STIN2103
Knowledge engineering & expert systems

Wan Hussain Wan Ishak

SOC 2079  Ext.: 4786  Email: hussain@uum.edu.my  Url: http://www.wanhussain.com
Knowledge Representation

- Types of knowledge
- Knowledge representation techniques
- Rule-based ES
Knowledge Acquisition & Analysis

- Problem Assessment
- Design & Implementation
- Testing
- Documentation
- Maintenance

exploration

reformulation

modification
Involve the following tasks:

- **Task 1:** Select knowledge representation technique
- **Task 2:** Select control technique
- **Task 3:** Select ES development software
- **Task 4:** Develop the prototype
- **Task 5:** Develop the interface
- **Task 6:** Develop the product
What is knowledge?

What?  How?  Why?

When?
What is knowledge?

"Intelligent requires knowledge"

Intelligence refers to the capacity to acquire and apply knowledge.
What is knowledge?

**Definition:** Understanding gained through experience; familiarity with the way to do something to perform a task; an accumulation of facts, procedural rules or heuristics.
Knowledge engineering & expert systems

Knowledge

Facts

Procedural Rules

Heuristic

KNOWLEDGE
Knowledge

- Facts
- Heuristic
- Procedural Rules
Types of knowledge

- Declarative (what it is)
- Procedural (how to do)
- Meta Knowledge (about other)
- Structural (mental model)
- Heuristic (shortcut)
## Types of knowledge

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<tr>
<th>Types of knowledge</th>
<th>Rules</th>
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<td>Strategies</td>
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<td>Procedures</td>
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<td>Declarative knowledge</td>
<td>Concepts</td>
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<td>Objects</td>
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<td></td>
<td>Facts</td>
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<tr>
<td>Meta-knowledge</td>
<td>Knowledge about the other types of knowledge and how to use them</td>
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<tr>
<td>Heuristic knowledge</td>
<td>Rules of thumb</td>
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<td>Structural knowledge</td>
<td>Rule sets</td>
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<tr>
<td></td>
<td>Concepts relationships</td>
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<tr>
<td></td>
<td>Concept to object relationships</td>
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</tbody>
</table>
Types of knowledge

Example:

- **Procedural knowledge**
  - to boil an egg we must do... then...

- **Declarative knowledge**
  - my room no. is 2079

- **Meta-knowledge**
  - if you want to know about heart attack, please read this book

- **Heuristic knowledge**
  - the clouds looks dark and heavy, ... heavy rain might fall...

- **Structural Knowledge**
  - a cat has four legs
This is Siti phone number...

03 8562219

Siti Fatimah Phone No.

Knowledge

Knowledge Hierarchy

Data

Information
Knowledge representation is a science of translating actual knowledge into a format that can be used by the computer.
Knowledge Representation

Knowledge Usage

Knowledge Representation

Knowledge Source
Why needs to represent knowledge?...

“You are given a project to develop a system that can diagnose heart attack?”

- How can you get information about heart attack?
- How do you understand the knowledge?
- Which knowledge to get into computer?
Knowledge Representation

Object

Knowledge Representation Methods

Logic

Rule
Object-Attribute-Value (O-A-V)
Object-Attribute-Value (O-A-V)

- Describe Doraemon
Semantic Network

- **Definition**: “method of knowledge representation using a graph made up of nodes and arcs”
- Graphical view of problem’s important objects, properties and relationships.
- Nodes represent objects & arcs represent the relationship.
- Arrows are commonly labeled with terms “IS-A” or “HAS”
- **Exceptional handling**: some exceptions for certain cases. “All birds can fly and ostrich is bird → can ostrich fly?”
Knowledge Representation

Semantic Network

- Parrot
- Bird
- Ostrich
- Walk
- Animal
- Air
- Wings
- Fly

- is-a
- has
- travel
- breathe

Parrot is-a Bird
Bird has Wings
Bird can travel
Ostrich travels
Fly travels
Animal can breathe
Frame

Definition :: “a data structure for representing stereotypical knowledge of some concept or object”
Frame

Frame Name: BIRD
Properties:
- Color = <unknown>
- Wings = 2
- Flies = True

Frame Name: OSTRICH
Class Name: BIRD
Properties:
- Color = brown/dark
- Wings = 2
- Flies = False

Two elements of frame:
- Frame Name: BIRD
- Frame Name: OSTRICH

Slot:
- Is the characteristic that describe an object
- Exp: color, food, no. of wings, ...

Facet:
- Value for slot
- Exp: yellow, 1, worm, ...
**Definition**: Rules → “a knowledge structure that relates some known information to other information and that can be concluded or inferred to be known”
Rule

Statement “IF” \(\rightarrow\) antecedent and “THEN” \(\rightarrow\) consequent

IF <antecedent> THEN <consequent>

IF thirsty THEN drink_a_water
Logic

- Often referred to propositional logic and predicate calculus.
Logic

- Propositional logic

  “The ball color is blue” → ball_color_blue

- Predicate calculus.

  “She likes chocolate” → likes (she, chocolate).
Selecting Knowledge Representation

Should choose a knowledge representation technique that best matches the way the expert mentally models the problem’s knowledge.

For practical reasons, you will have to consider the organization’s resources and capabilities.
Selecting Knowledge Representation

Rule-based

- Suitable if the expert discusses the problem primarily using IF/THEN type statements.

Frame-based

- Appropriate if the experts describes the problem by referencing important objects and their relationships.
- When the expert considers several similar objects when solving the problems.
Production system

Is the basis of today’s rule-based system.

Definition: *Production*

“Term used in cognitive psychology to describe the relationship between situations and actions, and more commonly referred to today as a rule.”

<table>
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<tr>
<th>ANTECEDENT</th>
<th>CONSEQUENT</th>
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<tbody>
<tr>
<td>Situation</td>
<td>Action</td>
</tr>
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</table>

Or

IF Situation THEN Action
Production system

When solving some problem humans use a set of productions from their long-term memory that apply to a given situation that is stored in their short-term memory. The situation causes some production to fire resulting in its action being added to their short-term memory. This process is similar to human reasoning: inferring new information from known information. With this additional information added to the short-term memory, the situation changes which could cause other productions to fire. This human problem solving model of evoking productions from long-term memory and changing the content of the short-term memory became known as the production system.
Production system model

- Long-term Memory (Productions)
- Reasoning
- Actions
- Short-term Memory (Situations)
- Situations

Production System Model
Definition - *Production System*

“A model of human problem solving where problem situations contained in the short-term memory are combined with productions in the long-term memory to infer new information which is added to the short-term memory.”
Definition - Rule-Based Expert System

“A computer program that processes problem-specific information contained in the working memory with set of rules contained in the knowledge base, using an inference engine to infer new information.”
Rule-Based ES

Modules in rule-based ES:

- Knowledge Base
  - Models a human’s long-term memory as a set of rules.

- Working Memory
  - Models a human’s short-term memory and contains problem facts both entered and inferred by the firing of the rules.

- Inference Engine
  - Models human reasoning by combining problem facts contained in the working memory with rules contained in the knowledge base to infer new information.
Rule-Based ES

Rule-based model

Knowledge Base (Rules) → Inference Engine → Conclusions → Working Memory (Facts) → Facts
Rule contained in the knowledge base represent the productions contained in the long-term memory and the facts contained in the working memory represent the situations in the short-term memory.

The inference engine acts as the reasoning module and compares the facts with the antecedents or premises of the rules to see which ones can fire.

Not necessarily an exact match for human problem solving, but provide a reasonable model for replicating the behavior with a computer.
Additional subsystems:

- **User interface** – the medium which the user views and interacts with the system.

- **Developer interface** – the medium which the knowledge engineer develops the system.

- **Explanation facility** – the subsystem for providing explanations on the reasoning of the system.

- **External programs** – that support the system such as database, spreadsheets, etc.
Rule-based system architecture

- Inference Engine
  - Working Memory
  - Explanations Facility
  - Knowledge Base
  - External Programs
  - User Interface
  - Developer Interface
  - User
  - Knowledge Engineer
Advantages of rule-based ES

- **Natural Expression** – human naturally express their solving knowledge in IF…THEN type statements.

- **Separation of Control from Knowledge** – separates the knowledge contained in the knowledge base from its control by inference engine – a trademark of all ES.

- **Modularity of knowledge** – easily review and verify its correctness.

- **Ease of expansion** – can expend and add new rules.

- **Proportional Growth of Intelligence** – as the number of rules increase, the system’s level of intelligence about the problem likewise increases.
Advantages of rule-based ES

- Use of Relevant Knowledge – system will use only the rules that are relevant to the problem.

- Derivation of Explanations from Rigid Syntax – explain the user how it reaches the conclusion.

- Consistency Checking – to assure that the same situations do not lead to different actions.

Exp:

IF hungry THEN eat…
IF hungry THEN drink…

- Utilization of Heuristic Knowledge – use heuristic knowledge in rules.
Advantages of rule-based ES

- Utilization of Uncertain Knowledge – rules can be easily written that capture this uncertain relationship.
  
  Exp:
  
  IF it is raining
  THEN class cancel CF 99

- Can Incorporate Variables – variables can be bound to a number of instances in the working memory and tested by the rule.
  
  Exp:
  
  IF ?Get high marks
  THEN ?Student excellent
Disadvantages of rule-based ES

- Require Exact Matching – antecedents in rules must match with facts in working memory.
- Have Opaque Rule Relationships – difficult to determine how rules are logically related through an inference chain.

Exp:

- IF C THEN D
- IF B THEN C
- IF A THEN B
Disadvantages of rule-based ES

- Can be Slow – systems with a large set of rules can be slow.

- Are Inappropriate for Some Problems – shortcoming of the rule-based system occurs when rules do not efficiently or naturally capture the representation of the domain’s knowledge.