

# ARTIFICIAL INTELLIGENCE

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## CHAPTER-5

# Representing Knowledge using Rules





# Forward Chaining and backward chaining in AI

In artificial intelligence, forward and backward chaining is one of the important topics, but before understanding forward and backward chaining lets first understand that from where these two terms came.

Inference engine:

The inference engine is the component of the intelligent system in artificial intelligence, which applies logical rules to the knowledge base to infer new information from known facts. The first inference engine was part of the expert system. Inference engine commonly proceeds in two modes, which are:

- Forward chaining
- Backward chaining



# Horn Clause and Definite clause:

Horn clause and definite clause are the forms of sentences, which enables knowledge base to use a more restricted and efficient inference algorithm. Logical inference algorithms use forward and backward chaining approaches, which require KB in the form of the **first-order definite clause**.

**Definite clause:** A clause which is a disjunction of literals with **exactly one positive literal** is known as a definite clause or strict horn clause.

**Horn clause:** A clause which is a disjunction of literals with **at most one positive literal** is known as horn clause. Hence all the definite clauses are horn clauses.

**Example:**  $(\neg p \vee \neg q \vee k)$ . It has only one positive literal  $k$ .

It is equivalent to  $p \wedge q \rightarrow k$





## A. Forward Chaining

Forward chaining is also known as a forward deduction or forward reasoning method when using an inference engine. It applies inference rules (Modus Ponens) in the forward direction to extract more data until a goal is reached.

The Forward-chaining algorithm starts from known facts, triggers all rules whose premises are satisfied, and add their conclusion to the known facts. This process repeats until the problem is solved.

### **Properties of Forward-Chaining:**

- It is a down-up approach, as it moves from bottom to top.
- It is a process of making a conclusion based on known facts or data, by starting from the initial state and reaches the goal state.
- Forward-chaining approach is also called as data-driven as we reach to the goal using available data.
- Forward -chaining approach is commonly used in the expert system, such as CLIPS, business, and production rule systems.





## Example:

"As per the law, it is a crime for an American to sell weapons to hostile nations. Country A, an enemy of America, has some missiles, and all the missiles were sold to it by Robert, who is an American citizen."

Prove that "Robert is criminal."

To solve the above problem, first, we will convert all the above facts into first-order definite clauses, and then we will use a forward-chaining algorithm to reach the goal.

## Facts Conversion into FOL:

- It is a crime for an American to sell weapons to hostile nations. (Let's say  $p$ ,  $q$ , and  $r$  are variables)

$$\text{American}(p) \wedge \text{weapon}(q) \wedge \text{sells}(p, q, r) \wedge \text{hostile}(r) \rightarrow \text{Criminal}(p) \quad \dots(1)$$

Country A has some missiles.  $\exists p \text{ Owns}(A, p) \wedge \text{Missile}(p)$ . It can be written in two definite clauses by using Existential Instantiation, introducing new Constant T1.

$$\text{Owns}(A, T1) \quad \dots(2)$$

$$\text{Missile}(T1) \quad \dots(3)$$







- All of the missiles were sold to country A by Robert.  
**?p Missiles(p)  $\wedge$  Owns (A, p)  $\rightarrow$  Sells (Robert, p, A) .....(4)**
- Missiles are weapons.  
**Missile(p)  $\rightarrow$  Weapons (p) .....(5)**
- Enemy of America is known as hostile.  
**Enemy(p, America)  $\rightarrow$  Hostile(p) .....(6)**
- Country A is an enemy of America.  
**Enemy (A, America) .....(7)**
- Robert is American  
**American(Robert). .....(8)**

## B. Backward Chaining

Backward-chaining is also known as a backward deduction or backward reasoning method when using an inference engine. A backward chaining algorithm is a form of reasoning, which starts with the goal and works backward, chaining through rules to find known facts that support the goal.





### **Properties of backward chaining:**

- It is known as a top-down approach.
- Backward-chaining is based on modus ponens inference rule.
- In backward chaining, the goal is broken into sub-goal or sub-goals to prove the facts true.
- It is called a goal-driven approach, as a list of goals decides which rules are selected and used.
- Backward -chaining algorithm is used in game theory, automated theorem proving tools, inference engines, proof assistants, and various AI applications.
- The backward-chaining method mostly used a depth-first search strategy for proof.
- The reasoning is the mental process of deriving logical conclusion and making predictions from available knowledge, facts, and beliefs. In artificial intelligence, the reasoning is essential so that the machine can also think rationally as a human brain, and can perform like a human.





### Example:

In backward-chaining, we will use the same above example, and will rewrite all the rules.

- $\text{American}(p) \wedge \text{weapon}(q) \wedge \text{sells}(p, q, r) \wedge \text{hostile}(r) \rightarrow \text{Criminal}(p) \dots(1)$
- $\text{Owns}(A, T1) \dots\dots\dots(2)$
- $\text{Missile}(T1)$
- $p \text{ Missiles}(p) \wedge \text{Owns}(A, p) \rightarrow \text{Sells}(\text{Robert}, p, A) \dots\dots(4)$
- $\text{Missile}(p) \rightarrow \text{Weapons}(p) \dots\dots\dots(5)$
- $\text{Enemy}(p, \text{America}) \rightarrow \text{Hostile}(p) \dots\dots\dots(6)$
- $\text{Enemy}(A, \text{America}) \dots\dots\dots(7)$
- $\text{American}(\text{Robert}). \dots\dots\dots(8)$

It is the activity of gaining knowledge or skill by studying, practising, being taught, or experiencing something. Learning enhances the awareness of the subjects of the study.



## Backward-Chaining proof:

In Backward chaining, we will start with our goal predicate, which is **Criminal(Robert)**, and then infer further rules.

### Step-1:

At the first step, we will take the goal fact. And from the goal fact, we will infer other facts, and at last, we will prove those facts true. So our goal fact is "Robert is Criminal," so following is the predicate of it.

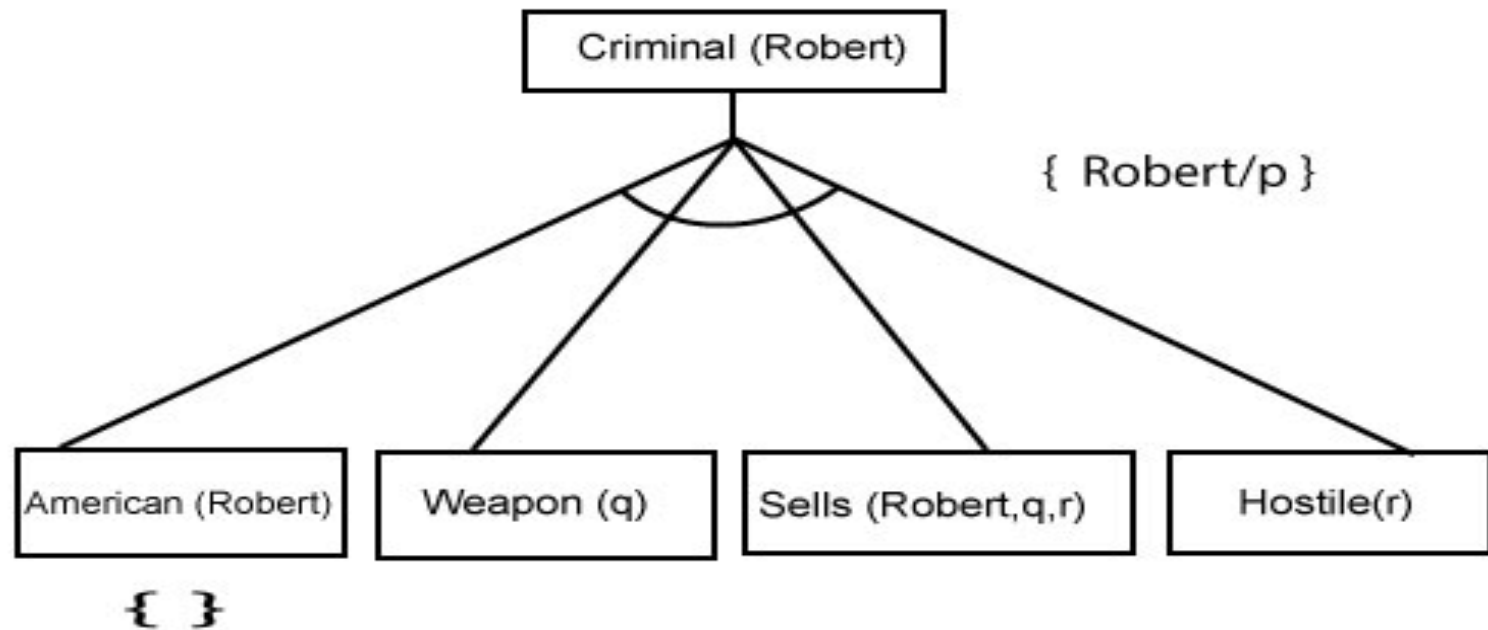
Criminal (Robert)

### Step-2:

At the second step, we will infer other facts from goal fact which satisfies the rules. So as we can see in Rule-1, the goal predicate Criminal (Robert) is present with substitution {Robert/P}. So we will add all the conjunctive facts below the first level and will replace p with Robert.

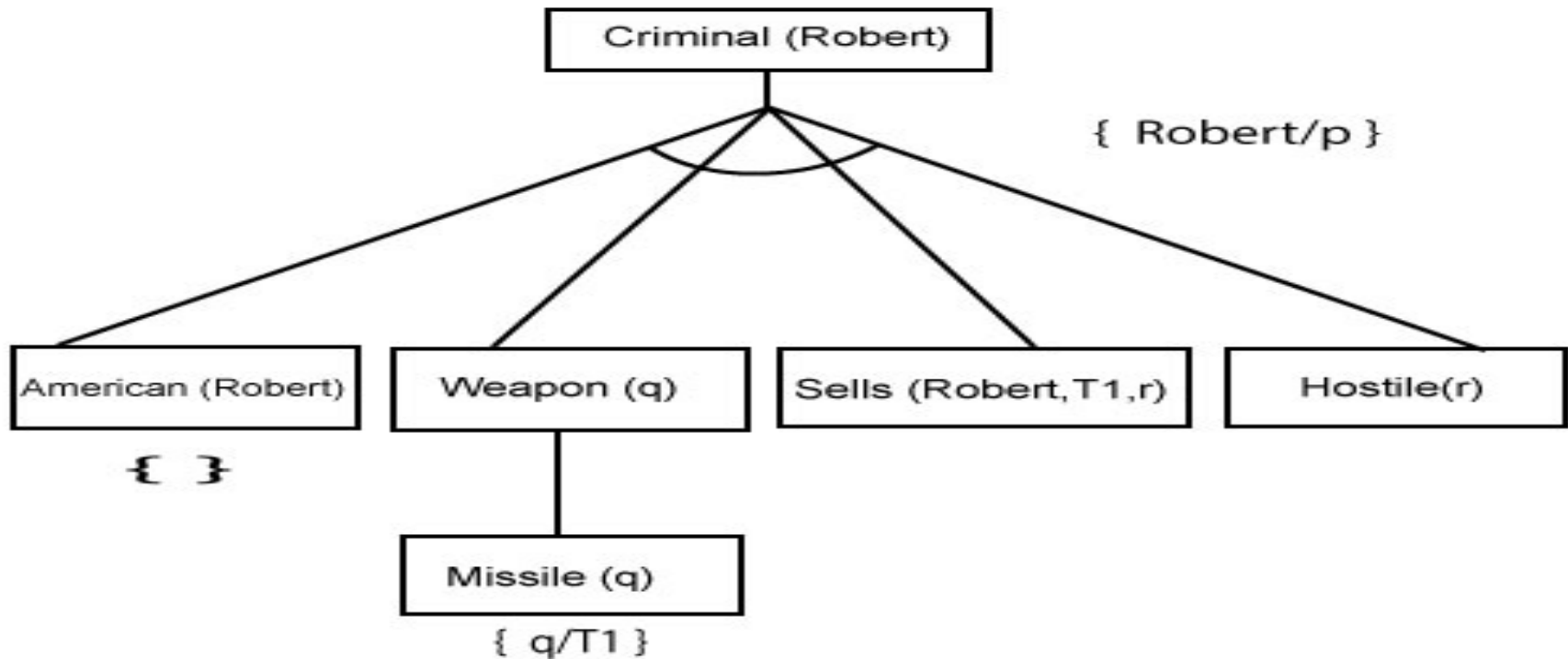
**Here we can see American (Robert) is a fact, so it is proved here.**





**Step-3:** At step-3, we will extract further fact Missile(q) which infer from Weapon(q), as it satisfies Rule-(5). Weapon (q) is also true with the substitution of a constant T1 at q.

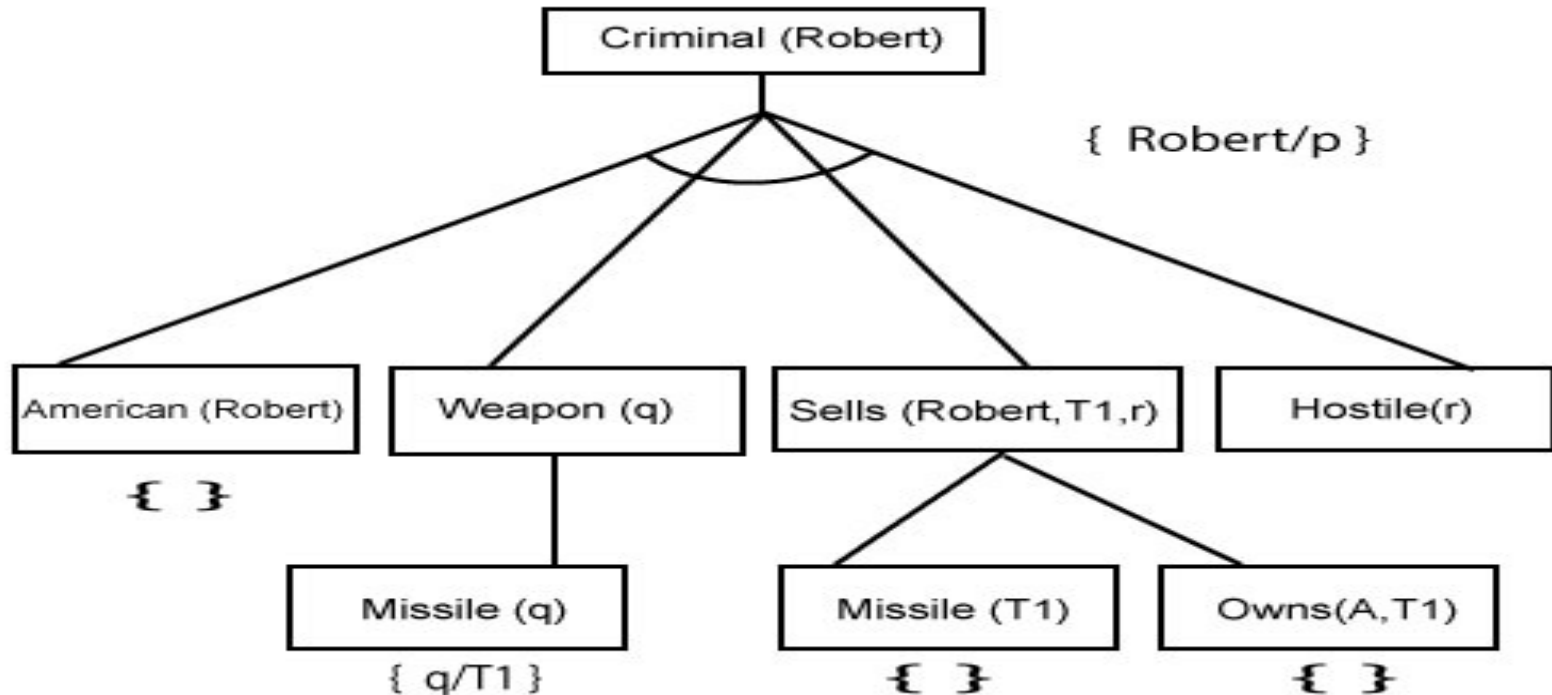




#### Step-4:

At step-4, we can infer facts Missile(T1) and Owns(A, T1) from Sells(Robert, T1, r) which satisfies the **Rule- 4**, with the substitution of A in place of r. So these two statements are proved here.

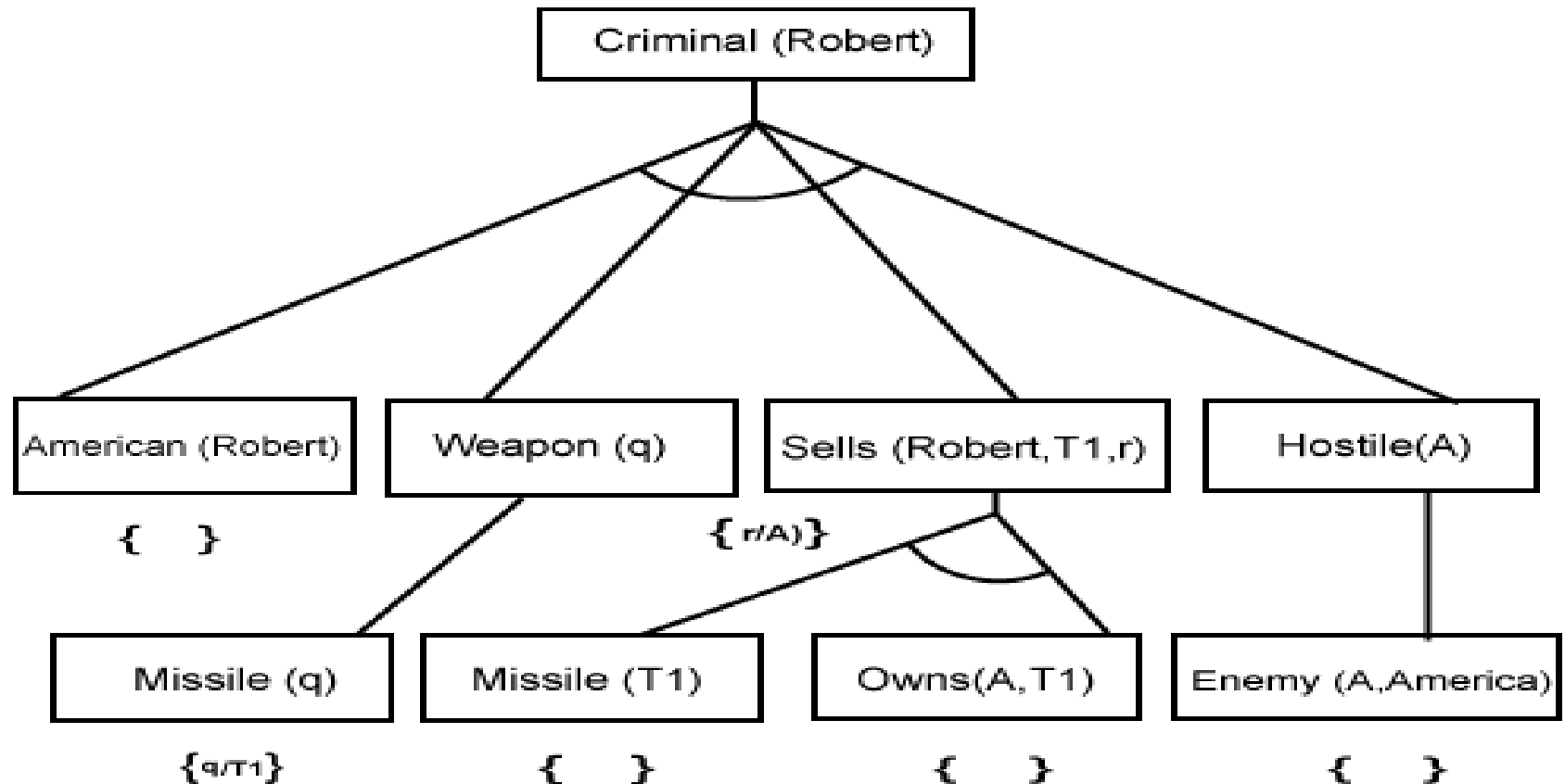




### Step-5:

At step-5, we can infer the fact **Enemy(A, America)** from **Hostile(A)** which satisfies Rule- 6. And hence all the statements are proved true using backward chaining.





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