Expert Systems

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Outcomes

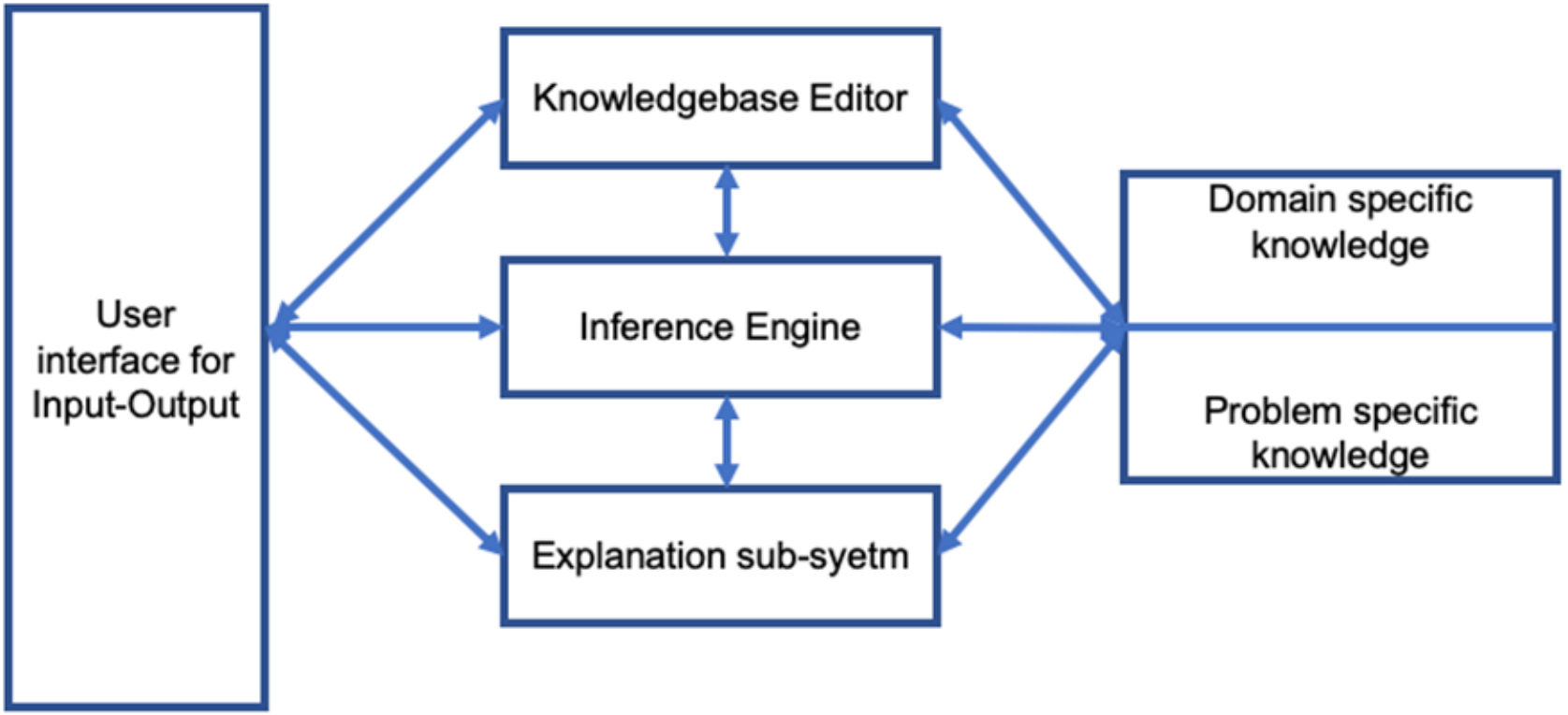
By the end of this module, you'll be able to:

- Understand the concept of expert systems
- Understand components of expert system
- Explain the roles involved in expert system implementation
- Define characteristics of expert systems
- Know applications, advantages and limitations of expert systems

Definition

- An intelligent computer program that employs knowledge and inference procedures to solve problems that are considered difficult enough to require significant human expertise for their solutions.

ES component diagram



ES components: User Interface

- Users interact with ES through this user interface to give input and to receive output.
- Various ES in the world use different interfaces to communicate with the user.
- Some of the examples are-
  - Input- speech input through a microphone, forms, questionnaire, dialogue boxes, various sensors, dialog boxes, command prompts, etc.
  - Output- speech through speakers, graphs, actions such as modem dialing a phone number, graphical output, textual results, etc

ES components: Inference Engine

- The inference engine is the brain of the ES.
- Contains customized algorithms, rules, reasoning methods, etc. to solve a specific problem.
- Interacts with the Knowledge Base to receive appropriate background and current information, facts-rules/ algorithms to apply to answer the user's query.
- Uses various options to compute solution.
- Some of the algorithm families used by inference engine are-
    1. Forward/backward chaining with if-then-else rules
    2. Machine learning algorithms
    3. Neural networks
    4. Bayesian network
    5. Decision trees
    6. Customized algorithms

ES components: Knowledge base

- The knowledge base is a collection of facts and the rules.
- The success of the Expert System mainly depends on the highly accurate and precise knowledge.
- The knowledge is generally a domain-specific one.
- The knowledge is typically divided in two parts- domain specific knowledge and problem specific knowledge.

ES components: Explanation subsystem

- The explanation subsystem is something unique to ES.
- When asked, the ES can explain its reasoning process of starting with the given information to all the intermediate states during the computation process.
- This can help in debugging where one can pinpoint missing a fact or a rule.
- It is also helpful in case of difference of opinion and it can be very well bounded by having access to the customers.

Is every AI program an expert system?

- Voice operated smart assistants?
- Smart driverless/auto-pilot cars?

CHALLENGES

- Knowledge acquisition problem
- Performance and speed
- size of the knowledge base
- Verifying consistency of decision rules when the rule base is very huge
- Prioritization of the rules in order to operate more efficiently,
- resolving ambiguities
- Updating of its knowledge quickly and effectively

Roles in building expert systems

- User
- Domain expert
  - one or more domain experts might be involved in the project.
  - The domain expert beholds hefty proficiency in the domain for which the expert system is under development.
  - It's not compulsory for the domain expert to have knowledge about AI, expert systems or computer programming

Roles in building expert systems

- Knowledge engineer
  - Generally more than one knowledge engineers work on project.
  - A knowledge engineer is specialized in the field of AI.
  - Possess knowledge on computer programming and is perhaps a computer scientist or programmer, who is expert in the field of building expert systems.
  - Typically, the system designers, programmers, testers, analysts, i.e., all of those who have worked on technical aspect of expert system development are believed to be knowledge engineers.

Roles in building expert systems

- The knowledge engineer should be well acquainted with-
  - various of knowledge representation techniques
  - intelligent searching strategies
  - expert system tools
  - software engineering methodologies those formalize the process and can also speedup the development.
  - Other expert systems working on similar problems or domains so as to understand their strengths-weaknesses and thus adapt the best practices, avoid mistakes in the expert system being developed.

Examples of Expert Systems

- ***MYCIN:*** *Mycin is one of the earliest expert system built in 1960's for medical diagnosis purpose. It took answers to series of questions in yes or no forms, used more than 600 simple inference rules and used backward chaining to give output. It could also give drug prescription to the patients.*
- ***DENDRAL:*** *This was another expert systems from 1960s and many expert systems, including Mycin, were derived from it. Its purpose was to identify unknown organic molecules. It used some graph theory algorithms for the same.*

Juvenile Delinquency Legal Reasoning Model

Objectives

- Ability to **extract and analyse correct precedent cases** and **court orders** is **critical.**
- Precedent cases (same juvenile or a differenet one) and court orders are **searched and extracted manually** causing **backlog** in trials.
- Using a Legal Reasoning model to **recommend court orders** for juvenile delinquency cases to overcome this.

Reasoning - Rule based

IF

(Juvenile is children beyond control)

THEN

The court make the following orders:

Sect. 46(2)(aa) sent to an approved school, place of refuge, probation hostels or centres

Sect. 46(2)(bb) placed for such period not exceeding three years under supervision of probation officer or appointed person by Court

- A straightforward transformation process of **legal statute to rule form**
- The purpose of this transformation is to **identify and select the rules** for offences committed.

Reasoning - Case based

Inputs : The whole cases from knowledge base

Output : The optimal *k* of each target case. The optimal *k* is the number of the fewest nearest neighbor cases with target case.

Procedure

a) For each case, use Hamming and Manhattan distance matrix to calculate distance between target cases with every precedent case. Average all distance matrixes to produce a single dissimilarity distance value.

b) Sort the dissimilarity distance values from the smallest to largest value.

c) Get the similar cases with optimal *k* by checking from the nearest neighbors of target case.

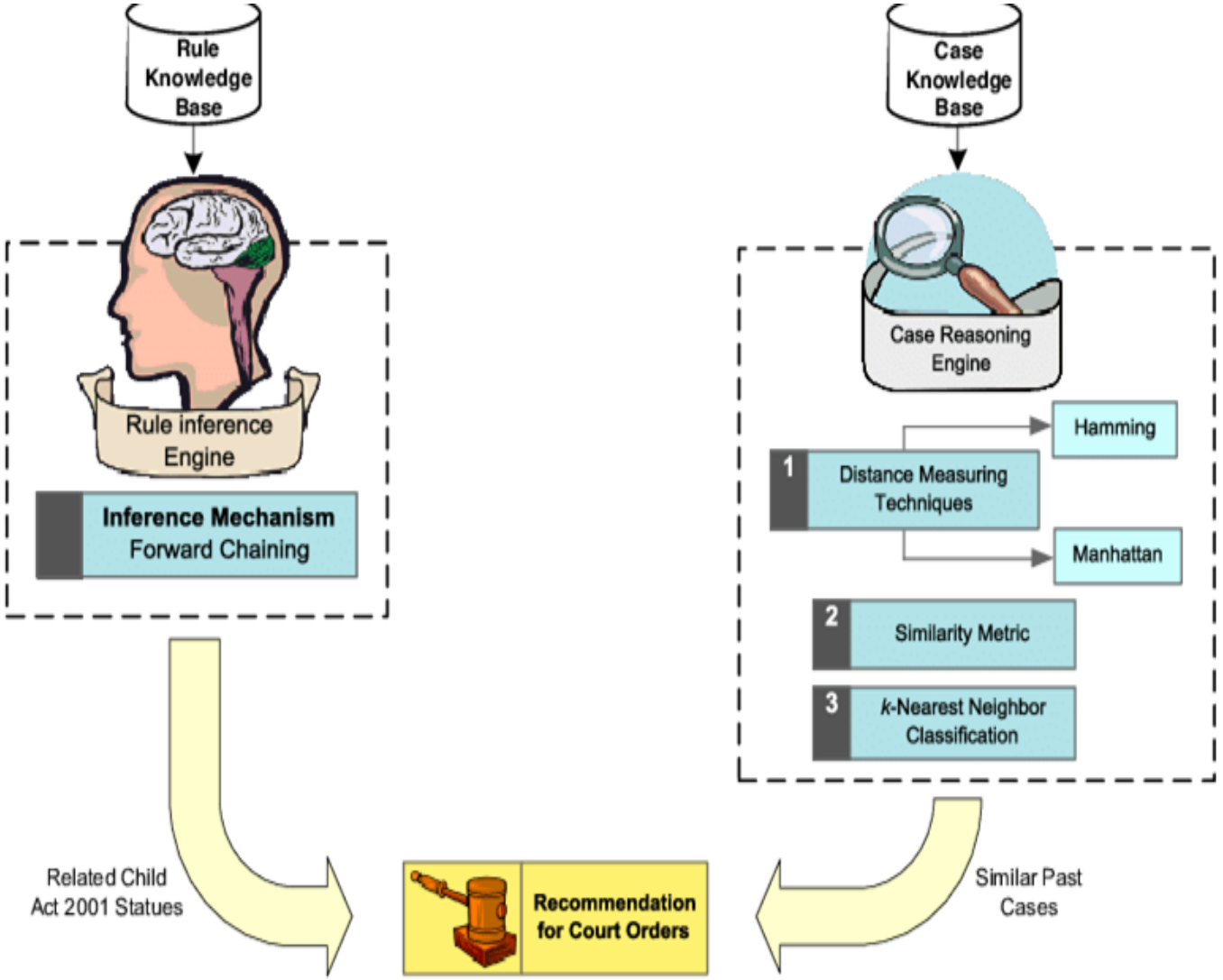
- This type of reasoning was conducted by **defining the facts of cases.**
- Facts of a case determine the **new case's relationship** with the **precedent cases.**
- Each case was further analysed to determine the **similarity index of the new case to precedent cases**.

Algorithm

Makes use of 3 algorithms to calculate similarity between new and precedent cases .

- Hamming algorithm was used to calculate the nominal data
- Manhattan algorithm to calculate nominal and continuous data
- Normalize values using similarity metric
- k-nearest neighbour algorithm used to classify similar precedent cases.

Basic Overall Working



Input-Output

Takes following factors as **input**:

- Age
- Gender
- Race
- Residence
- Parents' Education
- Parents' Profession
- Offence Committed

Displays **output** as:

CaseNo	Target Case	2	53	54
Similarity Percentage	-	100%	100%	100%
Age	17	17	17	17
Gender	Male	Male	Male	Male
Race	Malay	Malay	Malay	Malay
Custody Type	With parents	With parents	With parents	With parents
Residence Type	*'Rumah Kampung'*	*'Rumah Kampung'*	*'Rumah Kampung'*	*'Rumah Kampung'*
Parent Occupation	Private Sector	Private Sector	Private Sector	Private Sector
Parent Education	Secondary	Secondary	Secondary	Secondary
Parent Income	RM1001-RM2000	RM1001-RM2000	RM1001-RM2000	RM1001-RM2000
Offence	Under Poison Act 1952	Under Poison Act 1952	Under Poison Act 1952	Under Poison Act 1952
Orders	-	Sect 91(1)(b) Bond of good behaviour Sect 93(1)(a) Report at JKM	Sect 91(1)(b) Bond of good behaviour Sect 93(1)(a) Report at JKM	Sect 91(1)(b) Bond of good behaviour Sect 93(1)(a) Report at JKM


JABATAN KEBAJIKAN MASYARAKAT PERLIS
Case-based Reasoning (CBR)
Target Case : 1
Insert K value : 5
Get Case Similarity
Case 2=100%
Case 53=100%
Case 54=100%
Case 117=100%
Case 72=97.2222222222222%

Applications

- Quick retrieval of precedent cases and other information reduces backlog.
- Ensures fairness in the decision making process in courts.
- Can be used in resolving cases quickly.
- No involvement of emotions as it is an expert system.

An Expert System for Automobile Repairs and Maintenance

Many car owners and drivers have less knowledge on detecting and diagnosing faults in their cars. Automobile problem or fault detection is a complicated process which demands high level of knowledge and skill

User interface

- Customized GUI
- Choosing the work:
  - update the database(car type, classified faults and symptoms) or
  - diagnose the faults.
- Drop down menu to select fault type

Inference Engine

- Uses facts and heuristic
- Determines the solution by comparing the facts obtained from the analysis of the problems with supposed working mode of the car system.
- The inference engine imitates the specialist's reasoning process through the utilization of a problem solving strategy.
- The inferences were drawn by matching the if-part of the rules with the known facts in the working memory and placing back the result to the working memory.

Rules

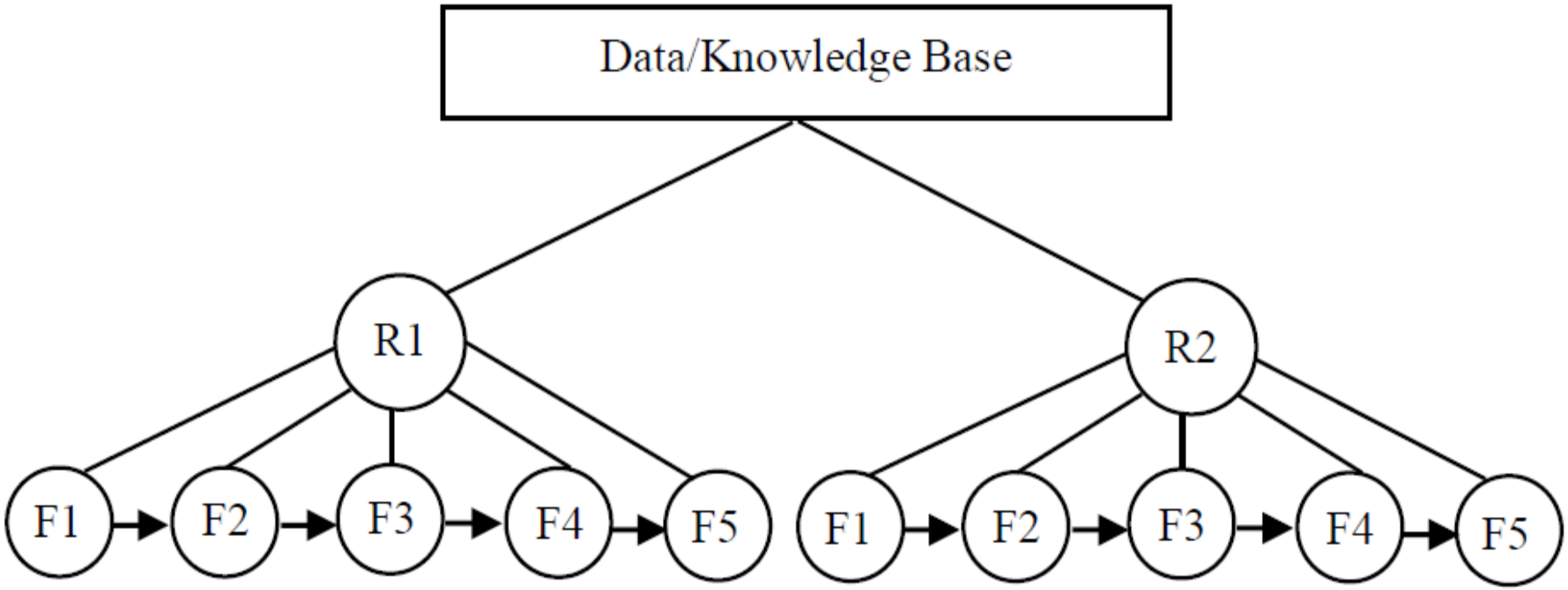


Figure 3. Search engine method (R: Record; F: Field; F1: Car type; F2: Class fault; F3: Symptom; and F4: Diagnosis)

Some Rules

- Rule 1: if key ignition to start the vehicle is turned on and engine fails to crank, then check the battery and battery terminals of the vehicle should be cleaned and tightened appropriately.
- Rule 2: if rule 1 is followed and vehicle still fails to crank, then confirm the fuel/ gas level of the vehicle if it is enough.
- Rule 3: if rule 1 is followed and there is enough fuel/gas but the engine still fails to crank, then switching operation should be checked.
- Rule 4: if the engine refuses to crank after the application of rules 1, 2 and 3, then contact an experience automobile personnel as the vehicle's fault/problem might be likely a major electrical problem.
- Rule 5: if there is bad, slow running jet block for carburettor and there is lack of fuel supply, then change the fuel pump

Applications

- Used where auto mechanic is not available
- Gives a temporary assistance to the car owners who are in need of an instant help
- Enables people to get closer to the world of computerization and technology.
- May allow auto-mechanic to do more work efficiently, which could generate more revenue.
- Finally, the system has the characteristics of a good expert system because of its high performance, responsiveness and user-friendliness.

MISTRAL: an expert system for the management of warnings from automatic monitoring systems of dams.

Problem Statement:

- A basic requirement of managing dam safety is the necessity to deal with monitoring data, which are interpreted in order to understand the state of the dam.
- MISTRAL is a knowledge-based system that supports safety managers when dealing with the interpretation of monitoring data gathered on dams.

Inputs and Outputs

- Input: MISTRAL receives data from the automatic monitoring system of a dam, identifies the state of the structure and generates natural-language explanations of the results of the evaluation.
- Output: MISTRAL provides the users with a database collecting all the data related to the control system (measurements, evaluations, explanations). It is possible to select a situation from the data base and show on the screen its graphic representation and explanations.

Sample domain specific and case specific knowledge.

- Reasoning about single measurements (RPIJ. Effect variables (for example, displacement of dam blocks) identify the state space (Level of basin and air temperature are examples of cause variables).
- Reasoning about families of measurements (phenomena) (RP3). Sets of effect variable belonging to the same type of instruments (for example, the set of extensometers installed in a dam) identify the state space.
- Reasoning about processes (RP4). Physical processes that might be active in the structure (such as rotation, translation, and seepage) identify the state space.

- Mistral implements via a rule-based system As an example, the following rule describes a part of the space state of a dam block's process rotation

  IF
  State of Plumbline1 is very anomalous AND direction of Plumbline1 is down AND State of Extensometer1 is very anomalous AND direction of Extensometer1 is down
  THEN
  State of rotation of DamBlock1 is very anomalous AND direction of rotation of DamBlock1 is down

- If the rule fires (all the conditions are true), then the activation state of the process assumes the value defined by the rule's conclusion. In the example, the high downstream displacement of a plumb line installed on a dam block and the high compression of a strain gauge in foundations under the block imply a high downstream rotation in the dam block.

Working

MISTRAL is a decision support system comprised of the following modules (figure 1):

- *Communication module:* it is the manager of the data communication from the monitoring system to MISTRAL;
- E*valuation module*: it identifies the current state of the dam;
- *Explanation module*: it generates a natural-language explanation of the deductions carried out by the evaluation module;
- *Man/machine interface*;
- D*atabase management module*: it is the manager of an internal database of measurements and evaluations.

Applications:

The 3 classes of users of the system exist:

- Dam manager: MISTRAL is used as a control panel, that shows the current state of the structure, and as a decision support system; the internal dynamic data base helps the dam managers understand the evolution of the dam state, in order to start necessary actions (e.g. inspections, retrofitting);
- Dam safety experts: skilled engineers use MISTRAL to store both theoretical knowledge and engineering judgment based on experience; they check the results of MISTRAL's evaluations against their own conclusions, in order to tune MISTRAL or to refine their own understanding of dam safety problems;
- Junior safety managers: MISTRAL can be used as a training tool, to understand past evaluations of the behaviors of a dam.

"Web Based Fuzzy Expert System for Lung Cancer Diagnosis"

Problem: the problem of detecting the lung cancer based on patients medical history.

Components

- User Interface:
  - *The UI consists of a form on a website.*
  - *The user must log in with their credentials (Medical Record Number) and the essentials details via a form on the website and the output is generated on screen with the diagnosis and the treatment suggestion.*
- General Knowledgebase:
  - *The KB is stored in a MySQL database.*
  - *consists of variables like anamnesis, doubling, time of the tumour, degree of smoking, age and performance status.*
  - *Anamnesis in turn consists of several other variables like fever, genetics, chest pain etc.*
  - *The general knowledgebase consists of 243 combinations of rules obtained from doctors via interview. They consist of the 5 input variables; anamnesis, degree of smoking etc. and the corresponding output.*

Components contd…

- Inference Engine:
  - *The inference engine uses fuzzy logic in order to perform a diagnosis.*
  - *The input variables are classified into fuzzy sets, and the weighted average of the fuzzy inputs is taken in order to the compute the final step.*
  - *Based on the weighted average, after de-fuzzification is performed, the tumour is either diagnosed as absent, benign or malignant.*

Features of the expert system

- *The given expert system is able to diagnose lung cancer using fuzzy logic with rules based on interviews from doctors and supporting data.*
- *The patients receive their diagnosis as well as a suggestion of the type of treatment required.*
- *The patient is either classified as healthy, having a benign tumour or having a malignant tumour.*

“Expert System for Financial Decision Making”

Problem- The Problem of deciding on the part of a consumer or a novice individual investor when to invest in the stock market and how to select what company’s share to buy in order to be able to get a good portfolio growth in the highly volatile stock market demands the development of expert systems for the novice investors.

Components of ES

- User Interface:
  - *Graphical User Interface like menus and graphics in the Windows Environment.*
  - *It enables the user to query the system, input the relevant information and then receive advice in the user's language.*
- Knowledge base editor
  - *The knowledge base editor is a simple editor that enables a subject matter expert to compose and rules to the expert system.*
  - *They can also convert the rules from one form to another.*

Components contd…

- Knowledge Base
  - *It Consists of Facts, Rules or heuristic rules – specific rule of thumb. The Prolog suite is widely used to formulate the knowledge into rules and store them in the knowledge base.*
    - Examples
      - *falls (investment):- rises (interest rate).*
      - *rises (Investment):- falls (interest rate).*
      - *rises (interest rate):- rise (stock price).*
      - *falls (interest rate):- falls (stock price).*
  - *Knowledge acquisition captures the knowledge from a financial expert with adequate knowledge and experience in this field. Source of knowledge are online journals, databases, reports, etc.*
  - *The Case Specific data contains facts of problem that happen during the consultation process when the user in interacting with the expert system. It compares this information with the one found in the knowledge base and also stores the reasoning in the working memory.*

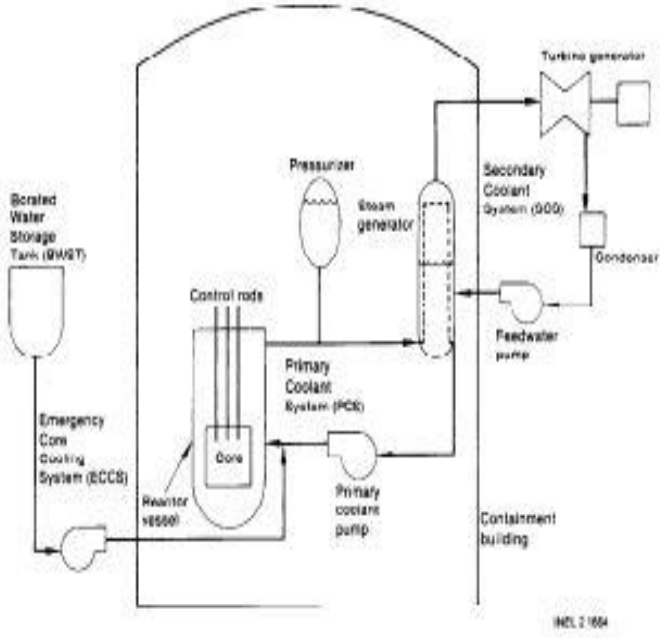
Components contd…

- Inference engine
  - *An inference rule is a statement that has two parts- an if-clause and a then-clause. An expert system's rule base is made up of many such inference rules which resemble human reasoning.*
  - *The system uses Forward chaining and backward chaining for reasoning.*

An Expert System for Diagnosis and Treatment of Nuclear Reactor Accidents

Input and Output

- Highly sensitive sensors are used which are efficient in sensing minute changes in physical factors such as temperature, pressure, radioactivity, concentration of poison rods, etc. In addition to the sensors, the system is equipped with monitors and peripherals so as to enable scientists to select and apply a protocol or run diagnosis.
- The output is displayed on a screen showing whether the reactor is operating as expected or not, along with options to deploy countermeasures after diagnosis.



Algorithms

- REACTOR has an inference engine which runs step by step diagnosis in case of any fault detected.
- The inference engine uses a response tree for for making a decision in case any fault or mishap is detected.

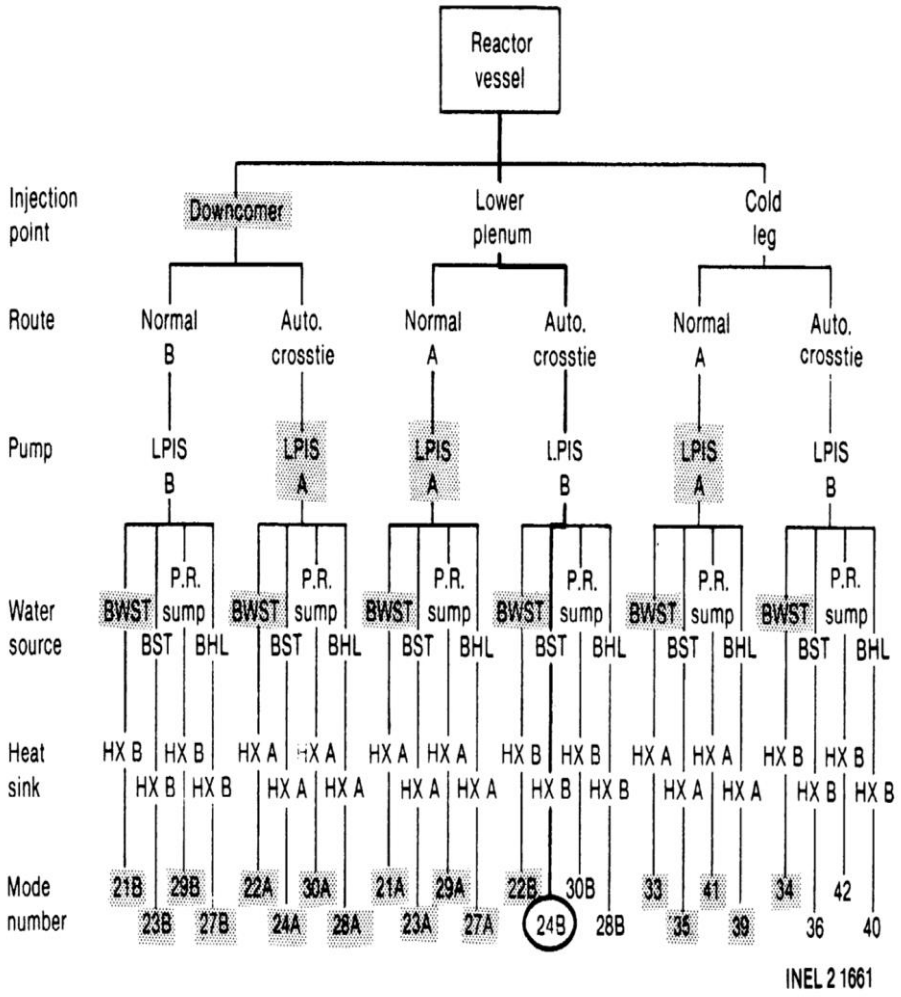


Figure 6. Response tree for LOFT LPIS.

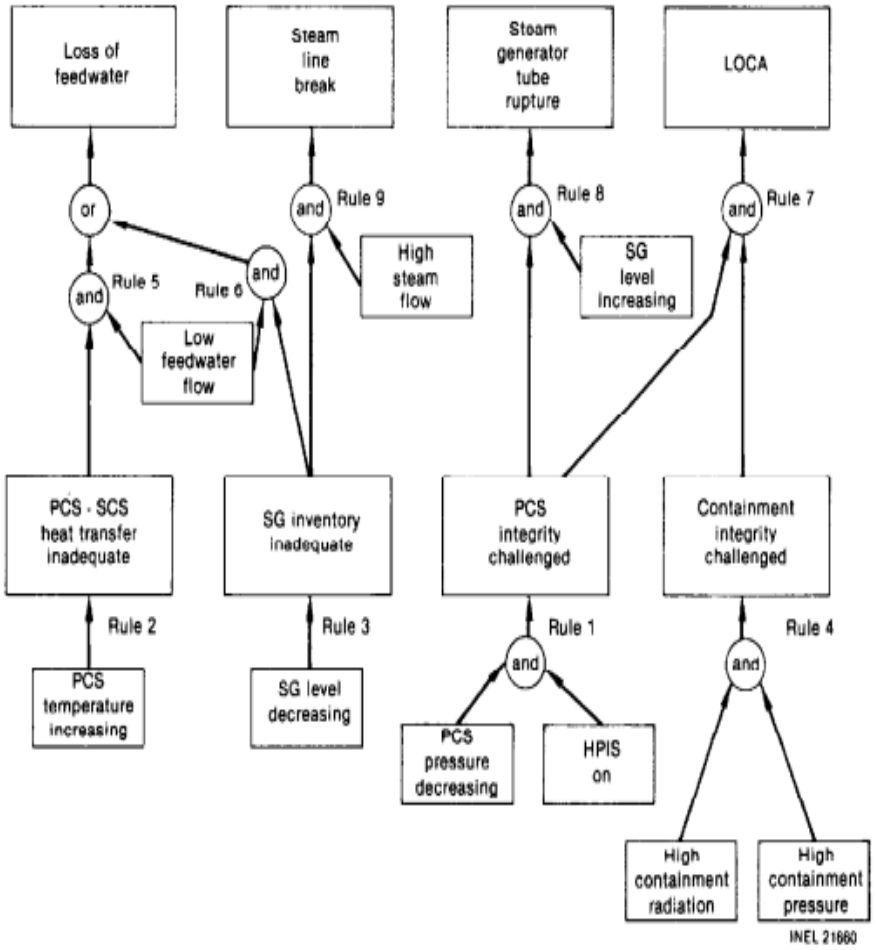
Event Oriented Knowledge

- Function-oriented knowledge and event-oriented knowledge.
- Function-oriented knowledge concerns the configuration
- Event-oriented knowledge describes the expected behavior of the reactor under known accident conditions.

```
((RULE 1
     (IF (PCS PRESSURE DECREASING)
         (HPIS ON))
     (THEN (PCS INTEGRITY CHALLENGED)))

 (RULE 2
     (IF (PCS TEMPERATURE INCREASING))
     (THEN (PCS-SCS HEAT TRANSFER INADEQUATE)))

 (RULE 3
     (IF (SG LEVEL DECREASING))
     (THEN (SG INVENTORY INADEQUATE)))

 (RULE 4
     (IF (HIGH CONTAINMENT RADIATION)
         (HIGH CONTAINMENT PRESSURE))
     (THEN (CONTAINMENT INTEGRITY CHALLENGED)))

 (RULE 5
     (IF (PCS-SCS HEAT TRANSFER INADEQUATE)
         (LOW FEEDWATER FLOW))
     (THEN (ACCIDENT IS LOSS OF FEEDWATER)))

 (RULE 6
     (IF (SG INVENTORY INADEQUATE)
         (LOW FEEDWATER FLOW))
     (THEN (ACCIDENT IS LOSS OF FEEDWATER)))

 (RULE 7
     (IF (PCS INTEGRITY CHALLENGED)
         (CONTAINMENT INTEGRITY CHALLENGED))
     (THEN (ACCIDENT IS LOCA)))

 (RULE 8
     (IF (PCS INTEGRITY CHALLENGED)
        (SG LEVEL INCREASING))
     (THEN (ACCIDENT IS STEAM GENERATOR TUBE
     RUPTURE)))

 (RULE 9
     (IF (SG INVENTORY INADEQUATE)
         (HIGH STEAM FLOW))
     THEN (ACCIDENT IS STEAM LINE BREAK))))
```

Reasoning

- Nuclear reactors are supposed to work only in a select few ways under strict parameters so as to avoid a catastrophe and have a fixed set of protocols to prevent any malfunction.
- Hence, REACTOR is more suited to follow a rule based reasoning.



Explanation Subsystem

- Operator is explained which rules are being applied at time of diagnosis.
- The knowledge base contains the required protocols as well as the prioritization of protocols to be implemented according to the danger level identified after diagnosis.

```
    (IS THIS TRUE?  PCS TEMPERATURE INCREASINC)

?NO

    (IS THIS TRUE?  SG LEVEL DECREASING)

?NO

    (IS THIS TRUE?  PCS PRESSURE DECREASING)

?YES

    (IS THIS TRUE?  HPIS ON)

?YES

    (RULE 1 DEDUCES PCS INTEGRITY CHALLENGED)
    (IS THIS TRUE?  HIGH CONTAINMENT RADIATION)

?NO

    (IS THIS TRUE?  SG LEVEL INCREASING)

?YES

    (RULE 8 DEDUCES ACCIDENT IS STEAM GENERATOR
    TUBE RUPTURE)
    (ACCIDENT IS STEAM GENERATOR TUBE RUPTURE)
```

Applications

- The application of REACTOR is pretty straightforward and yet quite complex.
- Nuclear reactors can cause a catastrophe in case of an accident. Hence REACTOR is an expert system specially designed to carry out sensitive tests and carry out necessary procedures for the safe functioning of nuclear reactors.

Characteristic of Expert System

- The expert systems are efficient, accurate and solve complex problems like any other human expert.
- Provided that ES are well equipped with the knowledge to make decisions, they are highly reliable and error-free.
- The knowledge base editor keeps the ES Flexible and open to adopting new knowledge.
- The ES have the ability to handle complex and challenging decision-making problems.
- Performance of the expert systems is characterized by quantity and quality of the knowledge integrated in the ES program.

Applications of expert systems

- Helping investors with Financial investments and risks' management
- Helping doctors for medical diagnosis, especially in remote medicine facilities
- Exploration of oil fields in oil industry.
- Maintenance and repairs of equipment in manufacturing industry.
- Management of complex production processes.
- Help desk management
- Malicious software detection
- Anomaly detection
- Cargo and airline scheduling
- Stock market analysis
- Profile analysis for loan approvals etc

Advantages of Expert System

- Schooling and educating human workforce for an expert's position is quite an expensive affair.
- The human experts may change job, may retire or may get tired with age. On the contrary, a computerised system is comparatively easy to build, can take input from multiple human experts, can be relocated, modified, copied at many places, can be put to work for extensive hours.
- The ES software has high availability and will not need vacation or fall ill etc.
- Accumulated knowledge of multiple human experts may help in improvement of decision quality
- The consultation from human experts is also a costly affair; their availability is another issue altogether. Investment into a good ES might be just one time cost than paying per session fees.

Advantages of Expert Systems

- If implemented properly, ES is quite Fast and accurate and has less chances of human errors
- ES are free from human virtues such as emotions, tensions, anxiety and fatigue.
- ES holds tremendous amount of information and doesn't forget to consider even tiniest bit of information while suggesting output(s), provided they have all the knowledge needed to make decisions.
- Human experts aren't immortal, but expert systems last longer, they can be modified as the knowledge and technology changes.
- Human experts sometimes act unpredictably to human nature, comparatively, expert systems are quite consistent.

Limitations of the expert system

- ES typically cannot give a reasonably accurate and reliable response in an unforeseen situation
- The knowledge is very vast and voluminous. Missing facts and rules in KB, uncertainty can make the ES give incorrect suggestions/decisions.
- Building and maintenance cost of an expert system is very expensive
- An expert system can combine knowledge of multiple human experts and give decisions accordingly, but it cannot be creative in similar situations. Rather, it would give almost same answer every time in those similar situations.
- A human expert can logically give decisions in other domains, but an ES will work only for specific domain and will fail tragically when faced with problem that is out of the scope of the chosen field.
- The ES cannot be flexible and adopt new learnings unless its programmed to do so.
- The initial setup cost and time taken by ES is expensive than using a human expert.

Differences between Neural Networks and Expert Systems

- Both expert systems and neural networks help users in decision making process. But the difference lies in their processes.
- An expert system gets the input through user interface. The inference engine then combines domain-specific and case-specific knowledge with the algorithmic processes contained in itself. The result is thus computed by inference engine and given to user through user interface to view.
- Neural networks use layers of neurons and non-linear in structure. They use previous patterns, samples, and inputs and outputs to make decisions.
- Example- a crime related expert system will analyse crime to give suspect, culprits and motives while neural network evaluation will be to figure out crime patterns and growth etc.

Summary

- Expert systems are type of AI programs
- Expert systems combine knowledge of multiple human experts and help the user in decision making.
- Expert systems are highly knowledge-based systems.
- User interface, knowledge base, inference engine, explanation subsystem and knowledgebase editor are main components of any expert systems.
- Inference engine is brain of expert systems and has algorithms from various algorithmic strategy families to give output to the user.
- Explanation subsystems is a unique feature of ES.

Summary contd..

- Expert systems have applications in various areas in real life.
- The expert systems are efficient, accurate, highly reliable, error-free, Flexible and open to adopting new knowledge
- One can compare the human expert and expert systems for their performance to see ES are better than having just one human expert.
- Neural networks and expert systems both help in decision making, but their working styles and outputs expected are different.
- Though it comes with many positive points, the expert systems cannot handle unforeseen events properly. It simply cannot think out of the box.

Questions?