

## CS561 Artificial Intelligence - Spring 2010 Midterm 2 Solutions

### 1. (25 points) First-order Logic / Knowledge Representation [Graded by Rohan]

#### Part a:

$\forall p \text{ Person}(p) \wedge \text{Person}(\text{Raymond}) \Rightarrow \text{Loves}(p, \text{Raymond})$   
 $\forall p \text{ Person}(p) \Rightarrow \text{Loves}(p, \text{Raymond})$   
 $\forall p \text{ Loves}(p, \text{Raymond})$

#### Part b:

$\forall c, d \text{ Cat}(c) \wedge \text{Dog}(d) \wedge \text{Day}(\text{Tuesday}) \Rightarrow \text{Rains}(c, \text{Tuesday}) \wedge \text{Rains}(d, \text{Tuesday})$   
 $\forall c, d \text{ Cat}(c) \wedge \text{Dog}(d) \Rightarrow \text{Rains}(c, \text{Tuesday}) \wedge \text{Rains}(d, \text{Tuesday})$

#### Part c:

$\exists d, o \text{ Dog}(d) \wedge \text{Owner}(o, d) \Rightarrow \forall c \text{ Cat}(c) \wedge \text{Likes}(o, c)$   
 $\exists d, o \forall c \text{ Dog}(d) \wedge \text{Owner}(o, d) \Rightarrow \text{Cat}(c) \wedge \text{Likes}(o, c)$

#### Part d:

$\exists x \text{ Person}(x) \Rightarrow \text{Human}(x) \equiv \exists x \neg \text{Person}(x) \vee \text{Human}(x)$   
but what we want is  $\exists x \text{ Person}(x) \wedge \text{Human}(x)$

Hence, using implication and existential quantification may yield incorrect results.

#### Part e:

$\forall x \text{ Person}(x) \Rightarrow \text{Human}(x) \equiv \forall x \neg \text{Person}(x) \vee \text{Human}(x)$

This means that if  $\text{Person}(x)$  is true, then  $\text{Human}(x)$  must be true. However  $\forall x \text{ Person}(x) \wedge \text{Human}(x)$  does not mean that if  $\text{Person}(x)$  is true that  $\text{Human}(x)$  must be true, therefore using and with universal quantification may yield incorrect results.

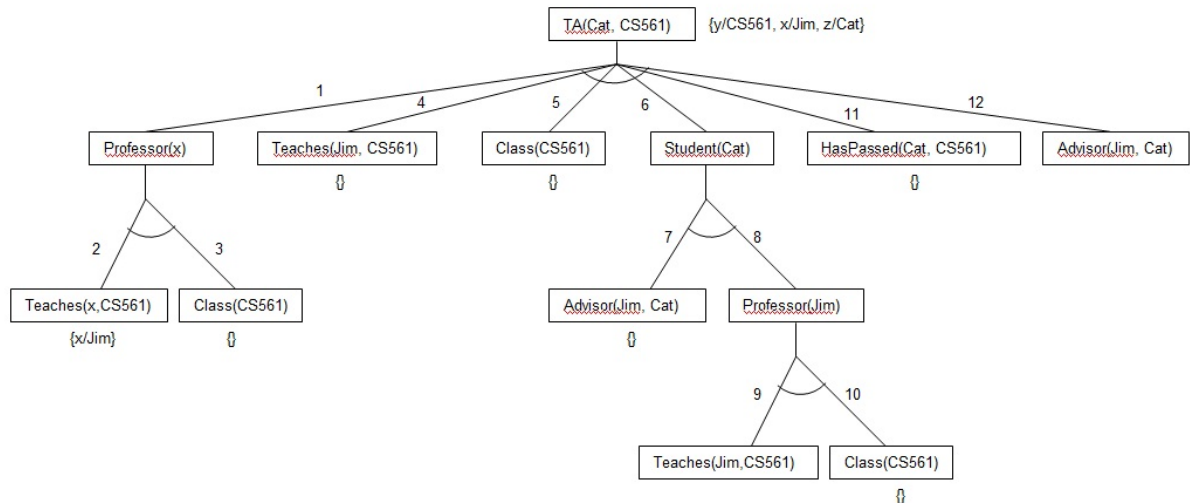
OR The key is using universal identifier, the predicate has to be universal truth. For all  $x \text{ Person}(x) \wedge \text{Human}(x)$ . Since all objects in the universe are not necessarily human/person, therefore this predicate cannot represent the correct semantics.

#### Part f:

Yes, but it may require a large number of literals making it far less efficient, but easier to evaluate.

### 2. (40 points) First-order Inference [Solution by Nadeesha, Part a. graded by William, Part b. graded by Nadeesha]

#### Part a:



### Grading key:

3 points: Show proof that backward chaining was attempted

1 point: Numbering the edges

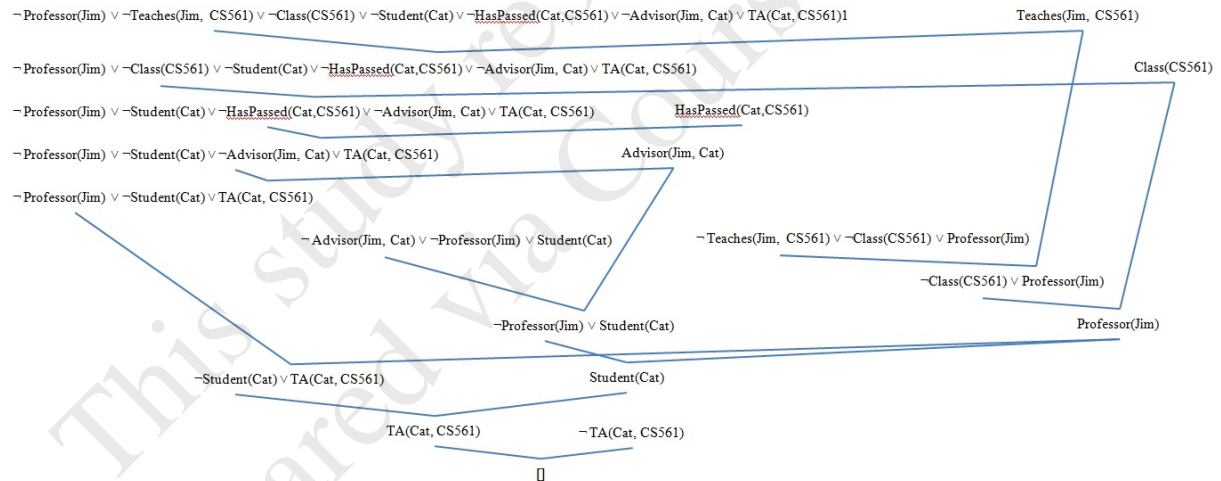
1 point: Unifications

9 points: Clauses to imply  $TA(z,y)$  (1 point for each clause and 0.5 point for each edge)

3 points: Clauses to imply  $Professor(x)$  (1 point for each clause and 0.5 point for each edge)

3 points: Clauses to imply  $Student(y)$  (1 point for each clause and 0.5 point for each edge)

### Part b:



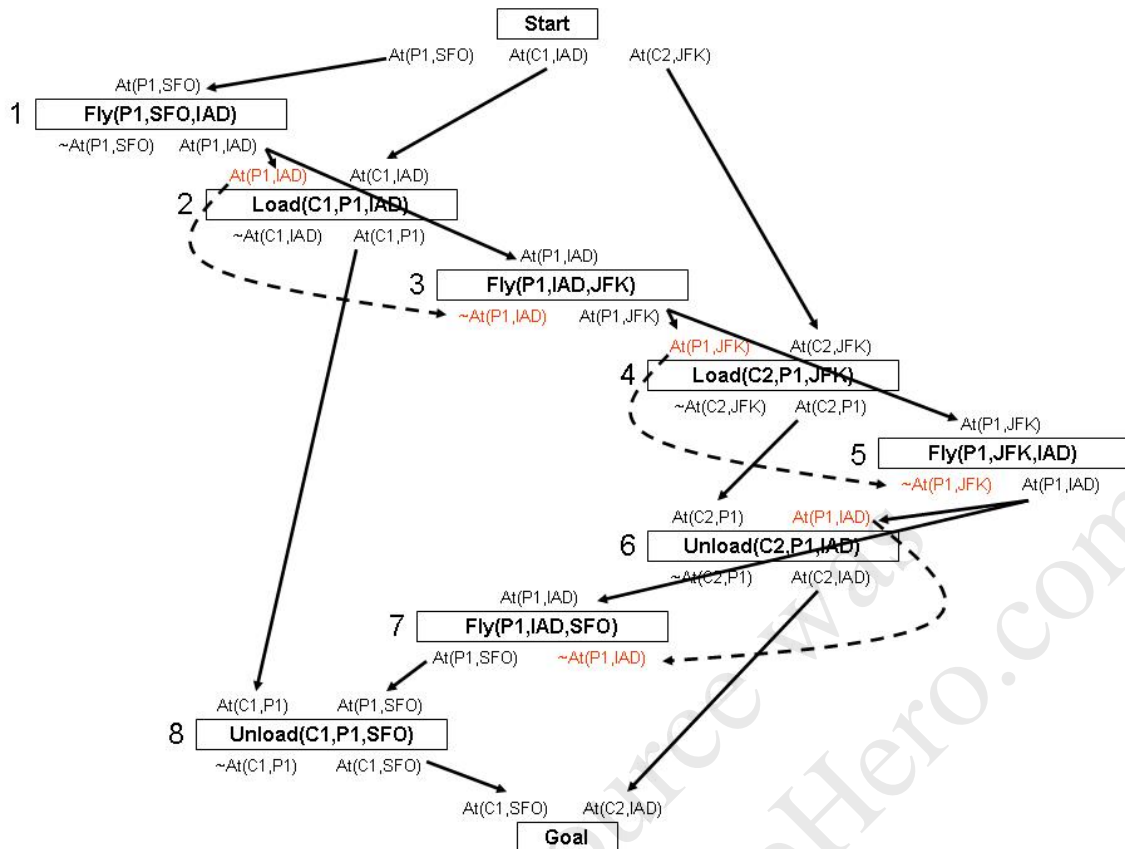
### Grading key:

-1 for each missing step towards the empty clause or each major error

## 3. (25 points) Planning (STRIPS) [Solution by William, Graded by Guan]

### Solution 1

#### Part a:



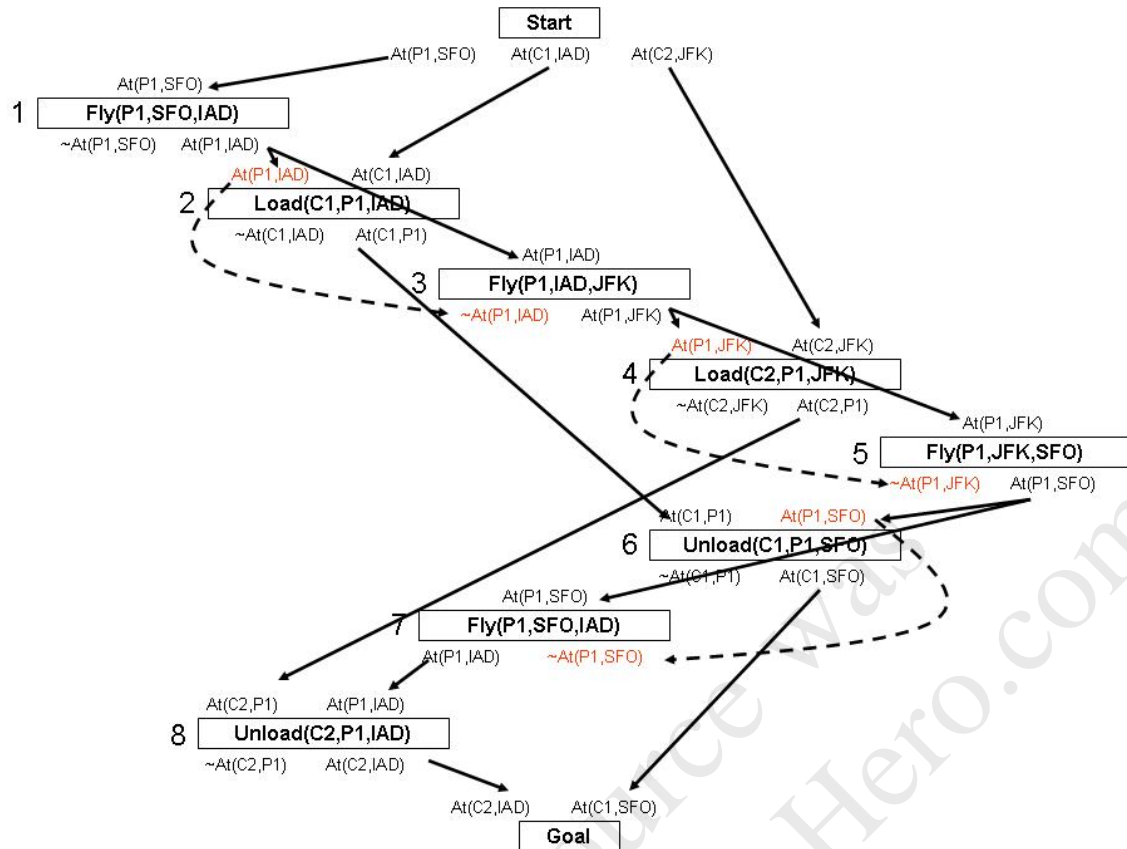
### Part b:

1 possible linear solution.

Solution:  $Fly(P1, SFO, IAD) \rightarrow Load(C1, P1, IAD) \rightarrow Fly(P1, IAD, JFK) \rightarrow Load(C2, P1, JFK) \rightarrow Fly(P1, JFK, IAD) \rightarrow Unload(C2, P1, IAD) \rightarrow Fly(P1, IAD, SFO) \rightarrow Unload(C1, P1, SFO)$

### Solution 2

Part a:



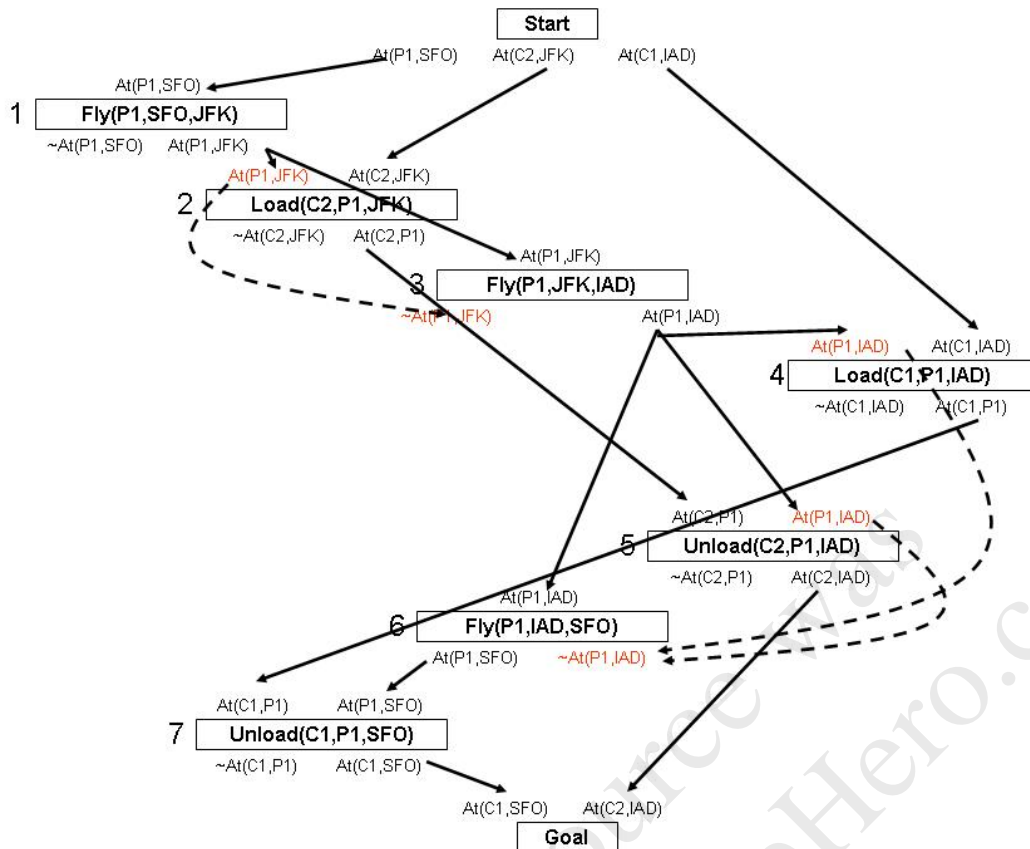
### Part b:

1 possible linear solution.

Solution: Fly(P1,SFO,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,SFO) -> Unload(C1,P1,SFO) -> Fly(P1,SFO,IAD) -> Unload(C2,P1,IAD)

### Solution 3

Part a:



### Part b:

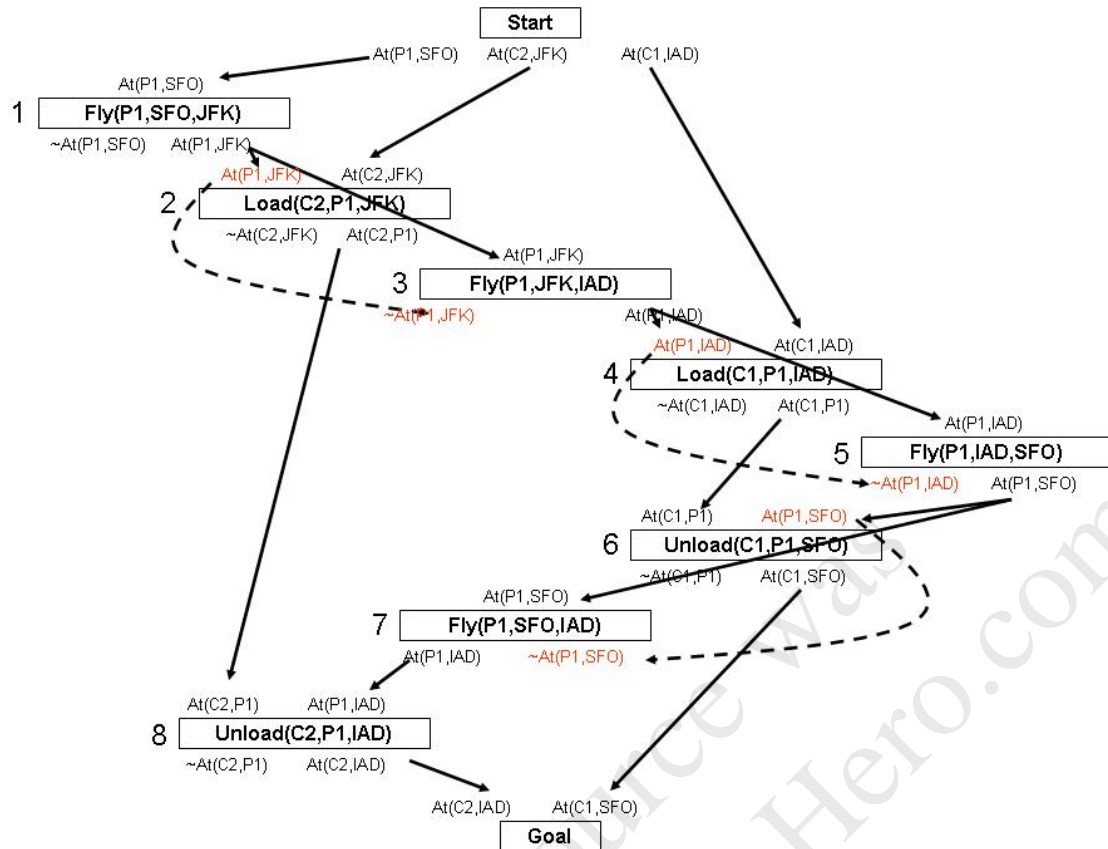
2 possible linear solutions.

Solution: Fly(P1,SFO,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Load(C1,P1,IAD) -> Unload(C2,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO)

Solution: Fly(P1,SFO,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Unload(C2,P1,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO)

### Solution 4

#### Part a:



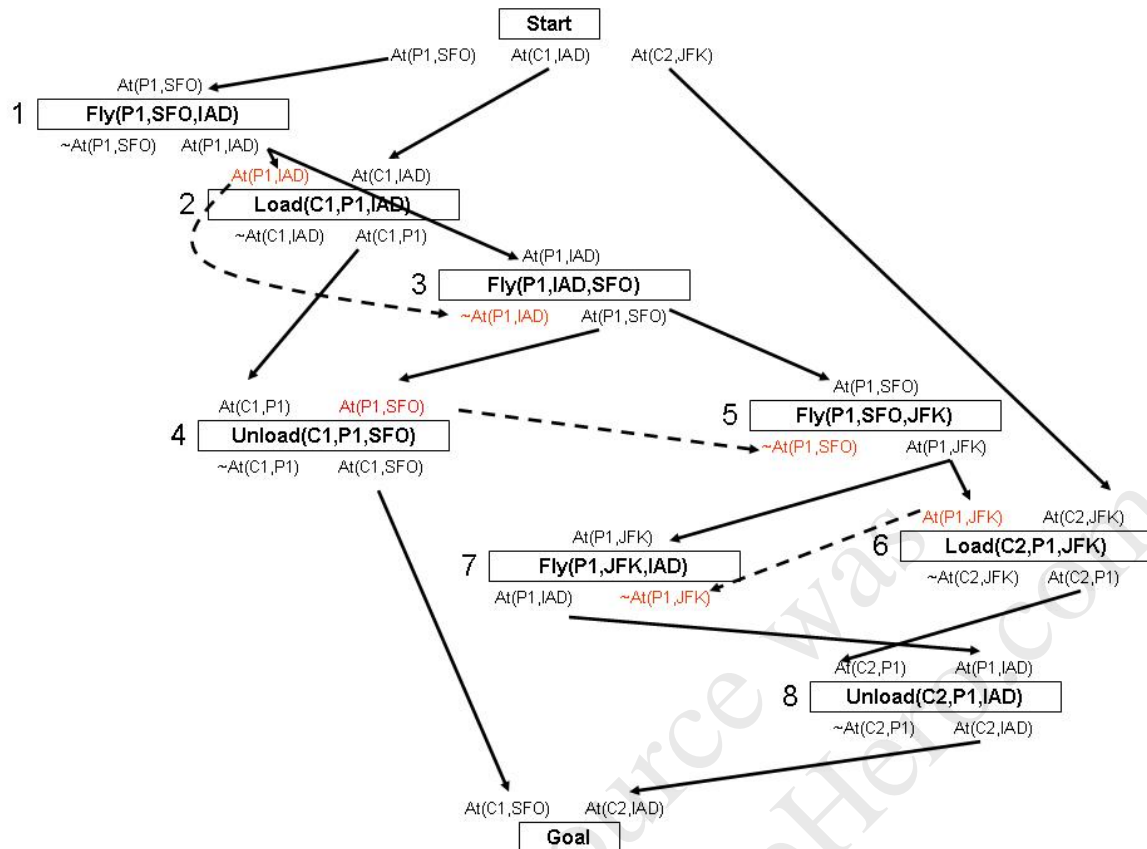
### Part b:

1 possible linear solutions.

Solution: Fly(P1,SFO,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO) -> Fly(P1,SFO,IAD) -> Unload(C2,P1,IAD)

### Solution 5

Part a:



### Part b:

1 possible linear solutions.

Solution: Fly(P1,SFO,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO) -> Fly(P1,SFO,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Unload(C2,P1,IAD)

### Grading Key:

- |                              |   |
|------------------------------|---|
| a)                           |   |
| write something              | 5 points  |
| understanding of planning    | 5 points if answer contains states and links    |
|                              | or 3 points                                     |
| correct                      | 2 points if answer is correct                   |
| finish                       | 2 points if answer has a finish state           |
| numbering actions            | 1 point   |
| causal link                  | 3 points if the line starts from the effect and |
| ends at another precondition | or 1 point if there's a line                    |
| clobbers                     | 2 points if all the clobbers are correct        |
|                              | or 1 point if the clobber are partially correct |
| b)                           |   |
| number of solutions          | 1 point   |
| solution                     | 4 points if correct                             |
|                              | or 1 or 2 or 3 points based on solution         |

#### 4. (15 points) Probability [Solution by William, Graded by Rohan]

By definition, the variables are independent. Only give partial credit for people who decides they are not dependent, unless they explicitly state their dependence assumptions.

**Part a:**

If you assume that the variables are independent, then

$$\begin{aligned} &P(x_1=\text{true}, x_2=\text{true}, x_3=\text{true}, x_4=\text{true}) \\ &= P(x_1=\text{true}) \times P(x_2=\text{true}) \times P(x_3=\text{true}) \times P(x_4=\text{true}) \\ &= 0.75 \times 0.75 \times 0.25 \times 0.25 \end{aligned}$$

Otherwise,

$$\begin{aligned} &P(x_1=\text{true}, x_2=\text{true}, x_3=\text{true}, x_4=\text{true}) \\ &= P(x_1=\text{true} | x_2=\text{true}, x_3=\text{true}, x_4=\text{true}) \times P(x_2=\text{true} | x_3=\text{true}, x_4=\text{true}) \times \\ &P(x_3=\text{true} | x_4=\text{true}) \times P(x_4=\text{true}) \\ &\text{or some other combination of conditional probabilities} \end{aligned}$$

**Part b:**

If you assume that the variables are independent, then

$$\begin{aligned} &P(x_1=\text{false}, x_2=\text{false}, x_3=\text{false}, x_4=\text{false}) \\ &= P(x_1=\text{false}) \times P(x_2=\text{false}) \times P(x_3=\text{false}) \times P(x_4=\text{false}) \\ &= (1-0.75) \times (1-0.75) \times (1-0.25) \times (1-0.25) \\ &= 0.25 \times 0.25 \times 0.75 \times 0.75 \end{aligned}$$

Otherwise,

$$\begin{aligned} &P(x_1=\text{false}, x_2=\text{false}, x_3=\text{false}, x_4=\text{false}) \\ &= P(x_1=\text{false} | x_2=\text{false}, x_3=\text{false}, x_4=\text{false}) \times \\ &P(x_2=\text{false} | x_3=\text{false}, x_4=\text{false}) \times P(x_3=\text{false} | x_4=\text{false}) \times P(x_4=\text{false}) \\ &\text{or some other combination of conditional probabilities} \end{aligned}$$

**Part c:**

If you assume that the variables are independent, then yes. Otherwise, no.

#### 5. (45 points) Probabilistic Inference [Solution by Harris, Graded by Harris]

**Part a:**

$$P(A \wedge B \wedge C \wedge D \wedge E) = P(F | E, B) P(E | C, D) P(C | A) P(D | B) P(B | A) P(A)$$

**Part b:**

As we know the truth value of A, B, C, E, F and according to the Bayesian Network, the probability of D depends on truth value of B.

Therefore, we only have to get the answer straight from the network  $P(D | B)$  for B is true and  $P(D | \sim B)$  for B is not true.



**Part c:**

Since D is independent of C, the observation of C will not affect the prob(D).

We can infer  $P(D|A) = P(D|B)P(B|A) + P(D|\sim B)P(\sim B|A)$

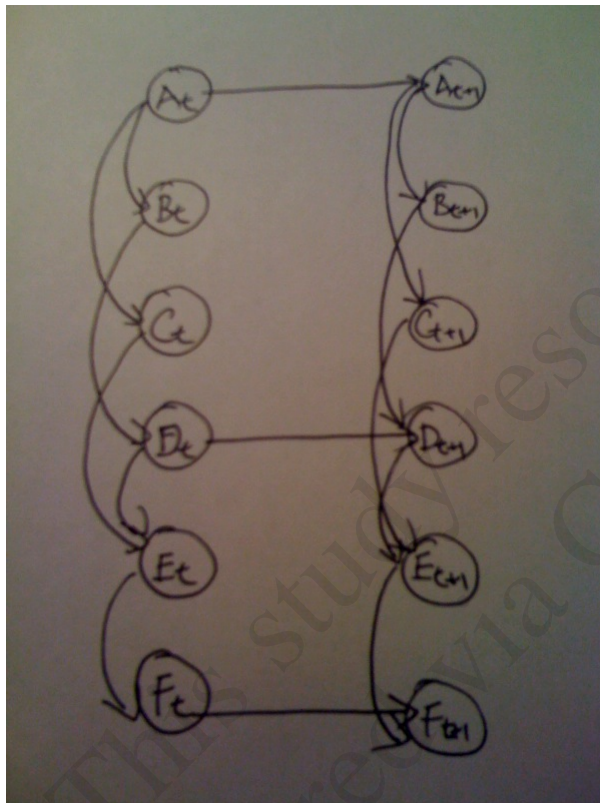
$P(D|\sim A) = P(D|B)P(B|\sim A) + P(D|\sim B)P(\sim B|\sim A)$

**Part d:**

It includes its parent (B), its child (E) and its child's parent (C).

**Part e:**

For direct inference of E, we need the observations of C and D only.

**Part f:**

For this, it is enough if they just add the three temporal nodes ( $A_t$ ,  $D_t$  and  $F_t$ ).