Expert Systems

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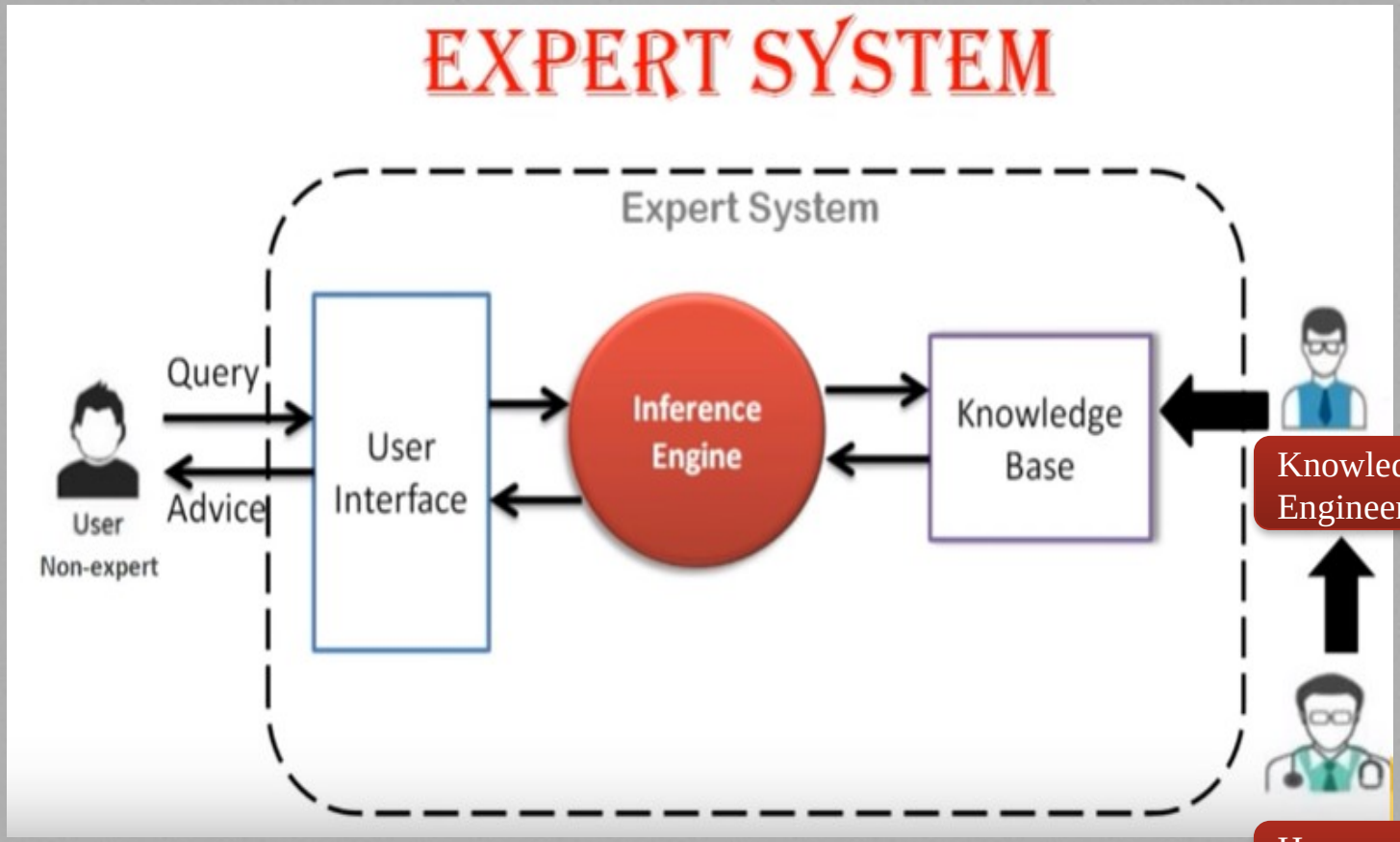
Introduction

- **Experts** are people who are very familiar with solving specific types of problems.

- An Expert System is an intelligent computer program that can perform special and difficult task(s) in some field(s) at the level of human experts.

Definition

- An expert system is a set of programs that manipulate encoded knowledge to solve problems in a specialized domain that normally requires human expertise.


EXPERT SYSTEM
Expert System
Query
Advice
User
Non-expert
User Interface
Inference Engine
Knowledge Base
Knowledge Engineer
Human Expert

CHARACTERISTICS OF AN EXPERT SYSTEM

- **High level Performance:** They should perform at the level of a human expert.

- **Domain Specificity:** Expert systems are typically very domain specific. For example, a diagnostic expert system for troubleshooting computers must actually perform all the necessary data manipulation as a human expert would.

- **Good Reliability:** The expert system must be as reliable as a human expert and should not crash.

- **Understandable:** The system should be understandable i.e. be able to explain the steps of reasoning while executing. It should justify its conclusions in the same way a human expert explains why he arrived at particular conclusion.

- **Adequate response time:** They should have the ability to respond in a reasonable amount of time. Time is crucial especially for real time systems.

- **Justified Reasoning:** This allows the users to ask the expert system to justify the solution or advice provided by it.

Applications of Expert Systems

Medical diagnosis	Strategy Games	Financial Advice
Identify Items	Discover Locations	Diagnose car engine problems

- **Medical diagnosis:**

  The knowledge base would contain medical information, the **symptoms** of the patient would be used as the **query**, and the **advice** would be a **diagnose** of the patient's illness.

- **Strategy games:**

  Playing **strategy games** like **chess** against a computer (the knowledge base would contain strategies and moves, the **player's moves** would be used as the **query**, and the **output** would be the **computer's 'expert' moves**).

- **Financial Advice:**

  whether to invest in a business, etc. (the knowledge base would contain **data about the performance of financial markets and businesses in the past**).

- **Identify Items:**

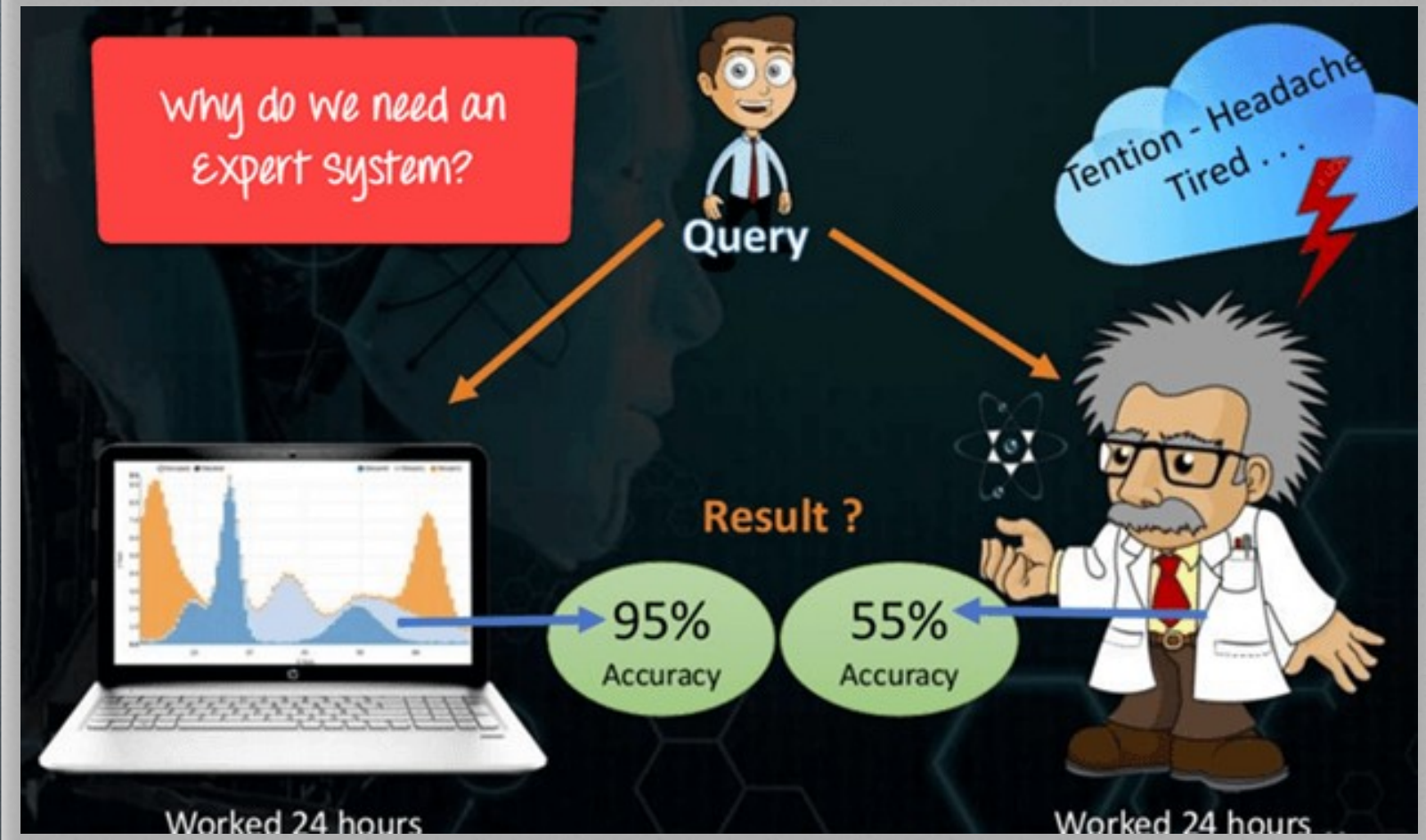
  Helping to **identify items** such as plants / animals / rocks / etc. (the knowledge base would contain **characteristics of every item**, the **details of an unknown item** would be used as the **query**, and the **advice** would be a likely **identification**).

- **Discover Locations:**

  Helping to **discover locations to drill for water / oil** (the knowledge base would contain **characteristics of likely rock formations where oil / water could be found**, the **details of a particular location** would be used as the **query**, and the advice would be the likelihood of finding oil / water there).

- Helping to **diagnose car engine problems.**

Importance of Expert Systems



1. It improves the decision quality
2. Cuts the expense of consulting experts for problem-solving
3. It provides fast and efficient solutions to problems in a narrow area of specialization.
4. It can gather scarce expertise and used it efficiently.
5. Offers consistent answer for the repetitive problem

6. Maintains a significant level of information.

7. Helps you to get fast and accurate answers.

8. A proper explanation of decision making.

9. Ability to solve complex and challenging. issues.

10. Expert Systems can work steadily work without getting emotional, tensed or fatigued.

Limitations of the Expert System

- Unable to make a creative response in an extraordinary situation
- Errors in the knowledge base can lead to wrong decision.
- The maintenance cost of an expert system is too expensive.
- Each problem is different therefore the solution from a human expert can also be different and more creative.

RULE BASED ARCHITECTURE OF AN EXPERT SYSTEM

- Rule based systems are also called as **production system**.
- Uses knowledge encoded in the form of production rules i.e. **if-then rules.**
- The rule has a **conditional part** on the **left** hand side and a **conclusion or action part** on the **right** hand side(**C -> A**).

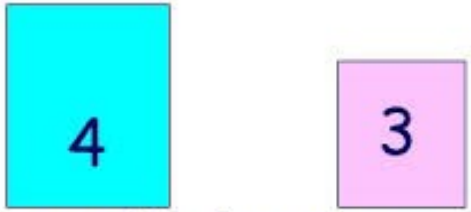
- For example **if: condition1 and condition2 and condition3**

  Then: Take action4

- The rule based architecture of an expert system consists of the **domain expert**, **knowledge engineer**, **inference engine**, **working memory**, **knowledge base**, **external interfaces**, **user interface**, **explanation module**, **database spreadsheets executable programs.**

Defining the problem

- A water jug problem: 4-gallon and 3-gallon



- no marker on the bottle
- pump to fill the water into the jug
- How can you get exactly 2 gallons of water into the 4-gallons jug?

1.	(X, Y) if $X < 4 \rightarrow (4, Y)$	Fill the 4-gallon jug
2.	(X, Y) if $Y < 3 \rightarrow (X, 3)$	Fill the 3-gallon jug
3.	(X, Y) if $X = d$ & $d > 0 \rightarrow (X\text{-}d, Y)$	Pour some water out of the 4-gallon jug
4.	(X, Y) if $Y = d$ & $d > 0 \rightarrow (X, Y - d)$	Pour some water out of 3-gallon jug
5.	(X, Y) if $X > 0 \rightarrow (0, Y)$	Empty the 4-gallon jug on the ground
6.	(X, Y) if $Y > 0 \rightarrow (X, 0)$	Empty the 3-gallon jug on the ground
7.	(X, Y) if $X + Y \leq 4$ and $Y > 0 \rightarrow 4, (Y - (4 - X))$	Pour water from the 3-gallon jug into the 4-gallon jug until the gallon jug is full.
8.	(X, Y) if $X + Y \geq 3$ and $X > 0 \rightarrow (X - (3 - Y), 3))$	Pour water from the 4-gallon jug into the 3-gallon jug until the 3-gallon jug is full.
9.	(X, Y) if $X + Y \leq 4$ and $Y > 0 \rightarrow (X + Y, 0)$	Pour all the water from the 3-gallon jug into the 4-gallon jug
10.	(X, Y) if $X + Y \leq 3$ and $X > 0 \rightarrow (0, X + Y)$	Pour all the water from the 4-gallon jug into the 3-gallon jug
11.	$(0, 2) \rightarrow (2, 0)$	Pour the 2-gallons water from 3-gallon jug into the 4;gallon jug
12.	$(2, Y) \rightarrow (0, Y)$	Empty the 2-gallons in the 4-gallon jug on the ground.

Fig. *Production rules (operators) for the water jug problem.*

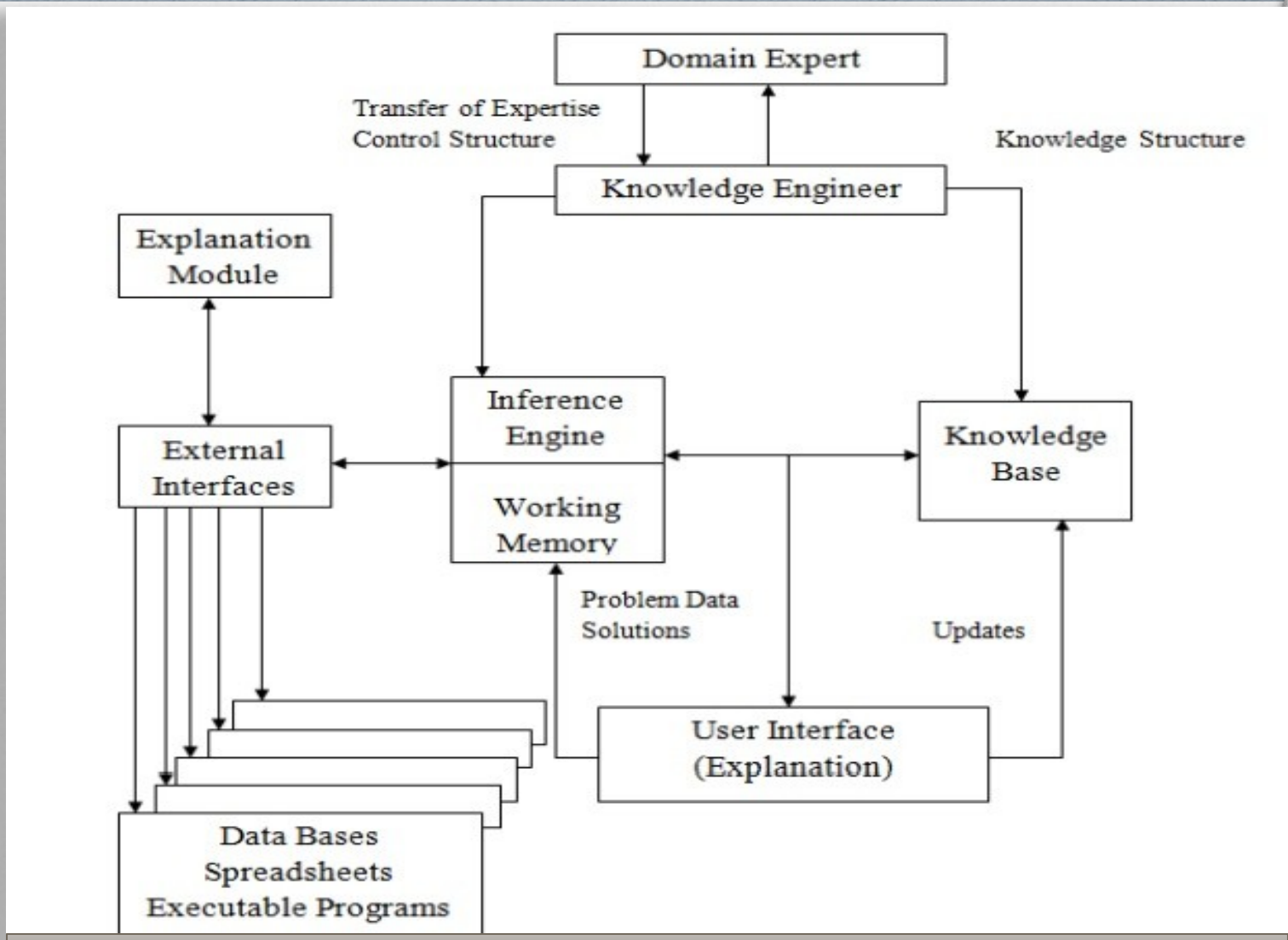


Fig: The rule based architecture of an expert system

1.**User Interface:**

- The user interacts with the system through a user interface.

- This module accepts the user queries and submits those to the expert system.

- The user normally consults the expert system for following reasons.

a) To get **answer** of his/her queries.

b) To get **explanation** about the solution for psychological satisfaction.

2.Explanation Module:

- It provides the user with an explanation of the reasoning process when requested.
- The credibility of expert system will be established only when it is able to explain “how and why” a particular conclusion is drawn.
- This explanation increases the belief of user in the expert system.

a) **Explanation(How):**

- To respond to a how query, the explanation module **traces the chain of rules fired during a consolation with the user.**
- It explains how a fact was deduced by the system and similarly how a rule was/wasn't used.

For e.g.

If the system (S) will give information about the parent-child relationship to the user (U) then the followings can be possible.

S: My diagnosis is “A is the father of B”

U: How?

S: The result was obtained by the addition of following facts and rules.

Fact no 11: A is the parent of Hari.

Fact no 15: A is a male.

Fact no 110: A is father of B:

A is parent of B, A is male.

So A is the father of B.

b) **Explanation (Why)?**

- To respond to a why query, the **explanation module must be able to explain why certain information is needed by the inference engine to complete a step in the reasoning process.**

- If the user doesn't understand the reason behind the question.

- The system is capable of explaining why the question was asked.

For example

S: Is the following true?

A is the father of B.

U:Why?

S:I need the fact:

A is the father of B to establish the following fact “B is the son of A”.

By using the rule no. 4:

A is the father of B:

B is the son of A.

3. **Working Memory:** It is a global database of facts used by the rules.

4. **Knowledge Engineering:**

- The **primary people** involved in building an expert system are the **knowledge engineer**, the **domain expert** and the **end user**.
- Once the knowledge engineer has obtained a **general overview of the problem domain and gone through several problem solving sessions with the domain expert**, he/she is ready to begin actually **designing the system**, selecting a way to **represent the knowledge**, determining the **search strategy** (backward or forward) and **designing the user interface**.

- After making **complete designs**, the knowledge engineer builds a **prototype**.
- The prototype should be able to solve problems in a small area of the domain.
- Once the prototype has been implemented, the knowledge engineer and domain expert **test** and **refine its knowledge by giving it problems to solve and correcting its disadvantages**

5. **Knowledge Base:**

- In rule based architecture of an expert system, the **knowledge base is the set of production rules**.

- The expertise concerning the problem area is represented by **productions**.

- In rule based architecture, **the condition actions pairs are represented as rules**, with the premises of the rules (**if part**) corresponding to the **condition** and the conclusion (**then part**) corresponding to the **action**.

- Case-specific data are kept in the working memory.

- The **core part** of an expert system is the **knowledge base** and for this reason an expert system is also called **a knowledge based system.**

- Expert system knowledge is usually **structured** in the form of a **tree** that consists of a **root frame** and a number of **sub frames**.

- A **simple knowledge base** can have only **one frame**, i.e. the root frame whereas a large and complex knowledge base may be structured on the basis of multiple frames.

6. Inference Engine:

- The inference engine accepts user input queries and responses to questions through the I/O interface.
- It uses the **dynamic information** together with the **static knowledge** stored in the knowledge base.
- The **knowledge** in the knowledge base is used to derive **conclusions** about the current case as presented by the user's input.
- **Inference engine is the module which finds an answer from the knowledge base.**
- It applies the knowledge to find the solution of the problem.

- In general, inference engine makes inferences by deciding **which rules are satisfied by facts, decides the priorities of the satisfied rules and executes the rule with the highest priority.**
- Generally **inferring process** is carried out recursively in 3 stages like **match**, **select** and **execute**.
- During the match stage, the contents of working memory are compared to facts and rules contained in the knowledge base.
- When proper and consistent matches are found, the corresponding rules are placed in a conflict set.

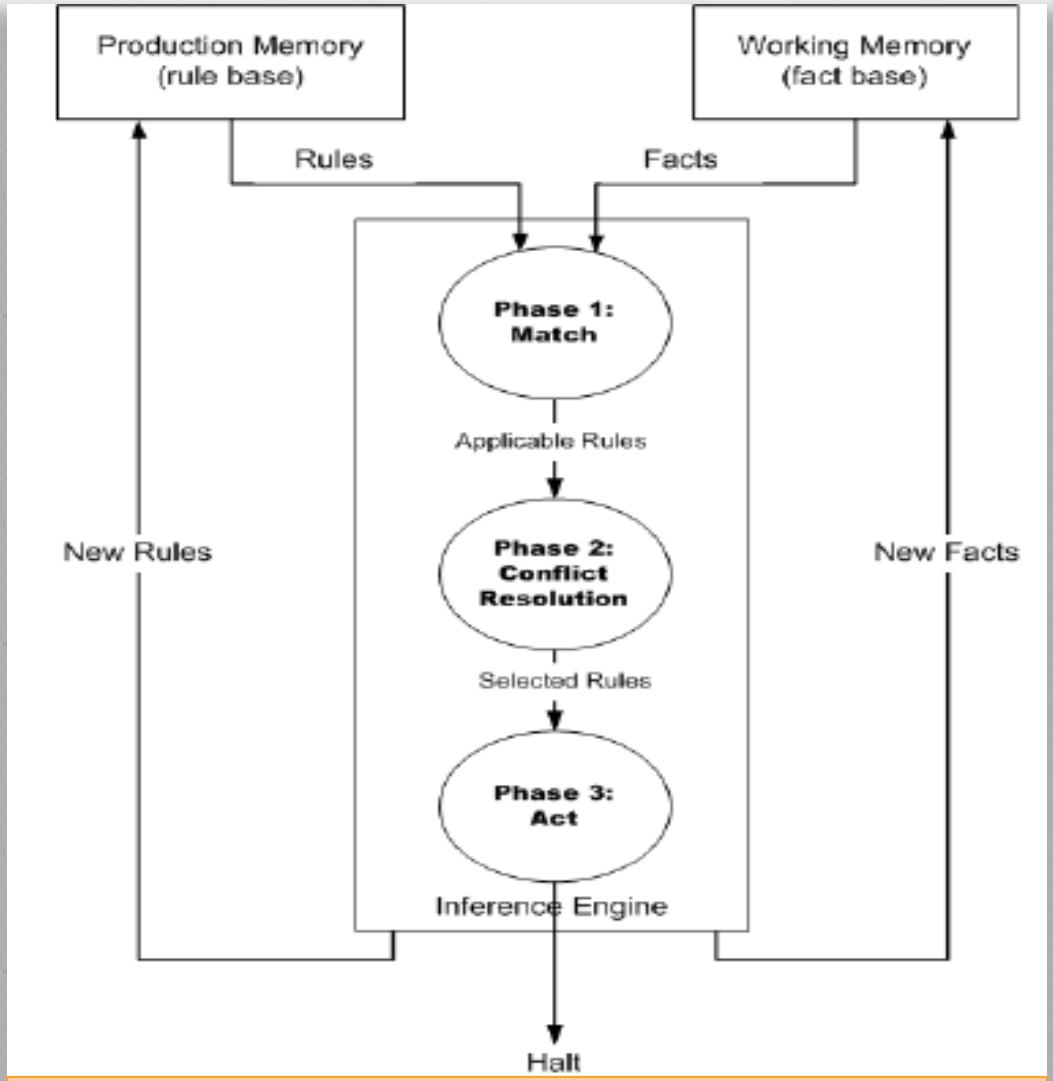


Fig: The production system inference cycle

Non production system architecture

- Instead of rules, these systems employ more **structured representation** schemes like **associative rules or semantic networks**, **frame** and **rule structures**, **decision trees**, or even specialized networks like **Neural Networks**.

Non production system architecture

- They are classified into six categories –

1. Associative or semantics architecture
2. Frame and rule structures
3. Decision network
4. Black board system architecture
5. Neural networks
6. Analogical reasoning

1. Associative or semantics architecture

- Associative network is made up of nodes connected by directed arcs.
- The **nodes** represent **objects**, **attributes**, **concepts**, or other basic entities and the **arcs**, which are labeled, describe the **relationship between the two nodes they connect.**
- Associative network representations are especially useful in **hierarchical representation** of knowledge structures
- For example **Binary tree**.

- Associative network representations are **not a popular form of representation for standard expert systems.**

- They are **used in natural languages** or **computer version systems.**

- One expert system based on the use of associative network representation is **CASNET** (**Casual Associative Network**),which was **developed at Rutgers for glaucoma one of the leading causes of blindness**. Main components of this network are –

1. patient observation
2. Disease categories

2. Frame Architecture

- Frame is **network of nodes and relations**.
- The attributes, values, and procedures are stored in specified slots.
- **Expert system has been constructed with frame architecture** and numbers of building tools that create and manipulate frame structured system have been developed.
- Example- A frame based system is **PIP** (**Present Illness Program**) system developed at 1970's.

- This medical knowledge in PIP is organized in frame structures where **each frames is composed of categories of slot with names such as typical findings**.

- Disease, solution, research, doctors, patients etc.

3. Decision Architecture

- Knowledge for expert systems may be stored in the form of a decision tree when the knowledge can be structured in **a top-to-bottom** manner.

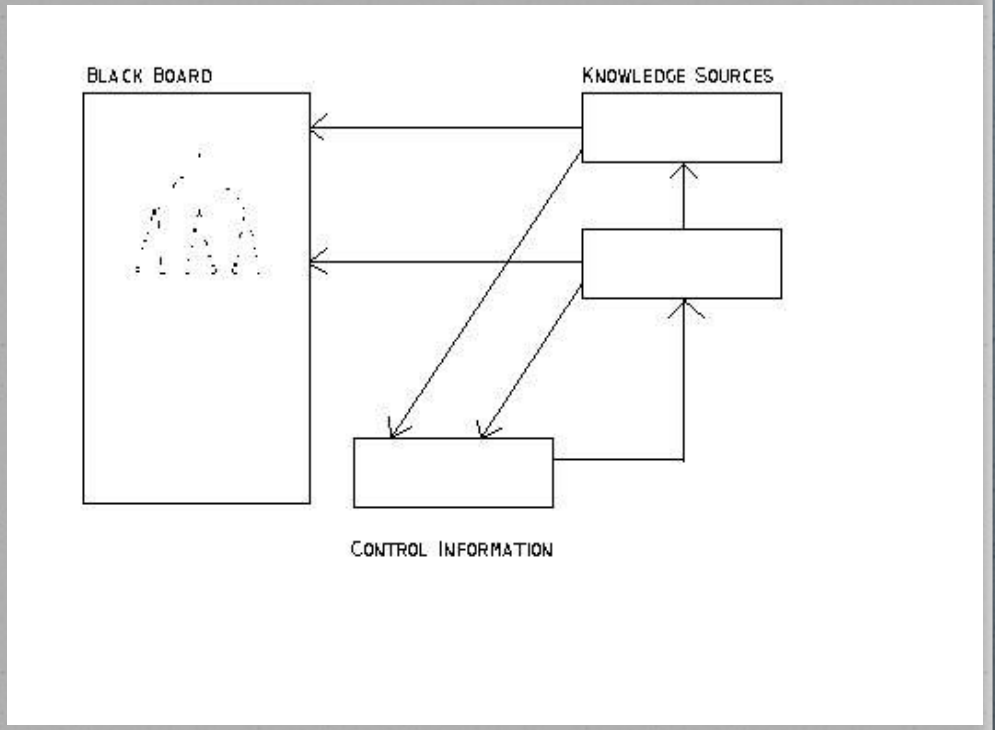
- Decision architecture is similar to **decision tree** in decision tree we can find **initial state(Starting node)** and **goal state(Last node).**

4. Black Board Architecture

- Black board architecture is special types of knowledge base system which uses a form of **opportunistic reasoning** .
- It uses both **forward & backward chaining** and chooses them **dynamically at each stage** in the problem solution process.
- Other reasoning methods(model driven, for example) may also be used.

- Blackboard systems are composed of 3 functional components:

1. Knowledge Sources
2. Blackboard
3. Control Information



- One of the first application was HEARSAY family of projects, which are speech –understanding systems.

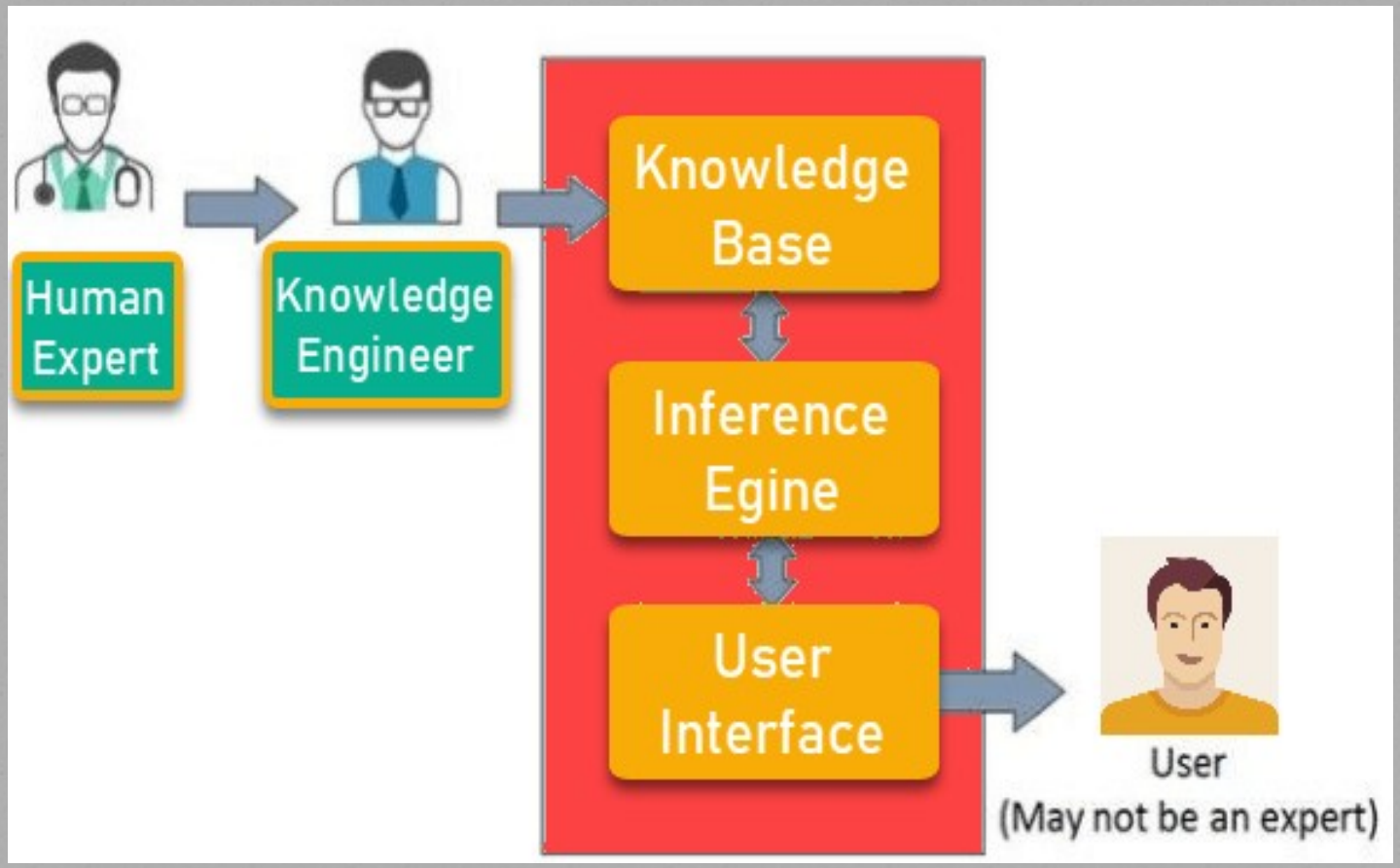
4. Neural Network Architecture

- Neural networks are large networks.
- Neural network is used to solve large problem into short form.
- It is used to solve mathematically and statistical problem.

5. Analogical Reasoning

- Expert systems based on analogical architectures solve new problems like humans, by finding a similar problem solution that is known and applying the known solution to the new problem, possibly with some modification.

Components of the expert system



1. User Interface

- The user interface is the most crucial part of the expert system.
- This component takes the user's query in a readable form and passes it to the inference engine.
- After that, it displays the results to the user. In other words, it's an interface that helps the user communicate with the expert system.

2. Inference Engine

- The inference engine is the **brain** of the expert system. Inference engine contains rules to solve a specific problem.
- **It refers the knowledge from the Knowledge Base**. It selects facts and rules to apply when trying to answer the user's query.
- It provides reasoning about the information in the knowledge base.
- It also helps in deducting the problem to find the solution. This component is also helpful for formulating conclusions.

3. Knowledge Base

- The knowledge base is a **repository of facts**.
- It stores all the **knowledge about the problem domain.**
- It is like a large container of knowledge which is obtained from different experts of a specific field.
- Thus we can say that the success of the Expert System mainly depends on the highly accurate and precise knowledge.

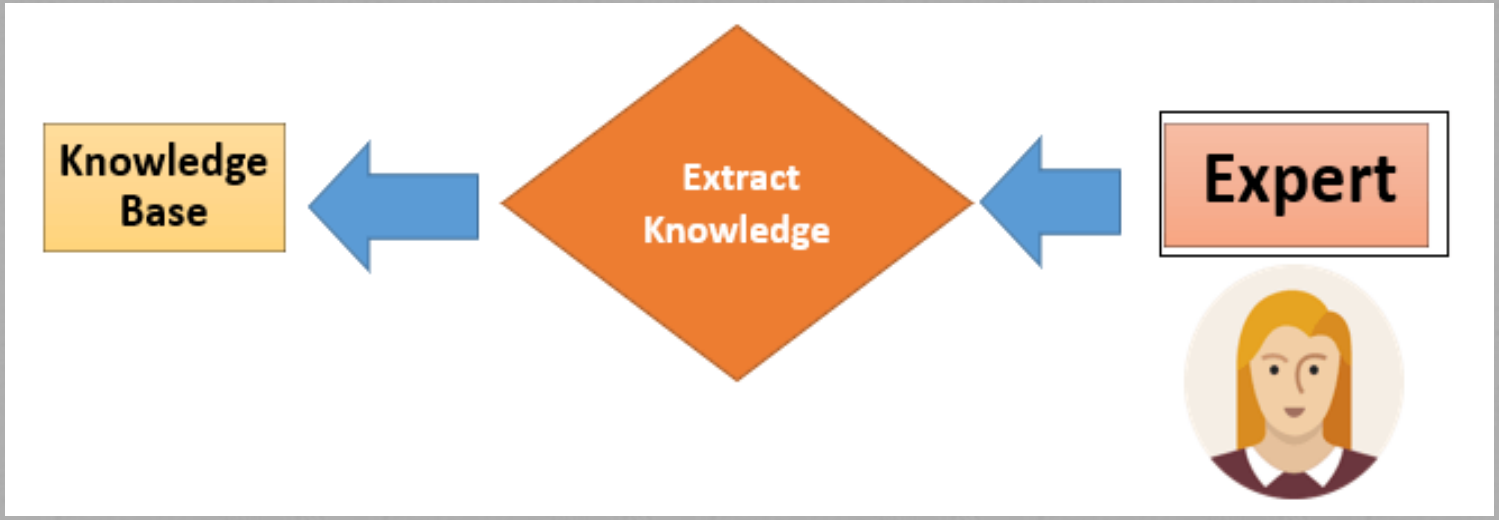
Other Key terms used in Expert systems

Facts and Rules

- A fact is a **small portion of important information**.
- Facts on their own are of very limited use.
- The rules are essential to select and apply facts to a user problem.

Knowledge Acquisition

- The term knowledge acquisition means how to get required domain knowledge by the expert system.
- The entire process starts by extracting knowledge from a human expert, converting the acquired knowledge into rules and injecting the developed rules into the knowledge base.



Early Expert Systems

- **DENDRAL** – used in chemical mass spectroscopy to identify chemical constituents
- **MYCIN** – medical diagnosis of illness
- **DIPMETER** – geological data analysis for oil
- **PROSPECTOR** – geological data analysis for minerals
- **XCON/R1** – configuring computer systems