Unit 3

Knowledge Representation and Reasoning

(10 Hours)

3.1 Definition and importance of Knowledge, Issues in Knowledge Representation

3.2. Knowledge Representation Systems: Semantic Nets, Frames, Conceptual Dependencies, Scripts, Rule Based Systems(Production System), Propositional Logic, Predicate Logic

3.3.Propositional Logic(PL): Syntax, Semantics, Formal logicconnectives, truth tables, tautology, validity, well-formedformula, Inference using Resolution,

3.4 Backward Chaining and Forward Chaining

3.5 Predicate Logic: FOPL, Syntax, Semantics, Quantification, Inference with FOPL, Inference using resolution

3.6 Bayes' Rule and its use, Bayesian Networks

3.7 Fuzzy Logic

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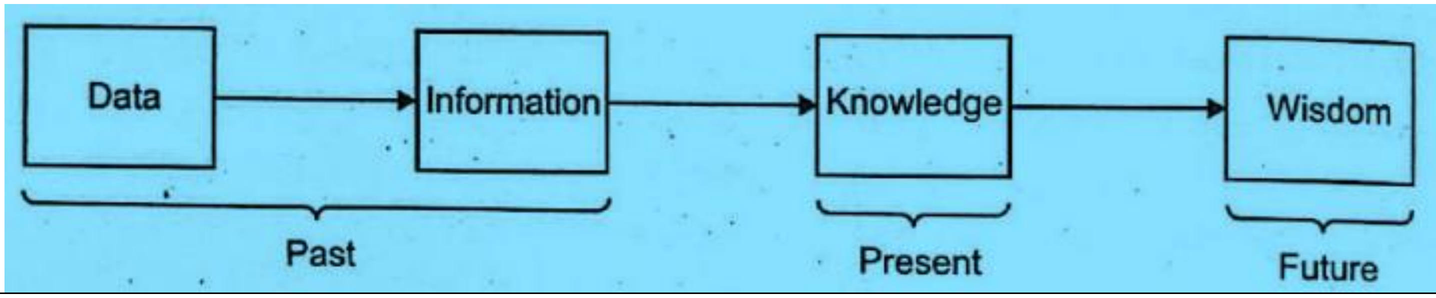
4.0 Introduction

Knowledge is a progression that starts with data which is of limited utility. Data when processed becomes information, information when interpreted or evaluated becomes knowledge and understanding, of the principles embodied with the knowledge is wisdom.



Data → Information → Knowledge → Wisdom (DIKW Model)

Imagine a health monitoring system used in a smart hospital.

🧩 **Step 1 — Data (Past)**
Raw, unprocessed facts with *no meaning* by themselves.

Example (Data):

- Temperature readings: **101.4°F, 99.8°F, 102.1°F**
- Heart rate values: **112 bpm, 108 bpm, 118 bpm**
- Oxygen level readings: **94%, 92%, 95%**

These are **just numbers** collected by sensors.

➡️ They do *not* tell us what is happening.

🧩 **Step 2 — Information (Past)**
Data processed to give **context and meaning**.

Example (Information):

- "Patient's temperature is **consistently above 101°F**."
- "Heart rate is **higher than normal**."
- "Oxygen level is **slightly low**."

Now the system interprets data → useful patterns.

➡️ Still no decision, but the system *understands what the data represents*.

🧩 **Step 3 — Knowledge (Present)**
Using **rules, models, and experience** to interpret information.

Example (Knowledge):
The AI system applies medical rules:

- IF fever > 101°F AND heart rate > 110 THEN → fever with tachycardia
- IF oxygen < 94% THEN → possible respiratory problem
- IF fever + cough + low oxygen THEN → **suspected pneumonia**

Here AI combines information + stored rules.

➡️ AI "knows" how symptoms relate to illnesses.

🧩 **Step 4 — Wisdom (Future)**
Ability to make **sound decisions or recommendations**.

Example (Wisdom):
Based on knowledge, AI suggests:

- "Patient may require a chest X-ray."
- "Start oxygen support immediately."
- "Alert the doctor with high priority."
- "Predict 24-hour risk of deterioration: HIGH."

☆ **In Contrast to AI**

The DIKW model naturally fits with **how AI systems operate**:

DIKW Level	**AI Perspective**
Data	Raw sensor input (temperature, images, GPS points)
Information	Feature extraction, preprocessing (e.g., detect fever, analyze pixels)
Knowledge	Inference rules, trained models, patterns learned
Wisdom	AI decision-making, predictions, recommendations

AI transforms data → wisdom using:

- Logic

Wisdom = **Choosing the best action** based on knowledge.
➡ This is closest to intelligent decision-making.

- Rules
- Machine learning
- Neural networks
- Inference engines

☆ 📌 Example 2: Smart Agriculture Monitoring System (Farmer's AI Tool)

System: AI system monitoring crops in Rupandehi or Chitwan.

1 Data (Past)

Collected by sensors and drones:

- Soil moisture readings
- Temperature values
- Leaf color pixels from images
- Rainfall logs

These are *raw, unprocessed*.

2 Information (Past)

Processed:

- Moisture is **below safe level**
- Crop leaf color = **yellow patches**
- Temperature = **higher than normal**
- Rainfall = **insufficient**

The system now understands crop conditions.

3 Knowledge (Present)

AI applies agriculture rules and ML models:

- "Low moisture + high temperature = risk of dehydration."
- "Yellow patches = early nitrogen deficiency."
- "Low rainfall = irrigation needed."

AI forms meaningful **agricultural knowledge**.

4 Wisdom (Future)

System gives **actionable advice**:

- "Irrigate the field within 4 hours."
- "Add nitrogen-rich fertilizer tomorrow morning."
- "Schedule shade nets during peak heat."
- "Predict yield loss: 15% if untreated."

This is **wisdom**—the ability to decide **what to do next**.

⭐ Short Summary for Both Examples

DIKW Stage	**Traffic System**	**Agriculture System**
Data	camera counts, GPS logs	soil moisture, leaf pixels
Information	jam detected, slow speed	crop stress found
Knowledge	causes jam, predicts patterns	nutrient deficiency rules
Wisdom	change signals, reroute traffic	irrigate, fertilize, protect crop

✅ What is Knowledge Representation (KR)?

Knowledge Representation is a field of Artificial Intelligence concerned with:

- **How knowledge about the world is structured**
- **How it is stored in a format that computers can use**
- **How it can be used for reasoning and decision making**

In simple terms:

"KR is the way an intelligent system understands, organizes, and uses knowledge to solve problems."

A KR system should allow a machine to behave **intelligently**, similar to a human who uses facts, rules, and experience to make decisions.

✅ Why Knowledge Representation is Needed?

Computers do not understand the real world naturally.
AI systems must convert **real-world information → machine-understandable structures**.

Knowledge Representation helps AI systems to:

- Understand problems
- Reason logically
- Draw conclusions
- Take actions
- Learn from previous knowledge

⭐ Key Goals of KR

1. **Represent the real world**
   – Objects, people, events, locations, properties, relationships
2. **Enable intelligent reasoning**
   – Derive new facts from known facts
3. **Support problem solving**
   – Diagnostics, planning, decision making
4. **Efficient storage & retrieval**
   – Organized knowledge for fast reasoning
5. **Provide a basis for communication**
   – Between AI systems and humans

⭐ Types of Knowledge Represented in KR

1️⃣ Declarative Knowledge

"Knowing *what*."
Facts about the world.

Example:

- Kathmandu is the capital of Nepal.
- A triangle has 3 sides.

2 Procedural Knowledge

"Knowing *how*."
How to perform tasks or procedures.

Example:

- How to solve a 2×2 Rubik's cube
- Steps to diagnose a patient

3 Meta-Knowledge

Knowledge about knowledge.

Example:

- "If symptoms are unclear, order additional tests."

4 Heuristic Knowledge

Experience-based rules used for quicker decisions.

Example:

- "If a laptop overheats frequently, check the fan."

⭐ Three Main Components in KR

1. Facts

Truths about the world.
Example:
"Patient John has fever."

2. Instances

Specific objects or examples.
Example:
John, **Laptop-01**, **Room-215**

3. Classes (Concepts)

Groups of similar objects.
Example:

- **Human**

- **Disease**
- **Electronic device**

⭐ Suitable Real-World Example (Hospital KR Example)

Suppose we represent knowledge for a **hospital diagnosis system**.

Facts:

- Patient(Ashok) has Fever
- Patient(Ashok) has Cough
- Temperature(Ashok) = 102°F

Rules:

IF Fever AND Cough → Possible Influenza
IF Temperature > 101°F → High Fever

Instance:

- Ashok is an instance of the class *Patient*.

Class hierarchy:

- Patient → Human
- Influenza → Viral Disease
- Disease → Medical Condition

Reasoning:

From the rules, the system can infer:

> **"Ashok may have influenza."**

This is the purpose of KR:
Represent → Reason → Conclude.

⭐ Relationship Between KR and Reasoning

Knowledge Representation is incomplete without **reasoning mechanisms**.

Reasoning allows AI to:

- Deduce new facts
- Check consistency
- Solve problems
- Diagnose conditions
- Make predictions

Example:

If the system knows:

- "All humans are mortal"
- "Sita is human"

It can reason:
→ "Sita is mortal."

⭐ Requirements of Good Knowledge Representation

✔ 1. Expressive

Meaning:
The representation must describe many types of knowledge such as:

- Objects
- Relations
- Events
- Rules
- Time
- Causes

Example:
A medical AI must represent:

- Objects → *Patient, Doctor, Virus, Medicine*
- Relations → *hasSymptom(Patient, Fever)*
- Events → *Diagnosis, Treatment, Recovery*
- Rules → *IF Fever AND Cough → Possible Flu*

This wide expressiveness allows the AI to understand the full medical scenario.

✔ 2. Unambiguous

Meaning:
Knowledge must have **one clear meaning**, not multiple interpretations.

Example:
Instead of vague text like:

- "Patient may have issues."

The AI uses precise logic:

- *Temperature(Patient)=102°F*
- *Symptom(Patient, Cough)=True*

This avoids confusion and ensures **consistent decisions**.

✔ 3. Efficient

Meaning:
Knowledge must be stored in a way that allows **fast reasoning**.

Example:
Instead of searching entire patient history, AI stores symptoms in indexed form:

- Fever: YES
- Cough: YES
- Oxygen: 93%

This allows fast rule checking:

IF Fever AND Cough AND Oxygen<94 THEN → Pneumonia Risk

Efficient structure → faster diagnosis.

✔ 4. Flexible

Meaning:
Easy to update, modify, or add new facts or rules.

Example:
If a new symptom of a disease is discovered:

Add rule:

IF High Fever AND Headache AND Red Eyes → Suspected Dengue

The system updates instantly **without redesigning everything**.

✓ 5. Structured

Meaning:
Knowledge must be organized meaningfully using:

- Graphs
- Frames
- Hierarchies
- Rules
- Ontologies

Example:
A medical knowledge structure:

```
Disease
 ├── Viral Disease
 │    ├── Flu
 │    ├── Dengue
 │    └── COVID
 └── Bacterial Disease
      ├── TB
      └── Pneumonia
```

This tree helps AI reason systematically.

✓ 6. Supports Inference

Meaning:
AI should derive **new knowledge** from existing knowledge.

Example:
Facts:

- Fever
- Cough
- Low Oxygen

Rule:

- IF Fever AND Cough AND Low Oxygen → Pneumonia

Inference:
The AI concludes:
➡️ *Patient is likely suffering from Pneumonia.*

⭐ **Quick Summary Table**

Feature	Meaning	Example in Medical AI
Expressive	Wide knowledge types	Symptoms, diseases, events
Unambiguous	Clear meaning	Exact symptom values
Efficient	Fast reasoning	Indexed symptom lookup
Flexible	Easy updates	Adding new disease rules
Structured	Organized form	Disease hierarchy tree
Supports Inference	Derives new facts	Diagnose pneumonia

4.1 Propositional Logic and Its Resolution

4.2 Predicate Logic and Its Resolution

4.3 Unification Algorithm

4.4 Forward Chaining, Backward Chaining and Conflict Resolution