CSCI B 551
Elements of Artificial Intelligence

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1. Represent the following in First Order Logic
   a) B551 is a course at IU
   courseAt(IU, B551)

   b) Mary likes all pastries except donuts
   $\forall$ x pastry(x) $\wedge$ x $\neq$ donut $\Rightarrow$ likes(Mary,x)

   c) If a printer doesnt print its broken, unless its unplugged.
   $\forall$ x printer(x) $\wedge$ broken(x) $\wedge$ plugged(x) $\Rightarrow \sim$ print(x)

   d) No student likes expensive textbooks.
   $\forall$ x,y student(x) $\wedge$ expensive(y) $\wedge$ textbook(y) $\Rightarrow \sim$ likes(x,y)

   e)Teach someone how to fish then they will fish forever
   $\forall$ x, y Person(x) $\wedge$ time(y) $\wedge$ taughtFishing(x) $\Rightarrow$ haveFish(x,y)

2. From "Horses are animals," it follows that "The head of a horse is the head of an animal." Demonstrate that this inference is valid by carrying out the following steps:

   a. Translate the premise and the conclusion into the language of first - order logic. Use three predicates: HeadOf (h,x) (meaning "h is the head of x"), Horse(x), and Animal(x).
   Premise: $\forall$ x horse(x) $\rightarrow$ animal(x)$\Rightarrow$ eq(1)
   Conclusion: $\forall$ x,h horse(x) $\wedge$ headof(h,x) $\Rightarrow \exists$ y animal(y) $\wedge$ headof(h,y) $\Rightarrow$ eq(2)

   b) Negate the conclusion, and convert the premise and the negated conclusion into conjunctive normal form.
   $\forall$ x horse(x) $\rightarrow$ animal(x) negating this yields
   $\exists$ x horse(x) $\wedge \sim$ animal(x) again negating this yields the CNF as below
   $\forall$ x $\sim$ horse(x) $\vee$ animal(x) $\Rightarrow$ eq(3)
   As the x holds true for all the values eliminating $\forall$ which gives us,
   $\sim$ horse(x) $\vee$ animal(x) $\rightarrow$ eq(4)

   Negate the conclusion as below,
   Firstly, remove the implication,
   $\forall$ x,h horse(x) $\wedge$ headof(h,x)) $\Rightarrow \exists$ y animal(y)$\wedge$ headof(h,y) yields this
   $\sim$($\forall$ x,h $\sim$ horse(x) $\vee \sim$ headof(h,x) $\vee \exists$ y animal(y)$\wedge$ headof(h,y))
   Now, negate the above result which finally gives us,
   $\exists$ x,h horse(x) $\wedge$ headof(h,x) $\wedge \forall$ y $\sim$ animal(y) $\vee \sim$ headof(h,y) $\Rightarrow$ eq(5)

$\exists$ can be removed by assuming a set of skolem constants for which the above equation will be true and $\forall$ can eliminated as the expression always holds true for any value of y. Finally, we get
horse(x) $\wedge$ headof(h,x) $\wedge \sim$ animal(y) $\vee \sim$ headof(h,y) $\Rightarrow$ eq(6)

c) Use resolution to show that the conclusion follows the premise.

Combining the eq(4) and eq(6) after eliminating the $\exists$ and $\forall$ we have,
horse(x) $\wedge$ headof(h,x) $\wedge \sim$ animal(y) $\vee \sim$ headof(h,y) $\wedge$ ($\sim$ horse(x) $\vee$ animal(x))
We finally get after reductions,
(headof(h,x) $\wedge$ animal(x)) $\wedge \sim$(animal(y)$\wedge$ headof(h,y)) leaving a null clause.

3. Ruled Based Systems Forward chaining is a data driven method of deriving a particular goal from a given knowledge base and set of inference rules.
Bread First Search is uninformed search strategy where in the agent visits all available states from the existing state. It follows the FIFO(First In First Out) technique. All the newly generated states are added to the back of the fringe. Implementing the forward chaining process for BFS, we begin with the set of inference rules and facts available.

$$
\begin{aligned}
Givenfacts \\
A \\
B \\
C \\
InferredRules \\
P \Rightarrow Q \\
L \wedge M \Rightarrow P \\
B \wedge L \Rightarrow M \\
A \wedge P \Rightarrow L \\
A \wedge B \Rightarrow L \\
GoalState : Q
\end{aligned}
$$

Here, we start with the facts that we have. The next generated state is determined by applying the rules. We have the initial state to be A,B. From the facts we know that A and B are true. From, the rules we know that when A and B are true L is true. The next state generated is A, B, L.
From rule 4 which states B and L are true implies M is true.The next state we get is A, B, L, M. Then rule 2 can be applied. L and M are true implies P is true yielding the fringe to be A, B, L, M, P. Then, rule 4 could be applied which gives us L. As we know we already have L in our fringe. We can use the rule P is true we end up with Q which is the goal state using the rule 1.
a) The agent's state is represented by the facts and the rules that it knows from the starting of the process.
b) As we know BFS uses the FIFO order. The successor states are generated by applying the rules on the facts in FIFO order as we have seen in the above example.

Reference:
Referred the logical agents concept for Q3 from Russell and Norvig.