Chap 9- Inference in FOL and Reasoning

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Reasoning

- After knowledge representation, Lets look at mechanisms to reasoning.
- Reasoning is the process of <u>deriving logical conclusions from given facts.</u>
- Durkin defines reasoning as ‘the process of working with knowledge, facts and problem solving strategies to draw conclusions’.

Types of Reasoning : Deductive

- Deductive reasoning : is based on deducing new information from logically related known information.
- A deductive argument offers assertions that lead automatically to a conclusion.
- If there is dry wood, oxygen and a spark, there will be a fire.
- Given: There is dry wood, oxygen and a spark
  We can deduce:
  - There will be a fire.

Types of Reasoning : Inductive

- Inductive reasoning is based on forming, or inducing a 'generalization' from a limited set of observations.
- Observation: All the crows that I have seen in my life are black.
- Conclusion: All crows are black
- Thus the essential difference is that inductive reasoning is based on experience while deductive reasoning is based on rules, hence the latter will always be correct.

Types of Reasoning : Abductive

- Abductive reasoning : Deduction is exact in the sense that deductions follow in a logically provable way from the axioms.
- Abduction is a form of deduction that allows for probable inference, i.e. the conclusion might be wrong,
- <u>Implication</u>: She carries an umbrella if it is raining
  Axiom: she is carrying an umbrella
  <u>Conclusion</u>: It is raining
- This conclusion might be <u>false</u>, because there could be other reasons that she is carrying an umbrella e.g. she might be carrying it to protect herself from the sun.

Types of Reasoning : Analogical

- Analogical reasoning works by drawing analogies (similarities) between two situations, looking for similarities and differences.
- When you say driving a truck is just like driving a car, by analogy you know that there are some similarities in the driving mechanism.
- But you also know that there are certain other distinct characteristics of each.

Types of Reasoning : Common-sense

- Common-sense reasoning : Common-sense reasoning is an informal form of reasoning that uses rules gained through <u>experience</u> or what we call rules-of-thumb.
- It operates on heuristic (experimental) knowledge and heuristic rules.

Types of Reasoning : Non-Monotonic reasoning

- Non-Monotonic reasoning is used when the facts of the case are likely to change after some time.
- Rule:
  IF the wind blows
  THEN the curtains sway
- When the wind stops blowing, the curtains should sway no longer.
- However, if we use monotonic reasoning, this would not happen. The fact that the curtains are saying would be retained even after the wind stopped blowing.

Inference

- A process of deriving new information from known information.
- In the domain of AI, the component of the system that performs inference is called an inference engine.
- We will look at inference within the framework of 'logic', which we introduced earlier.
- We can use proof system :
  - –Begin with initial premises of the proof (or knowledge base)
  - –Use rules, i.e. apply rules to the known information
  - –Add new statements, based on the rules that match

Inference….working example

- Knowledge Base
  Rule 1:
  IF father (X, Y)
  AND father (X, Z)
  THEN brother (Y, Z)
  Rule 2:
  IF father (X, Y)
  THEN payTuition (X, Y)
  Rule 3:
  IF brother (X, Y)
  THEN like (X, Y)

- Working Memory
- father (M.Tariq, Ali)
  father (M.Tariq, Ahmed)
  …….Inference Engine…..
- brother (? , ?)
  payTuition (? , ?)
  payTuition (? , ?)
  like (? , ?)

Rules of Inference

The table below gives the four rules of inference together:

$\begin{array}{l}\alpha \rightarrow \beta \\ \underline{\alpha \qquad\quad} \\ \beta\end{array}$	$\begin{array}{l}\alpha \rightarrow \beta \\ \underline{\neg\beta \qquad\quad} \\ \neg\alpha\end{array}$	$\begin{array}{l}\alpha \\ \underline{\beta} \\ \alpha \wedge \beta\end{array}$	$\begin{array}{l}\underline{\alpha \wedge \beta} \\ \alpha\end{array}$
Modus Ponens	Modus Tolens	And-Introduction	And-elimination

Figure : Table of Rules of Inference

Rules of Inference….An Example

Step	Formula	Derivation
1	$A \wedge B$	Given
2	$A \rightarrow C$	Given
3	$(B \wedge C) \rightarrow D$	Given
4	A	1 And-elimination
5	C	4, 2 Modus Ponens
6	B	1 And-elimination
7	$B \wedge C$	5, 6 And-introduction
8	D	7, 3 Modus Ponens

Resolution Rule

A	β	Γ	$\neg\beta$	$\alpha \vee \beta$	$\neg\beta \vee \gamma$	$\alpha \vee \gamma$
F	F	F	T	F	T	F
F	F	T	T	F	T	T
F	T	F	F	T	F	F
F	T	T	F	T	T	T
T	F	F	T	T	T	T
T	F	T	T	T	T	T
T	T	F	F	T	F	T
T	T	T	F	T	T	T

$$\frac{\alpha \vee \beta \quad\quad \neg\beta \vee \gamma}{\alpha \vee \gamma}$$

Rules of Inference for Quantifiers

- Universal Instantiation:

$$\frac{\forall x P(x)}{\therefore P(c)}$$

- Universal Generalization:

$$\frac{P(c) \text{ for an arbitrary } c}{\therefore \forall x P(x)}$$

- Existential Instantiation:

$$\frac{\exists x P(x)}{\therefore P(c) \text{ for some element } c}$$

- Existential Generalization:

$$\frac{P(c) \text{ for some element } c}{\therefore \exists x P(x)}$$

$$\frac{\begin{array}{c}\forall x\,(H(x) \rightarrow M(x)) \\ H(\text{Sachin})\end{array}}{\therefore M(\text{Sachin})}$$

Rules of Inference for Quantifiers

Step	Valid Argument	Reason
(1)	$\forall x\,(H(x) \to M(x))$	Premise
(2)	$H(Sachin) \to M(Sachin)$	Universal instantiation from (1)
(3)	$H(Sachin)$	Premise
(4)	$M(Sachin)$	Modus ponens from (2) and (3)

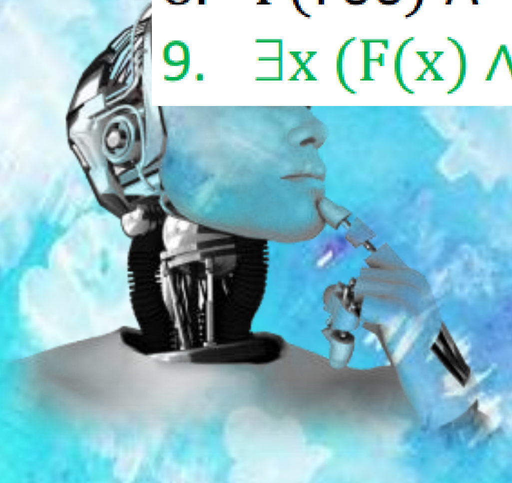
Rules of Inference for Quantifiers

- “All lions are fierce.”
- “Some lions do not drink coffee.”
- Does it follow that: “Some fierce creatures do not drink coffee.”

1. $\forall x\,(L(x) \rightarrow F(x))$
2. $\exists x\,(L(x) \land \neg C(x))$
3. $\exists x\,(F(x) \land \neg C(x))$

Rules of Inference for Quantifiers

1.	$\exists x\,(L(x) \land \neg C(x))$	Premise
2.	$L(Foo) \land \neg C(Foo)$	Existential Instantiation from (1)
3.	$L(Foo)$	Simplification from (2)
4.	$\neg C(Foo)$	Simplification from (2)
5.	$\forall x\,(L(x) \rightarrow F(x))$	Premise
6.	$L(Foo) \rightarrow F(Foo)$	Universal instantiation from (5)
7.	$F(Foo)$	Modus ponens from (3) and (6)
8.	$F(Foo) \land \neg C(Foo)$	Conjunction from (4) and (7)
9.	$\exists x\,(F(x) \land \neg C(x))$	Existential generalization from (8)



Unificatation

- Am Inference rules that requires finding substitutions that make different logical expressions UNIFICATION look identical.
- This process is called **unification** and is a key component of all first-order UNIFIER inference algorithms.
- The UNIFY algorithm takes two sentences and returns a **unifier** for them if one exists:
- UNIFY(p, q)= θ where SUBST(θ, p)= SUBST(θ, q) .

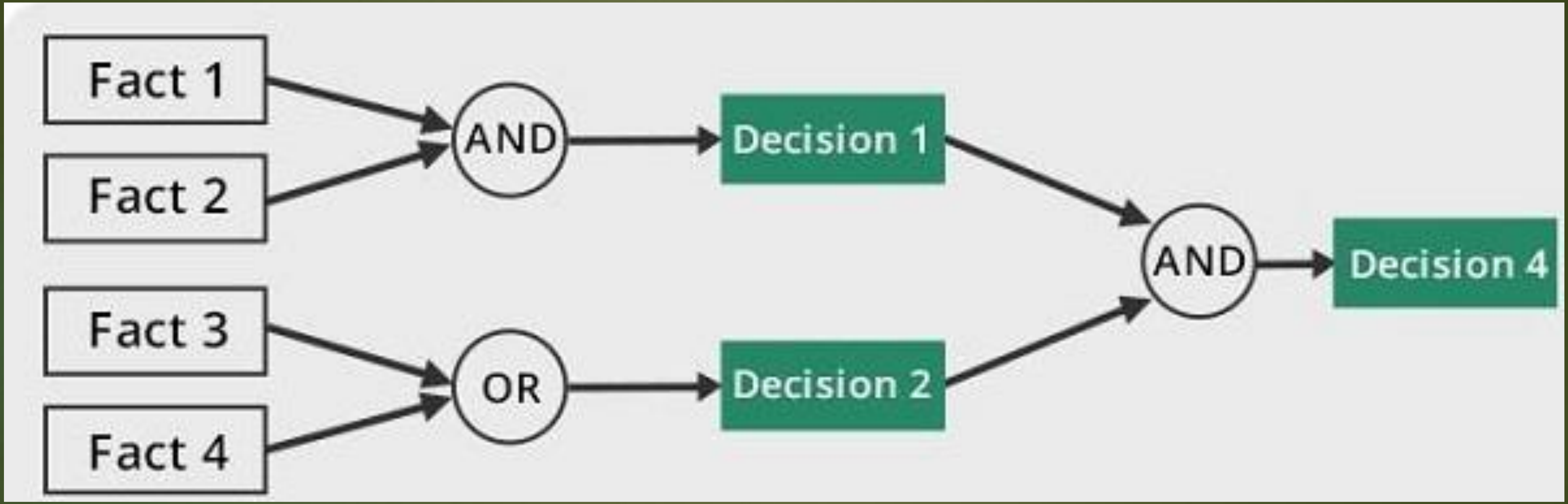
Unification

- Suppose we have a query AskVars(Knows(John, x)): whom does John know? Answers to this query can be found
- UNIFY(Knows(John, x), Knows(John, Jane)) = {x/Jane}
  UNIFY(Knows(John, x), Knows(y, Bill)) = {x/Bill, y/John}
- UNIFY(Knows(John, x), Knows(y, Mother(y))) = {y/John, x/Mother(John)}
- UNIFY(Knows(John, x), Knows(x, Elizabeth)) = fail .
- UNIFY(Knows(John, x), Knows(x17, Elizabeth)) = {x/Elizabeth, x17/John}

Forward chaining

- Let’s look at how a doctor goes about diagnosing a patient. He asks the patient for symptoms and then infers diagnosis from symptoms.
- Forward chaining is based on the same idea. It is an “inference strategy that begins with a set of known facts, derives new facts using rules whose premises match the known facts, and continues this process until a goal sate is reached or until no further rules have premises that match the known or derived facts” .
- it is a data-driven approach.

Forward chaining



Approach

- Add facts to working memory (WM)
- Take each rule in turn and check to see if any of its premises match the facts in the WM
- When matches found for all premises of a rule, place the conclusion of the rule in WM.
- Repeat this process until no more facts can be added. Each repetition of the process is called a pass.

An Example

Doctor example (forward chaining)

Rules

Rule 1

IF	The patient has deep cough
AND	We suspect an infection
THEN	The patient has Pneumonia

Rule 2

IF	The patient's temperature is above 100
THEN	Patient has fever

Rule 3

IF	The patient has been sick for over a fortnight
AND	The patient has a fever
THEN	We suspect an infection

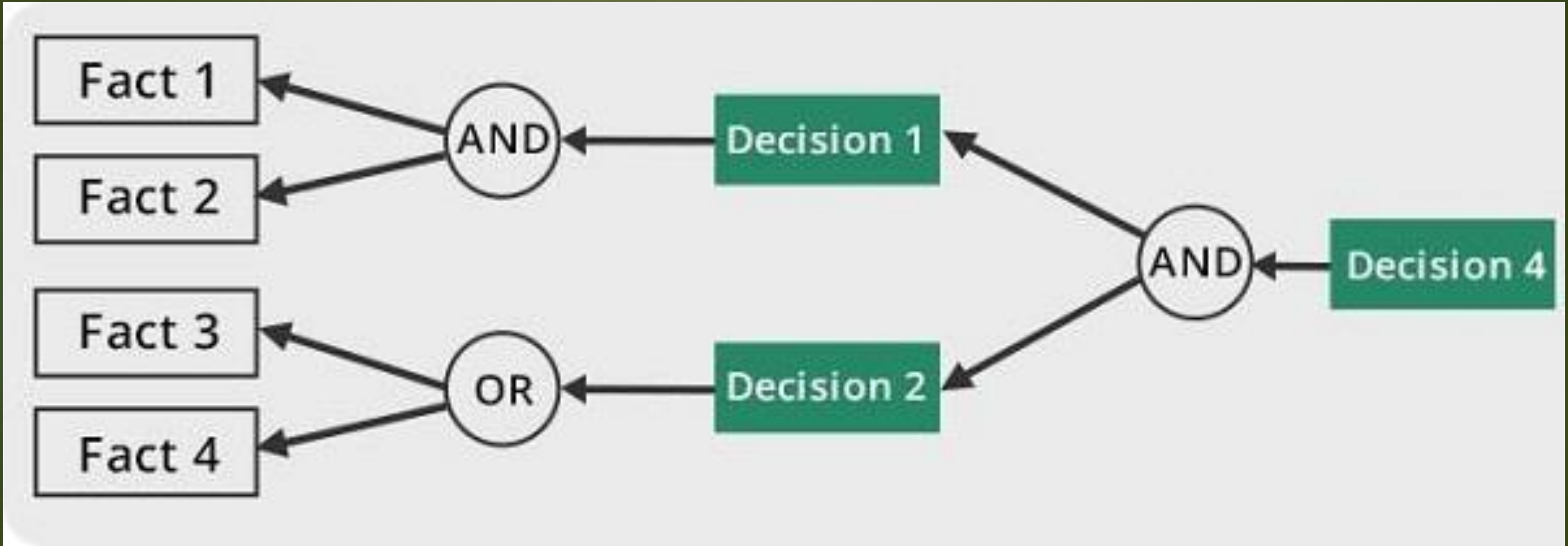
Case facts

- Patients temperature= 103
- Patient has been sick for over a month
- Patient has violent coughing fits

Backward chaining

- Backward chaining is an inference strategy that works backward from a
hypothesis to a proof.
- You begin with a hypothesis about what the situation might be. Then you prove it using given facts.
- For Example a doctor may suspect some disease and proceed by inspection of symptoms.
- In backward chaining terminology, the hypothesis to prove is called the goal.

Backward chaining



Thanks ……

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