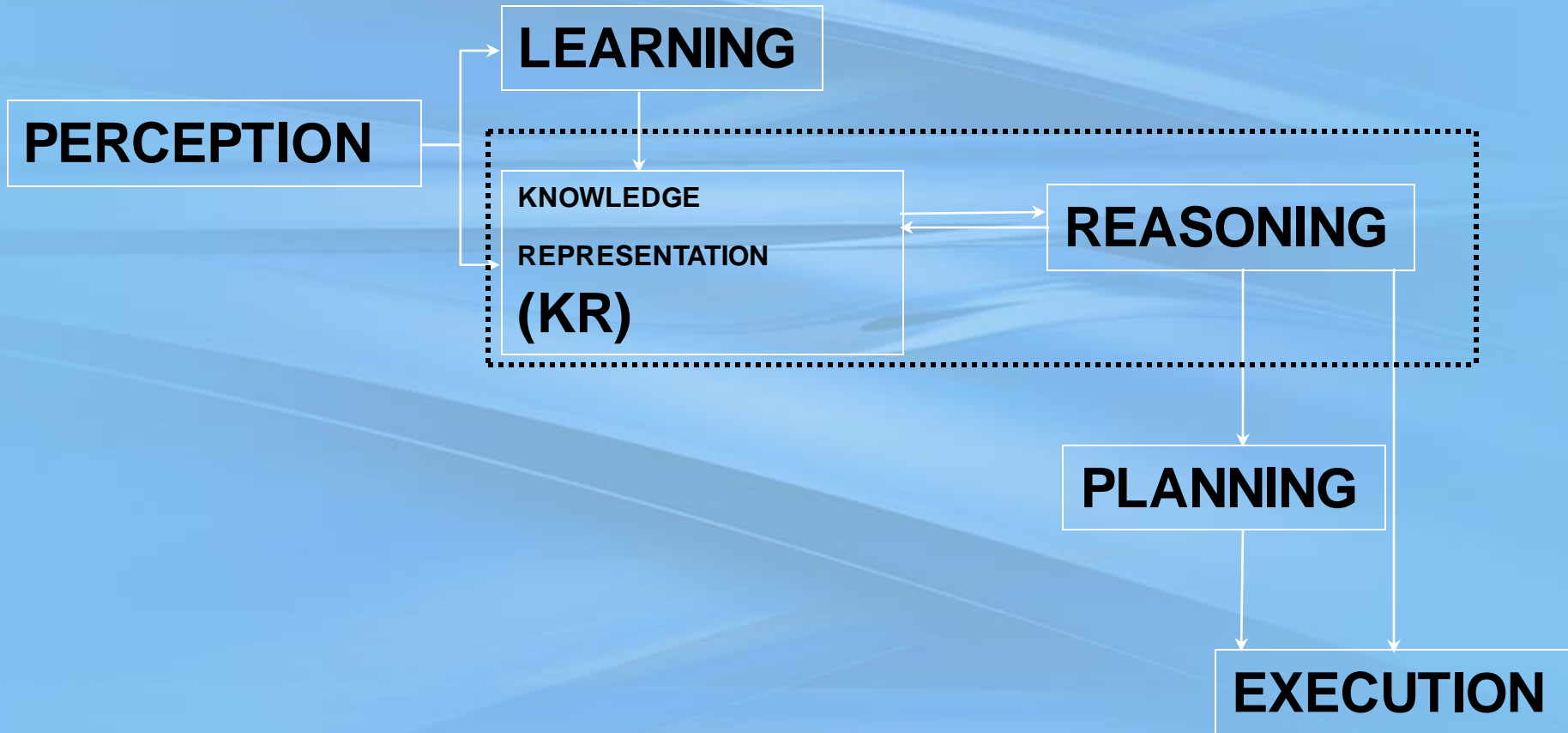


# Lecture Contents

- Types of Knowledge: procedural, declarative, meta, heuristic, structural
- Knowledge Representation Techniques
  - Facts
  - Object-attribute Value Triplets
  - Semantic Networks
  - Frames
  - Logic:
    - Propositional Calculus
    - Predicate Calculus

# The AI Cycle



# The Dilemma

- We do not know how the KR and reasoning components are implemented in humans, even though we can see their manifestation in the form of intelligent behavior.
- Hence, the need for a synthetic (artificial) way to model the knowledge representation and reasoning capability of humans in computers.

# The Simple Approach

- Instead of focusing on how knowledge is acquired, we will assume for now that knowledge is externally injected into the system.
- For now, we focus on how to **represent** some given knowledge and then how to **reason** about that knowledge for the purpose of inference
- **Knowledge acquisition and learning will be discussed later**

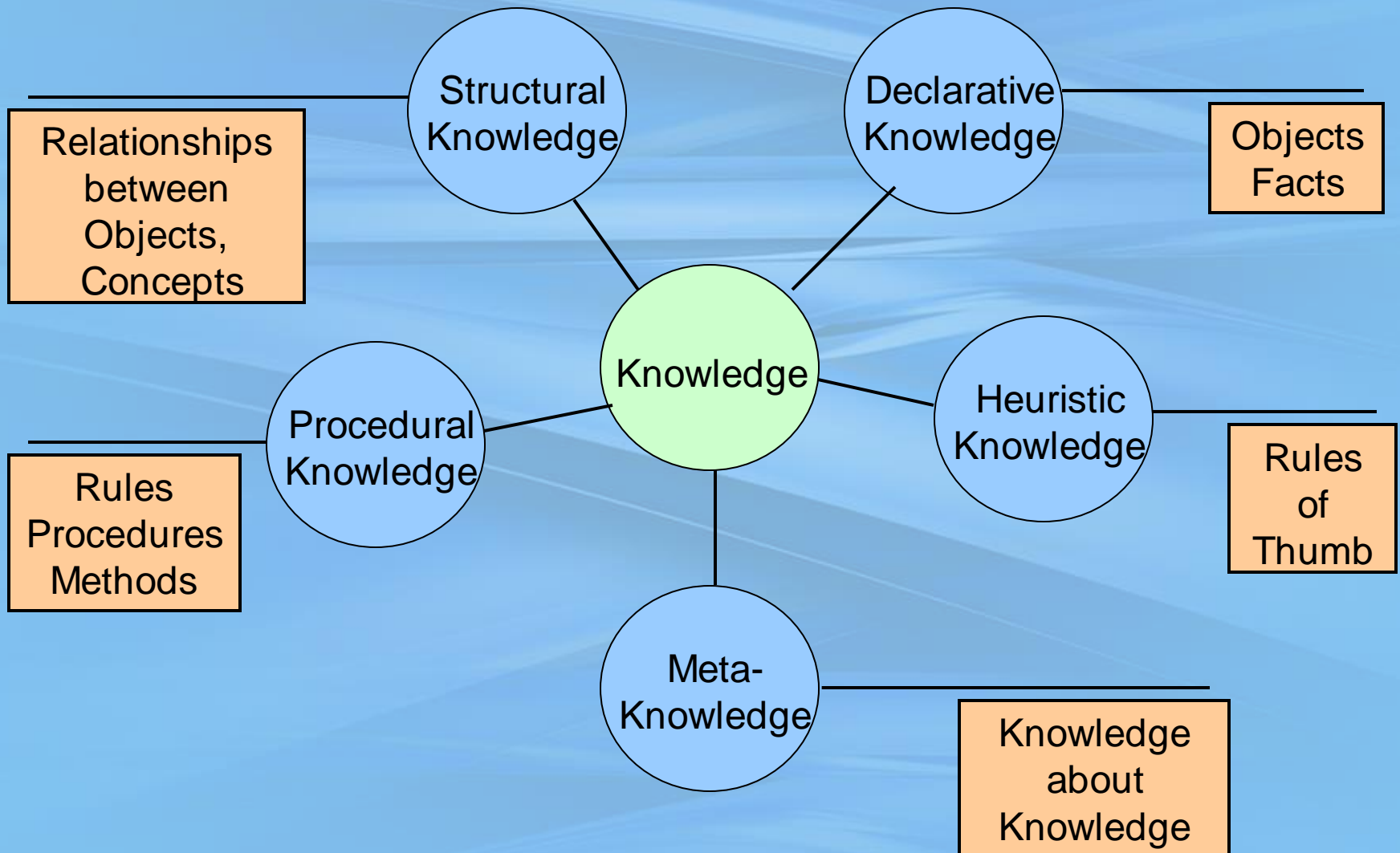
# What is Knowledge

- “Understanding of a subject area”  
Durkin
- Domain: A well-focused subject area

# Types of Knowledge

- **Procedural knowledge:** Describes how to do things, provides a set of directions of how to perform certain tasks, e.g., how to drive a car
- **Declarative knowledge:** It describes objects, rather than processes. What is known about a situation. e.g. it is sunny today, cherries are red
- **Meta knowledge:** Knowledge about knowledge, e.g., the knowledge that blood pressure is more important for diagnosing a medical condition than eye color.
- **Heuristic knowledge:** Rule-of-thumb. e.g. if I start seeing shops, I am close to the market.
  - Sometimes called shallow knowledge.
  - Empirical as opposed to deterministic
- **Structural knowledge:** Describes structures and their relationships. e.g. the how the various parts of the car fit together to make a car, or knowledge structures in terms of concepts, sub concepts, and objects.

# Types of Knowledge



# Towards Representation



- There are multiple approaches that come to mind
  - Pictures and symbols. This is how the earliest humans represented knowledge when sophisticated linguistic systems had not yet evolved
  - Graphs and Networks
  - Numbers

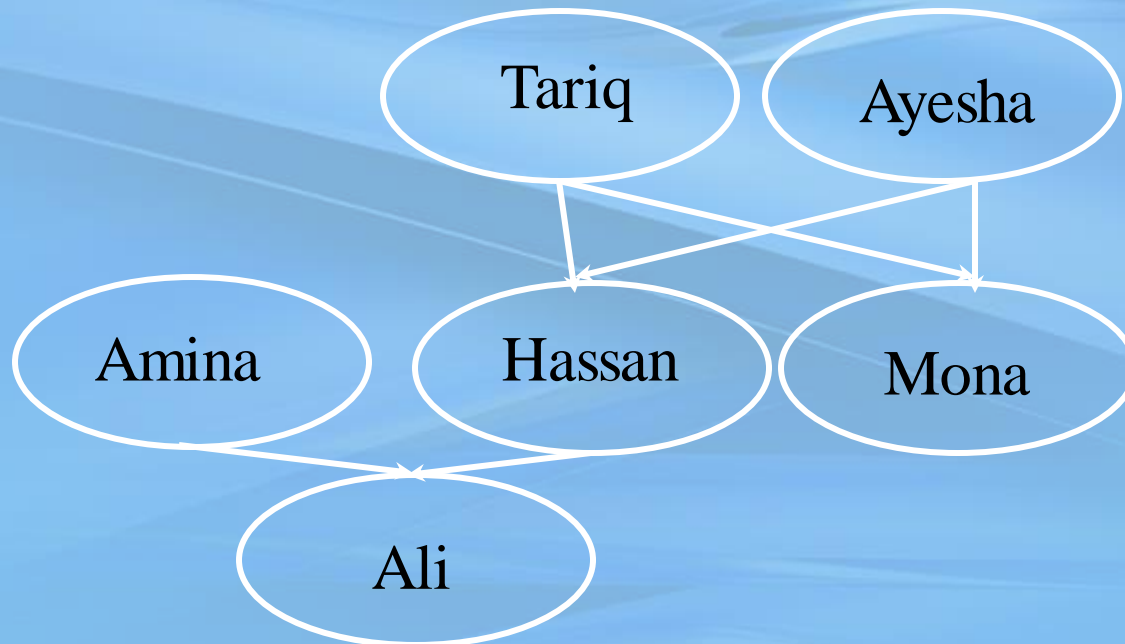


# Representation: Pictures

- What types of knowledge is best represented using pictures? e.g. can we represent the relationship between individuals in a family using a picture?
- To store procedural knowledge, we could use a series of pictures. e.g. how to boil an egg. A **series** of pictures showing the process.
  - Pictures are best suited for recognition tasks
  - Structural information
- How useful is such a representation for a computer?
  - Not very easily translated to useful information because computers cannot interpret pictures automatically.
  - But useful for human understanding because they allow a high level view of a concept to be obtained readily.

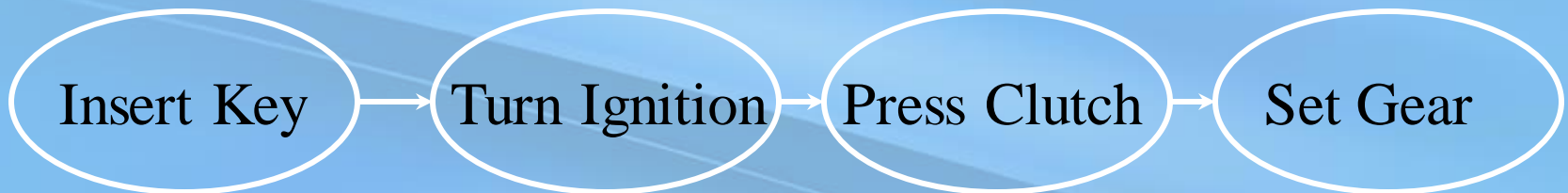
# Representation: Graphs & Networks

- Graphs and Networks allow relationships between entities to be incorporated, e.g., to show family relationships, now we can use a graph.



# Graphs and Networks

- May be used to represent procedural knowledge.
- e.g. How to start a car?

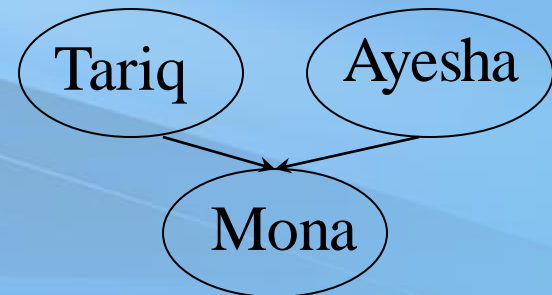


# **Representation: Numbers**

- Numbers are an integral part of the knowledge representation used by humans.
- Translate easily to computer representation.
- Eventually, every representation we use gets translated to numbers in the computers internal representation.

# Knowledge of a Family

- By a picture
- By a graph
- Description in words
  - Tariq is Mona's Father
  - Ayesha is Mona's Mother
  - Mona is Tariq and Ayesha's Daughter



# Formal KR Techniques

- Now, we will discuss some formal methods of knowledge representation in AI.
- Each method is suited to representing a certain type of knowledge.
- Choosing the proper representation is important because it must facilitate reasoning. As the saying goes 'Knowledge is Power'.

# Facts

- Facts are a basic block of knowledge (the atomic units of knowledge)
- They represent declarative knowledge.
- A Proposition is the statement of a fact. Each proposition has an associated truth value. It may be true or false.
- In AI, to represent a fact, we use a proposition and its associated truth value
- e.g.
  - Proposition A: It is raining
  - Proposition B: I have an umbrella
  - Proposition C: I will go to school



# Types of facts

- **single-valued or multiple –valued**: e.g. an individual can only have one eye color, but may have many cars. So the value of attribute cars may contain more than one value.
- **uncertain facts**: e.g. it will **probably** be sunny today. We may chose to store **numerical certainty values** with such facts.
- **fuzzy facts**, which are **ambiguous** in nature. e.g. The book is heavy/light. Fuzzy representation used. Use certainty factor values to specify value of “truth”.



# Object-Attribute-Value Triplets

- A type of fact composed of three parts
- Used to assert a particular property of some object.
- e.g. Ali's eye color is brown.
  - Object: Ali
  - Attribute: eye color
  - Value: brown
- e.g. Ahmed's son is Ali
  - Object: Ahmed
  - Attribute: son
  - Value: Ali



# Rules

- “A Knowledge structure that relates some known information to other information that can be concluded or inferred to be true.”  
(Durkin)
- Represent procedural knowledge
- **Components** of a rule
  - **Antecedent or premise**: IF part
  - **Consequent or conclusion**: THEN part
- e.g. IF it is raining THEN I will not go to school
  - Premise: It is raining
  - Conclusion: I will not go to school.

# Compound Rules

- **Multiple premises may be joined using AND (conjunctions) and OR (disjunctions)**
- e.g.
  - IF it is raining AND I have an umbrella  
THEN I will go to school.
  - IF it is raining OR it is snowing THEN I  
will not go to school

# Types of Rules

- **Relationship**

- e.g. IF you hear a loud sound THEN the silencer is not working

- **Recommendation**

- IF it is raining THEN bring an umbrella

- **Directive**

- IF it is raining AND you don't have an umbrella THEN wait for the rain to stop

# Types of Rules (Cont.)

- **Variable Rules**

- If the same type of rule is to be applied to multiple objects, we use variable rules, i.e. rules with variables

- e.g.

- If X is a Student

- AND X's GPA > 3.7

- THEN place X on honor roll.

- Such rules are called **pattern-matching rules**.
- The rule is matched with known facts and different possibilities for the variables are tested, to determine the truth of the fact.

# Types of Rules (Cont.)

- **Uncertain Rules**

- e.g. IF you have never won a match THEN you will **most probably** not win this time.

- **Meta Rules**

- Rules that describe how to use other rules
- e.g. IF You are coughing AND you have chest congestion THEN use the set of respiratory disease rules.

- **Rule Sets**

- As in the previous example, we may group rules into categories in our knowledge representation, e.g. the set of respiratory disease rules