Midterm 2 Exam

CSCI 561 Spring 2020: Foundations of Artificial Intelligence

Problems	**Points**
1. General Knowledge	10
2. Propositional Logic	20
3. First Order Logic	22
4. Inference	20
5. Planning	20
6. Multiple Choice related to Discussions	8

DO NOT OPEN EXAM UNTIL YOU ARE TOLD TO

Instructions:

1. Date: March 25, 2020
2. Maximum credits/points/percentage for this midterm: 100
3. The percentages for each question are indicated in square brackets [ ] near the question.
4. **No books** (or any other material) are allowed.
5. **Write down your name, student ID and USC email address.**
6. **Your exam will be scanned and uploaded online.**
7. **Write within the boxes provided for your answers.**
8. **Do NOT write on the 2D barcode.**
9. **Do not write within less than 1" from the paper edges to avoid lost work during scanning.**
10. **The back of the pages will not be graded. You may use it for scratch paper.**
11. **The back of the pages will not be scanned. Do not write any answer there!**
12. No questions during the exam. **If something is unclear to you, write that in your exam.**
13. **Be brief: a few words are enough if precise and using the correct vocabulary studied in class.**
14. When finished, raise completed exam sheets until approached by proctor.
15. **Adhere to the Academic Integrity code.**

1. [10%] General Knowledge

1	T	F
2	T	F
3	T	F
4	T	F
5	T	F
6	T	F
7	T	F
8	T	F
9	T	F
10	T	F

(T) 1: In FOL, => is a natural connective to use with Universal Quantifiers.

(F) 2: Successor-state axioms state that some predicate is true after an action if and only if either the action made it true, or it was already true and the action made it false.

(F) 3: Inference procedure *i* is complete if and only if
whenever $KB \vdash_i \alpha$, it is also true that $KB \models \alpha$

(T) 4: A logic sentence is valid if and only if it is true in all models.

(T) 5: Prolog uses backward chaining.

(T) 6: A plan is complete if and only if every precondition of every step in the plan is achieved.

(F) 7: This sentence is syntactically correct in first-order logic:
$\forall$ x,y (x=y) $\Leftrightarrow$ ($\forall$ p, p(x) $\Leftrightarrow$ p(y))

(F) 8: The following sentence is false:
$KB \models \alpha$ if and only if $(KB \Rightarrow \alpha)$ is valid

(T) 9: The Resolution procedure is complete.

(T) 10: In FOL, for any alpha, $A \wedge \neg A$ |= alpha

2. [20%] Propositional Logic

2-1 The following symbols translate to the following English phrases or premises -

m: It is monday

p: Mary loves Pat

q: Mary loves Quincy

a) [6%] Using the above symbols, translate the given statements into propositional logic statements:

1. If Mary loves Pat, then Mary loves Quincy
   Answer: ($p \Rightarrow q$)
2. If it is Monday, then Mary loves Pat or Quincy.
   Answer: ($m \Rightarrow p \vee q$)
3. If it is Monday, then Mary loves Quincy
   Answer: (m ⇒ q)

b) [8%] Now consider the following from part a: Statements (1) and (2) are in the KB and (3) is α. Enumerate the truth table to discuss whether the sentence α is entailed by the knowledge base or not. Draw your table in the space below. There should be one row for each model. There should be columns for each propositional symbol. There should be sufficient number of additional columns to prove entailment.

Operator Precedence (Just for clarification - Not needed in the answer)
The ¬ operator has higher precedence than ∧; ∧ has higher precedence than ∨; and ∨ has higher precedence than ⇒ and ⇔

Rubric:
If 1st 3 columns (pertaining to symbols): give 1 mark
If middle 3 columns (pertaining to KB) correct : give 5 marks (2 + 2 + 1)
If last column correct : give 2 marks

Answer: Yes, α is entailed by the knowledge base [Not compulsory]
Table: [8%]

m	p	q	$m \Rightarrow p \vee q$ (2)	$p \Rightarrow q$ (1)	KB (1 ∧ 2)	(α) $m \Rightarrow q$ (3)
1	1	1	1	1	1	1
1	1	0	1	0	0	0

1	0	1	1	1	1	1
1	0	0	0	1	0	0
0	1	1	1	1	1	1
0	1	0	1	0	0	1
0	0	1	1	1	1	1
0	0	0	1	1	1	1

c) [2%] Is α entailed by the knowledge base? Explain how one can tell by examining your table.

Answer: Yes [1%], as we can see from the last two columns, whenever KB is T, α is also T (see rows 1, 3, 5, 7, and 8). Thus, KB entails α. [1%] for correct reasoning

2-2 [2%] Circle the sentence that is the CNF form of this sentence : **A ⇔ (B ∨ E)**

1) (¬A ∨ B ∨ E) ∧ (B ∨ A) ∧ (E ∨ A)
2) (¬A ∨ B ∨ E) ∧ (¬B ∨ A) ∧ (¬E ∨ A)
3) (¬A ∧B ∧ E) ∨ (¬B ∧ A) ∨ (¬E ∧ A)
4) (B ∨ A) ∧ (E ∨ A)
5) (B ∧ A) ∧ (E ∧ A)

Answer : 2) (¬A ∨ B ∨ E) ∧ (¬B ∨ A) ∧ (¬E ∨ A)

2-3 [2%] Is the given propositional sentence valid, satisfiable or unsatisfiable?

¬p ∧ p ⇒ q

Answer : Valid

Reason: As per operator precedence : The ¬ operator has higher precedence than ∧; ∧ has higher precedence than ∨; and ∨ has higher precedence than ⇒ and ⇔
Thus, ¬p ∧ p is always False. False ⇒ Anything is True (Always)

3. [22%] First Order Logic

Background

1. Two **student**s can be **friend**s with each other.
2. Two **student**s can be **classmate**s with each other in a **class** of a **semester**.
3. A **student** can **take** a **class** in a **semester**.
4. A **student** may **pass** a **class** in a **semester**.

3-1 [8%] Define predicates for the statements

Instructions:

1. Use the original forms of the verbs to define the names of predicates. (Eg. use Pass instead of Passes or Passed)
2. The names of predicates should be one word.
3. Use uppercase for the first character in the names of predicates. (Eg. use Pass instead of pass)
4. Use relations instead of functions to define predicates.
5. Each sentence in the background should correspond to one predicate.
6. Each word in **bold** should appear in your definition. For example, in background-3, **student**, **take**, **class** and **semester** should be in your answer.

Rubric:

1. (2%)Friend(x, y): Student x and student y are friends.
2. (2%)Classmate(x, y, C, S): Student x and student y are classmates in class C in semester S.
3. (2%)Take(x, C, S): Student x takes class C in semester S.
4. (2%)Pass(x, C, S): Student x passes class C in semester S.

No partial score.

3-2 [10%] Translate the following statements into FOL

Statements:

1. Some students in class CSCI561 in Spring2020 are friends.
2. All students who took CSCI561 in Fall2019 and passed it are not taking CSCI561 in Spring2020.
3. Some students are classmates both in class CSCI585 of Fall2019 and class CSCI561 of Fall2020 but they are still not friends.
4. No student will take CSCI571 in Fall2020 if they passed CSCI570, CSCI585 and CSCI561 in any of the semesters.
5. In any given semester, friends always take the exact same classes.

Instructions:

1. Please use the full name of the Constants that appear in the statements. (Eg. do not use “561” to represent “CSCI561”.)
2. Please use only the predicates you defined in question 3-1 in your translations.
3. Partial answers that fail to correctly translate all of the information in the given sentences will not receive any score.

Rubric:

1. $\exists x\ \exists y\ Take(x,\ CSCI561,\ Spring2020)\ \wedge Take(y,\ CSCI561,\ Spring2020)\ \wedge Friend(x,\ y)$
2. $\forall x\ Pass(x,\ CSCI561,\ Fall2019) \Rightarrow \neg Take(x,\ CSCI561,\ Spring2020)$ Or
   $\forall x\ (Take(x,\ CSCI561,\ Fall2019)\ \wedge\ Pass(x,\ CSCI561,\ Fall2019))\ \Rightarrow\ \neg Take(x,\ CSCI561,\ Spring2020)$
3. $\exists x\ \exists y\ Classmate(x,\ y,\ CSCI585,\ Fall2019) \wedge Classmate(x,\ y,\ CSCI561,\ Spring2020) \wedge \neg Friend(x,\ y)$
4. $\forall x\ (\exists S1\ \exists S2\ \exists S3\ (Pass(x,\ CSCI570,\ S1) \wedge Pass(x,\ CSCI585,\ S2) \wedge Pass(x,\ CSCI561,\ S3)) \Rightarrow \neg Take(x,\ CSCI571,\ Fall2020))$
5. $\forall x \forall y \forall C \forall S\ (Friend(x,\ y) \Rightarrow (Take(x, C, S) \Leftrightarrow Take(y, C, S)))$ or any other equivalent translation like:
   $\forall x \forall y \forall C \forall S\ (Friend(x,\ y) \Rightarrow ((Take(x, C, S)\ \wedge\ Take(y, C, S))\ \vee\ (\neg Take(x, C, S)\ \wedge\ \neg Take(y, C, S))))$
   Or
   $\forall x \forall y \forall C \forall S\ (Friend(x,\ y) \Rightarrow ((Take(x, C, S) \Rightarrow Take(y, C, S))\ \wedge\ (\neg Take(x, C, S) \Rightarrow \neg Take(y, C, S))))$
   Or
   $\forall x \forall y \forall C \forall S\ (Friend(x,\ y) \Rightarrow ((Take(x, C, S) \Rightarrow Take(y, C, S))\ \wedge\ (Take(y, C, S) \Rightarrow Take(x, C, S))))$

The answers may not be exactly the same. As long as all the details are correctly translated, the answers should be given full credit.

3-3 [4%] Convert the following FOL sentence into CNF

$$\forall x\, ((\exists y\ \exists z\ Friend(x, y) \wedge Friend(y,\ z)) \vee (\exists y\ Friend(x\ , y)))$$

Rubric:

$\forall x\, ((\exists y\ \exists z\ Friend(x, y) \wedge Friend(y, z)) \vee (\exists y\ Friend(x\ , y)))$

$\rightarrow \forall x\ (Friend(x, f(x)) \wedge Friend(f(x), g(x))) \vee (\exists w\ Friend(x, w))$

$\rightarrow (Friend(x, f(x)) \wedge Friend(f(x), g(x))) \vee Friend(x, h(x))$

$\rightarrow [Friend(x, f(x)) \vee Friend(x, h(x))] \wedge [Friend(f(x), g(x)) \vee Friend(x, h(x))]$

Note: In Skolemnization function names are flexible as long as the meaning is the same. 1% for correctly standardizing variables (also give credit if the second 'y' is not standardized but directly replaced with proper skolem function), 1% for correct skolemnization, 1% for correctly dropping quantifiers, and 1% for correctly distributing $\vee$ over $\wedge$.

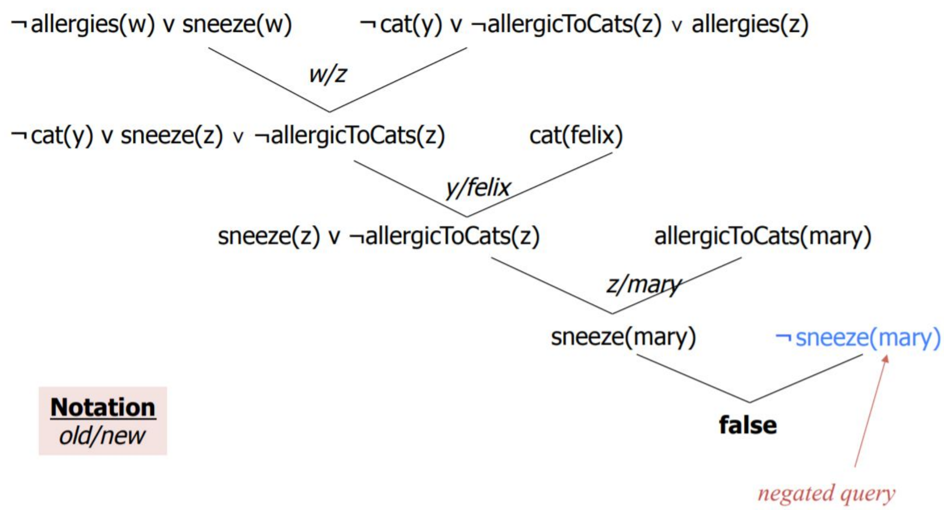
4. [20%] Inference

Given Knowledge Base

1. allergies(X) → sneeze(X)
2. cat(Y) ∧ allergicToCats(X) → allergies(X)
3. cat(felix)
4. allergicToCats(mary)

Infer the following Goal by resolution: **sneeze(mary)**

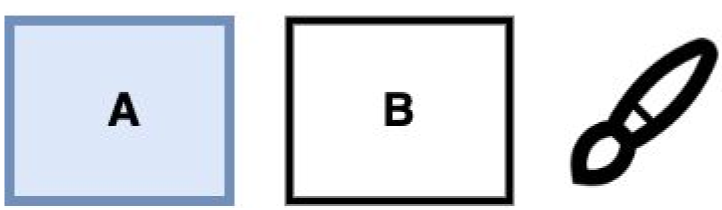
Rubric: Draw basic resolution tree (4%), correct answer (4%) each resolution (3% x 4) (Note: many resolution trees are possible.)



5. [20%] Planning

Consider the following painting world. We have two blocks (**A** and **B**), two colors (**RED** and **BLUE**), and a brush. The following rules apply in the world:

● The brush should be dry before getting dipped into the paint.
● The brush should be wet with the right color before painting.
● The block should be blank before getting painted.



Initially, block A is blue and block B is blank. The brush is dry and has no color.

Consider b = block, c = color
The preconditions/effects are:
Color(b, c), WetBrush(c), DryBrush(), Blank(b)

The actions are:
DipBrush(c), RemoveColor(b), DryBrush(), Paint(b, c)

The actions DipBrush(c) and DryBrush() are defined as:

Action: DipBrush(c)
Preconditions: DryBrush()
Effects: WetBrush(c), ~DryBrush()

Action: DryBrush()
Preconditions: --
Effects: DryBrush()

Write down any assumptions you are making to avoid losing marks.

5A. [5%] Using the predicates given in preconditions/effects above, write down the description of the state above under the closed-world assumption (Block A is blue, Block B is blank, and the brush is dry).

DryBrush(), Color(A,Blue), Blank(B)

-2% for each wrong/missing till zero

-1% for each extra

5B. [6%] Write down the schema for actions Paint(b,c) that paints a block with a specific color and RemoveColor(b) that removes the color from a block.
[If the schema is not the same as below, but is reasonably defined and consistent, give credit.]

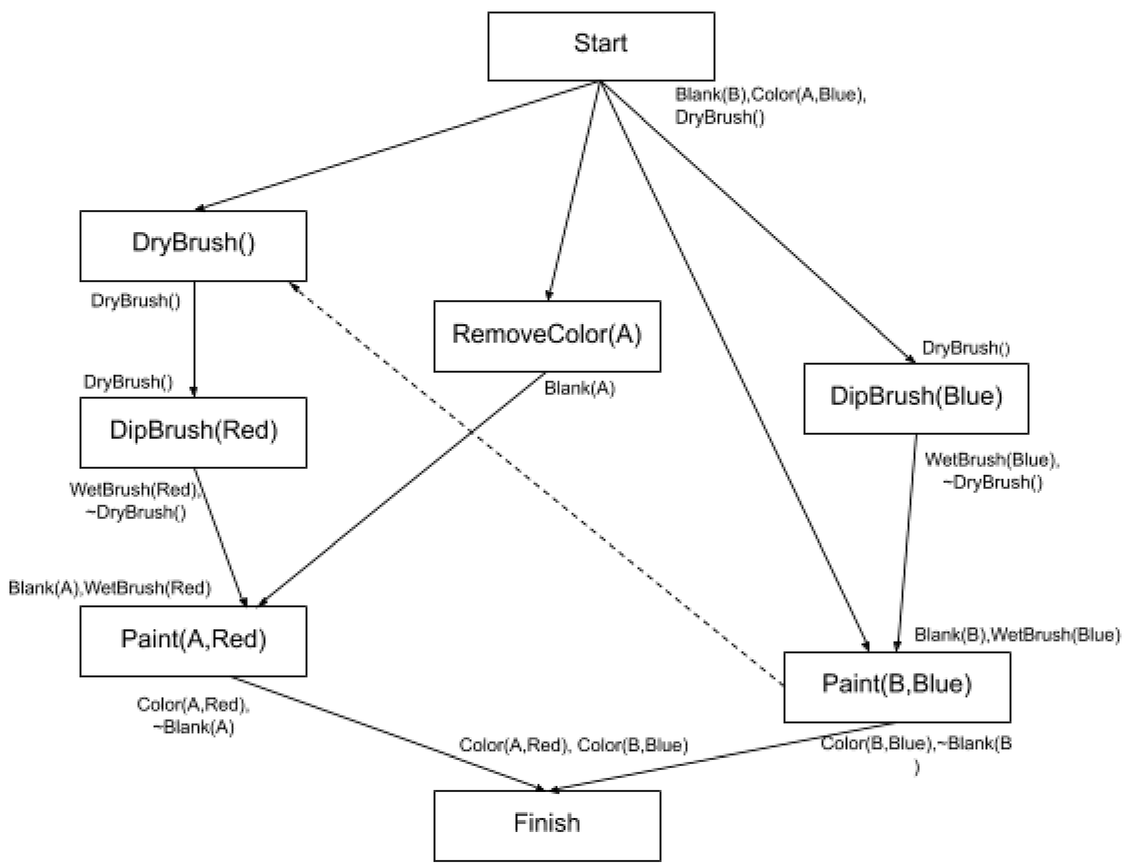
Action: Paint(b,c)
Preconditions: Blank(b), WetBrush(c) [-0.5% for any wrong/missing/extra predicate]
Effects: Color(b,c) , ~Blank(b) [-0.5% for any wrong/missing/extra predicate]

Action: RemoveColor(b)
Preconditions: -- / ~ Blank(b) / Color(b,c) [-1% for any wrong/missing/extra predicate]
Effects: Blank(b) [-1% for any wrong/missing/extra predicate]

5C. [9%]

Show the partial order plan for achieving the state:
Color(A, Red), Color(B, Blue)
Your answer must be a complete plan and in the form of a graph showing the actions from the Start state to the Final state using the actions above. Your answer must clearly show the precedence relationships between actions and causal links as applicable, allowing the plan executor to have as much choice in the sequencing of actions without violating any causal links.

[If the schema is not the plan as below, but is reasonably defined and consistent, give credit.]



-1% for any wrong/missing/extra action/arrow
-1% any precondition unsatisfied
-3% if not fully parallel that is not having as much choice
-5% if fully sequential and no parallelism

6. [8%] Multiple Choice related to Discussions

Each question has zero or more correct choices.
Circle the letters (a., b., c., etc) of all correct choices.
Partial credit: beware that you lose 1% for each wrong answer, up to losing 2% for each question (so: all correct = 2%; 1 mistake = 1%, 2+ mistakes = 0%).

1. In the discussion, we discussed logical entailment and logical inference, please circle all that are true

a. Entailment can be completely checked in the agent's brain/mind (F)
b. Entailment can be checked by truth tables because truth tables divide all possible worlds into groups (T)
c. Inference is the same as Entailment (F)
d. The best inference procedures should be sound and complete (T)
e. A conclusion derived from a sound inference procedure is not-consistent with entailment (F)

2. In the discussion, we discussed propositional and first-order logic, please circle all that are true

a. First-order logic cannot represent propositions whereas propositional logic can (F)
b. In first-order logic, objects are returned from predicates but not functions (F)
c. Objects are involved only in first-order logic and not in propositional logic (F)
d. Predicates cannot be used as arguments of other predicates in first-order logic (T)
e. Propositional logic can represent relationships between objects (T)

3. In the discussion, we discussed many logic inference mechanisms, please circle all that are true

a. Skolemization must consider the scopes of the variables (T)
b. Resolution can only use Conjunctive Normal Form (F)
c. Proof by contradiction can only be done by resolution (F)
d. Neither forward chaining nor backward chaining is complete (T)
e. Backward chaining is more efficient than forward chaining (T)

4. In the discussion, we discussed actions and planning, please circle all that are true

a. Defining actions need fluent predicates but not atemporal predicates (F)
b. Postconditions of an action must include all the changes made by the action (T)
c. All partial-order plans can be combined into a total-order plan (F)
d. Planning itself cannot change the definitions of actions (T)
e. Some planning problems can be solved using first-order logic (T)

SCRATCH PAPER PAGE - Please use this as your scratch paper (not graded).

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