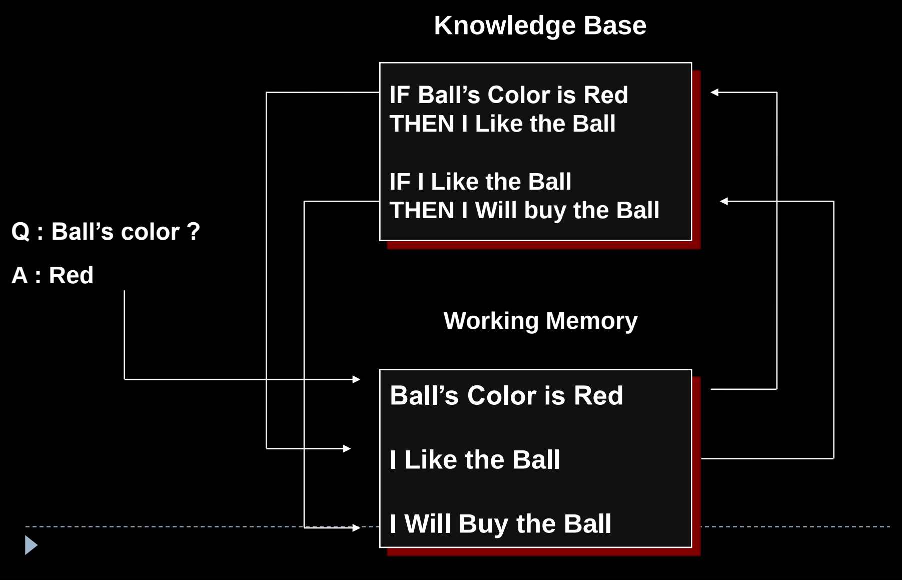
Additional Components

- In addition to the essential components there can be:
- External databases
  - Many Expert System shells have ODBC capabilities
- External Progams
- Developer Interface
  - Includes
    - Knowledge base editors
    - Debugging Aids

Additional structure of a rule-based expert system



Rule-based system operation



Inferencing Strategies

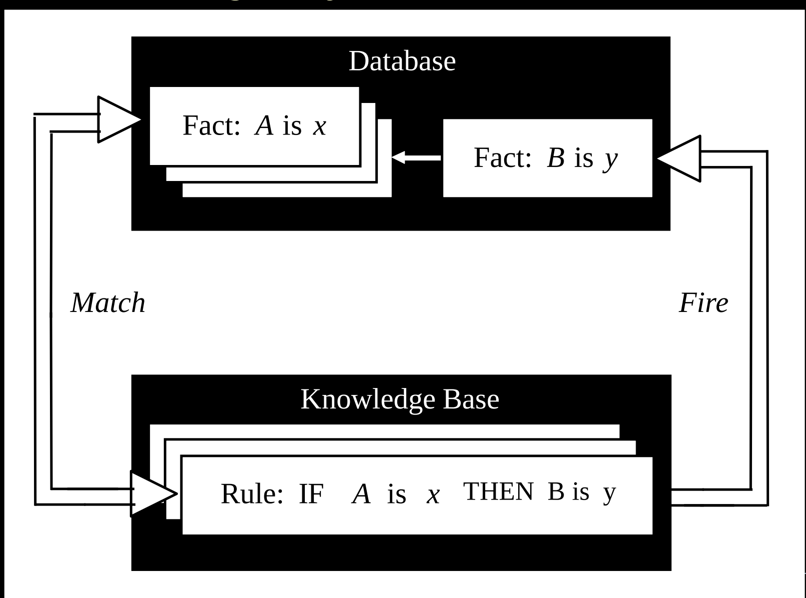
Two strategies:

- Forward chaining → data driven
- Backward chaining → goal driven

Forward Chaining - Data Driven

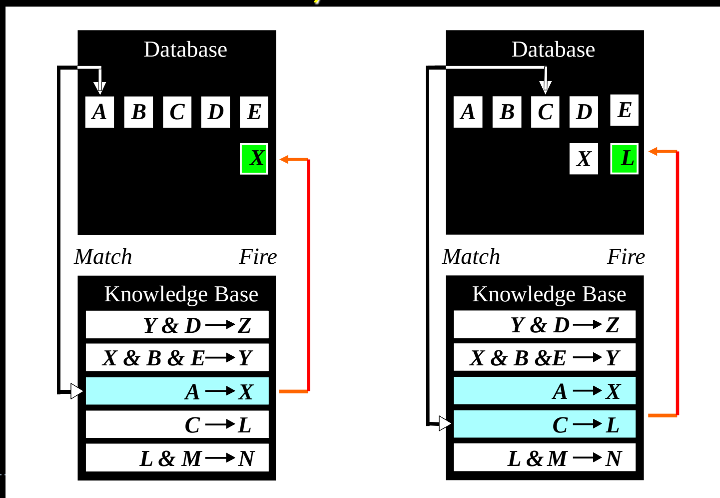
- Forward chaining:
  - Is **data driven** reasoning - the reasoning starts from the known data and proceeds forward with that data
  - Start with a set of facts (i.e. assertions)
  - Match conditions of rules against items in database
  - When rule is fired, add consequent to database
  - Continue until no rules left to fire

Inference Engine cycles via a match-fire procedure



Forward chaining

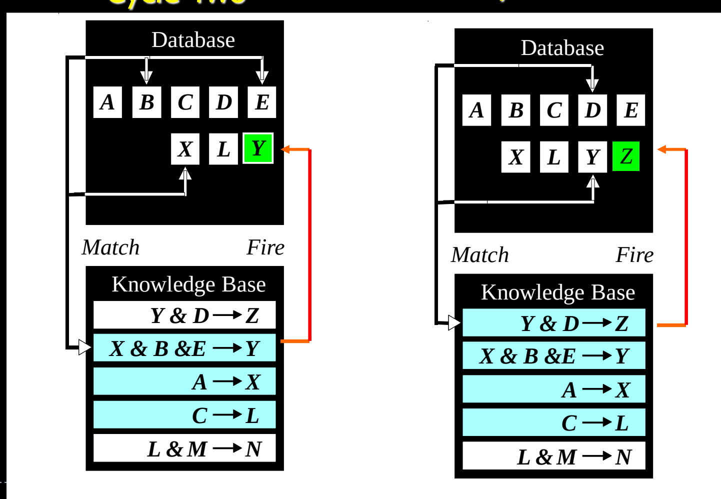
Cycle One



Forward chaining

Cycle Two

Cycle Three



Forward chaining Example

Rule 1

If patient has sore throat
And suspect a bacterial Infection
Then patient has strep throat

Rule 2

If patient temperature > 100
Then patient has a fever

Rule 3

If patient has been sick over one month
And patient has a fever
Then we suspect a bacterial Infection

Forward chaining Example

Database

patient temperature = 102
patient been sick for two months
patient has sore throat

Cycle 1: Rule 2 true -> conclude
Patient has a fever

patient has a fever

Cycle 2: Rule 3 true -> conclude
bacterial infection

bacterial infection

Cycle 3: Rule 1 true -> conclude
patient has strep throat

patient has strep throat

Backward Chaining – Goal Driven

- In contrast backward chaining:
  - goal driven, try to prove a specific goal
  - Work backwards from a ***conclusion*** and try to reach a set of conditions which establish that conclusion.
  - Start with a goal and use this to establish a set of sub-goals.
  - continue until goal is proved (or disproved), or no more matches

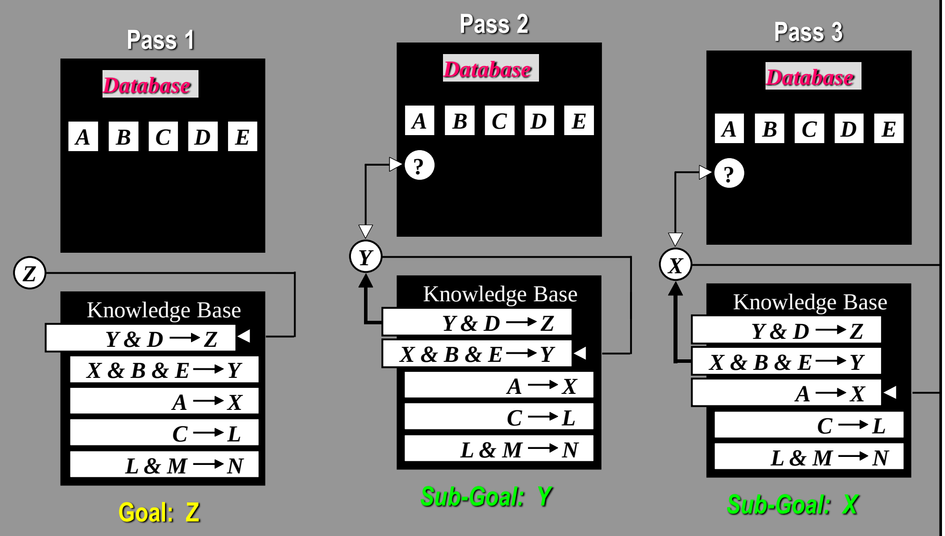
Backward chaining

- Backward chaining is the ***goal-driven reasoning***.
- In backward chaining, an expert system has the goal (a *hypothetical solution*) and the inference engine attempts to find the evidence to prove it.
- First, the knowledge base is searched 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.
- However, this is rarely the case.

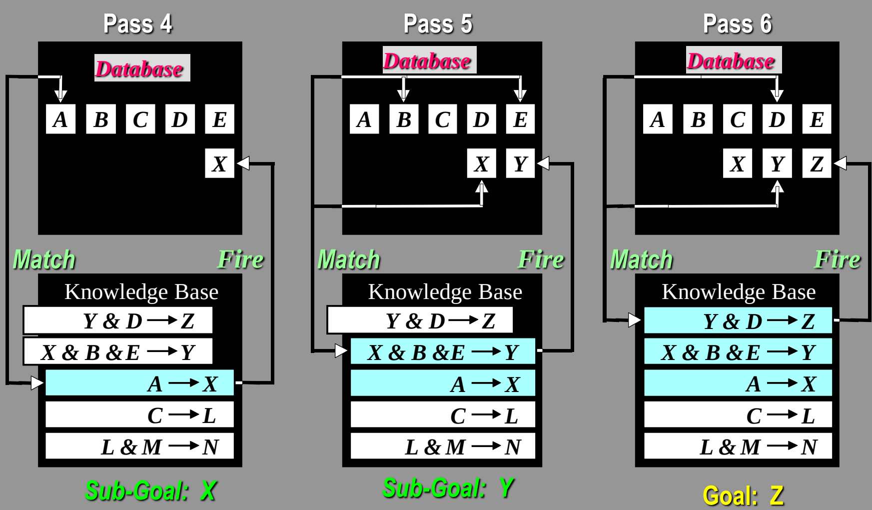
Backward chaining

- Thus the inference engine puts aside the rule it is working with (the rule is said to ***stack***)
- And sets up a new goal, a ***subgoal***, to prove the IF part of this rule
- 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 – Example 1



Backward Chaining – Example 1



Backward Chaining - Example 2

Rule 1

If patient has sore throat

And suspect a bacterial Infection

Then patient has strep throat

Rule 2

If patient temperature > 100

Then patient has a fever

Rule 3

If patient has been sick over one month

And patient has a fever

Then we suspect a bacterial Infection

Start with same set of facts:

patient temperature = 102

patient has been sick for two months

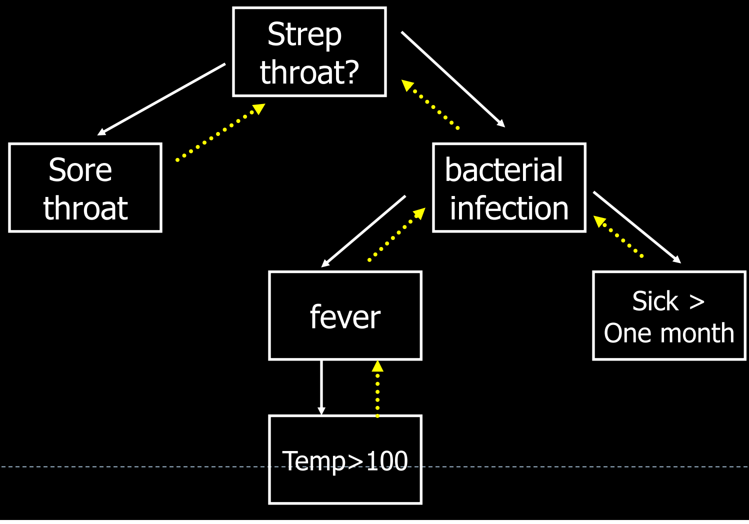
patient has sore throat

But now start with goal

Patient has a strep throat

And try to prove this given the rules and the facts.

Example 2 : Backward Chaining



Choosing between forward and backward chaining?

- 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.

Forward Chaining - Evaluation

- Advantages:
  - Works well when problem naturally begins by gathering information
  - Planning, control, monitoring
- Disadvantages:
  - Difficult to recognise if some evidence is more important than others
  - May ask un-related questions

Backward Chaining - Evaluation

- Advantages:
  - Remains focussed on a goal
  - Produces a series of questions that are relevant
  - Good for diagnosis
- Disadvantages:
  - Will continue to follow a line of reasoning even when it should switch.