Midterm 2 Exam

CSCI 561 Fall 2015: Artificial Intelligence

Student ID:

Last Name: ______________________________________

First Name: ______________________________________

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Instructions:

1. Date: **11/2/2015 from 5:00pm – 6:20 pm in SGM-123**
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. **The back of the pages will not be graded. You may use it for scratch paper.**
10. No questions during the exam. **If something is unclear to you, write that in your exam.**
11. **Be brief: a few words are often enough if they are precise and use the correct vocabulary studied in class.**
12. When finished, raise completed exam sheets until approached by proctor.
13. **Adhere to the Academic Integrity code.**

Problems	**100 Percent total**
1- General AI Knowledge	10
2- Propositional Logic	30
3- First Order Logic	35
4- Planning	15
5- Discussion-related	10

1. [10%] General AI Knowledge

[1 Point each]

For each of the statements below, fill in the bubble T if the statement is always and unconditionally true, or fill in the bubble F if it is always false, sometimes false, or just does not make sense.

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

1. **F** A good knowledge base will be able to answer any question.
2. **F** A truth table will grow polynomially with the number of variables.
3. **F** Fuzzy logic uses a step called segregation to combine results from several rules.
4. **F** Using particular letters for variables in FOL sentences ensures that the values can only be of a certain type.
5. **T** Successor-state axioms solve the representational frame problem.
6. **T** The completeness theorem states that any sentence entailed by a set of sentences can be proven from that set.
7. **F** Some sentences in propositional logic cannot be converted to CNF.
8. **T** Soundness of an inference algorithm means that the algorithm doesn't reach bogus conclusions.
9. **T** Some sentences in propositional logic cannot be converted to Horn Form.
10. **F** Generalized Modus Ponens will derive a solution for all possible values of the variables in the rule.

2. [30%] Propositional Logic

2.1 CNF [15%]

Convert the following propositional sentence into CNF.
Your answer must be simplified as much as possible and must exactly match the CNF form. You will lose points for any part of your final converted sentence that is not in CNF. At each step, describe the rule used for simplification.

$$\left[\neg(\boldsymbol{A} \Rightarrow \boldsymbol{B}) \vee [(\boldsymbol{C} \vee \boldsymbol{D}) \Rightarrow \boldsymbol{E}]\right] \Rightarrow (\boldsymbol{B} \wedge \boldsymbol{C})$$

Eliminate $\Rightarrow$, replace $\boldsymbol{\alpha} \Rightarrow \boldsymbol{\beta}$, with $\neg\boldsymbol{\alpha} \vee \boldsymbol{\beta}$ [4 points]

$$\neg\left[\neg(\neg \boldsymbol{A} \vee \boldsymbol{B}) \vee [\neg(\boldsymbol{C} \vee \boldsymbol{D}) \vee \boldsymbol{E}]\right] \vee (\boldsymbol{B} \wedge \boldsymbol{C})$$

De Morgan's Law, and double negation [4 points]

$$\left[\neg\neg(\neg \boldsymbol{A} \vee \boldsymbol{B}) \wedge \neg[\neg(\boldsymbol{C} \vee \boldsymbol{D}) \vee \boldsymbol{E}]\right] \vee (\boldsymbol{B} \wedge \boldsymbol{C})$$

$$[(\neg \boldsymbol{A} \vee \boldsymbol{B}) \wedge \neg\neg(\boldsymbol{C} \vee \boldsymbol{D}) \wedge \neg \boldsymbol{E}] \vee (\boldsymbol{B} \wedge \boldsymbol{C})$$

$$[(\neg \boldsymbol{A} \vee \boldsymbol{B}) \wedge (\boldsymbol{C} \vee \boldsymbol{D}) \wedge \neg \boldsymbol{E}] \vee (\boldsymbol{B} \wedge \boldsymbol{C})$$

Distributive law [7 points]

$$[(\neg \boldsymbol{A} \vee \boldsymbol{B} \vee \boldsymbol{B}) \wedge (\boldsymbol{C} \vee \boldsymbol{D} \vee \boldsymbol{B}) \wedge (\neg \boldsymbol{E} \vee \boldsymbol{B}) \wedge (\neg \boldsymbol{A} \vee \boldsymbol{B} \vee \boldsymbol{C}) \wedge (\boldsymbol{C} \vee \boldsymbol{D} \vee \boldsymbol{C}) \wedge (\neg \boldsymbol{E} \vee \boldsymbol{C})]$$

Since, $(\boldsymbol{\alpha} \vee \boldsymbol{\alpha}) = \boldsymbol{\alpha}$, [also acceptable, but optional step]

$$[(\neg \boldsymbol{A} \vee \boldsymbol{B}) \wedge (\boldsymbol{C} \vee \boldsymbol{D} \vee \boldsymbol{B}) \wedge (\neg \boldsymbol{E} \vee \boldsymbol{B}) \wedge (\neg \boldsymbol{A} \vee \boldsymbol{B} \vee \boldsymbol{C}) \wedge (\boldsymbol{C} \vee \boldsymbol{D}) \wedge (\neg \boldsymbol{E} \vee \boldsymbol{C})]$$

Since, $(\boldsymbol{\alpha} \vee \boldsymbol{\beta}) \wedge (\boldsymbol{\alpha} \vee \boldsymbol{\beta} \vee \boldsymbol{\gamma}) = (\boldsymbol{\alpha} \vee \boldsymbol{\beta})$ [also acceptable, but optional step]

$$[(\neg \boldsymbol{A} \vee \boldsymbol{B}) \wedge (\neg \boldsymbol{E} \vee \boldsymbol{B}) \wedge (\boldsymbol{C} \vee \boldsymbol{D}) \wedge (\neg \boldsymbol{E} \vee \boldsymbol{C})]$$

Note to graders: The order in which the rules are applied may differ. Further, given the commutativity of $\wedge$ operator, the order of clauses in the answer may differ as well.

If the simplification rule is not mentioned, deduct 1 point per step. students may have used different names for the rules, also acceptable
Any of the answers in green are acceptable.

2.2. [15%] Language and Representation.
You are given three boxes.
Exactly one of them contains Gold,
the other two are empty.
Let $\mathbf{B_i}$ represent {Box *i* contains Gold} and $\neg\mathbf{B_i}$ represent {Box *i* is empty}. Answer the following:

1. **[3%]** Represent the statement "Exactly One box contains Gold" using propositional logic in DNF using $\mathbf{B_1}$, $\mathbf{B_2}$, $\mathbf{B_3}$ as proposition symbols. ***(F1)***

$$(\boldsymbol{B_1} \wedge \neg \boldsymbol{B_2} \wedge \neg \boldsymbol{B_3}) \vee (\neg \boldsymbol{B_1} \wedge \boldsymbol{B_2} \wedge \neg \boldsymbol{B_3}) \vee (\neg \boldsymbol{B_1} \wedge \neg \boldsymbol{B_2} \wedge \boldsymbol{B_3})$$

[1] **[1]** **[1]**

2. **[6%]** Each box has a label as follows:
   a. **Box 1: This box is empty ($\neg\mathbf{B_1}$)**
   b. **Box 2: This box is empty ($\neg\mathbf{B_2}$)**
   c. **Box 3: The Gold is in Box 2 ($\mathbf{B_2}$)**

   Exactly one of the above statements is true (other two are false). Represent this fact using propositional logic. ***(F2)***

$$(\neg \boldsymbol{B_1} \wedge \neg\neg \boldsymbol{B_2} \wedge \neg \boldsymbol{B_2}) \vee (\neg\neg \boldsymbol{B_1} \wedge \neg \boldsymbol{B_2} \wedge \neg \boldsymbol{B_2}) \vee (\neg\neg \boldsymbol{B_1} \wedge \neg\neg \boldsymbol{B_2} \wedge \boldsymbol{B_2})$$

[2] **[2]** **[2]**

$$= (\boldsymbol{B_1} \wedge \neg \boldsymbol{B_2}) \vee (\boldsymbol{B_1} \wedge \boldsymbol{B_2}) = \boldsymbol{B_1}$$ **[Accept any of the three forms]**

[optional simplification, however if this written and is incorrect, deduct 2 points]

3. ***[6%]*** Use a truth table to enumerate and find values for ***(F1)*** and ***(F2)*** statements above and ***find the box that contains Gold.***
   [3, for the table, 1.5 for each column F1 and F2, no partial credit within the column]

B1	**B2**	**B3**	**F1 [1.5 pts]**	**F2 [1.5 pts]**
F	F	F	**F**	**F**
F	F	T	**T**	**F**
F	T	F	**T**	**F**
F	T	T	**F**	**F**
T	F	F	**T**	**T**
T	F	T	**F**	**T**
T	T	F	**F**	**T**
T	T	T	**F**	**T**

[3] **The only assignment that satisfies F1 and F2 is B1=T, B2=F, B3=F, hence Gold is in B1**

3. [35%] First Order Logic

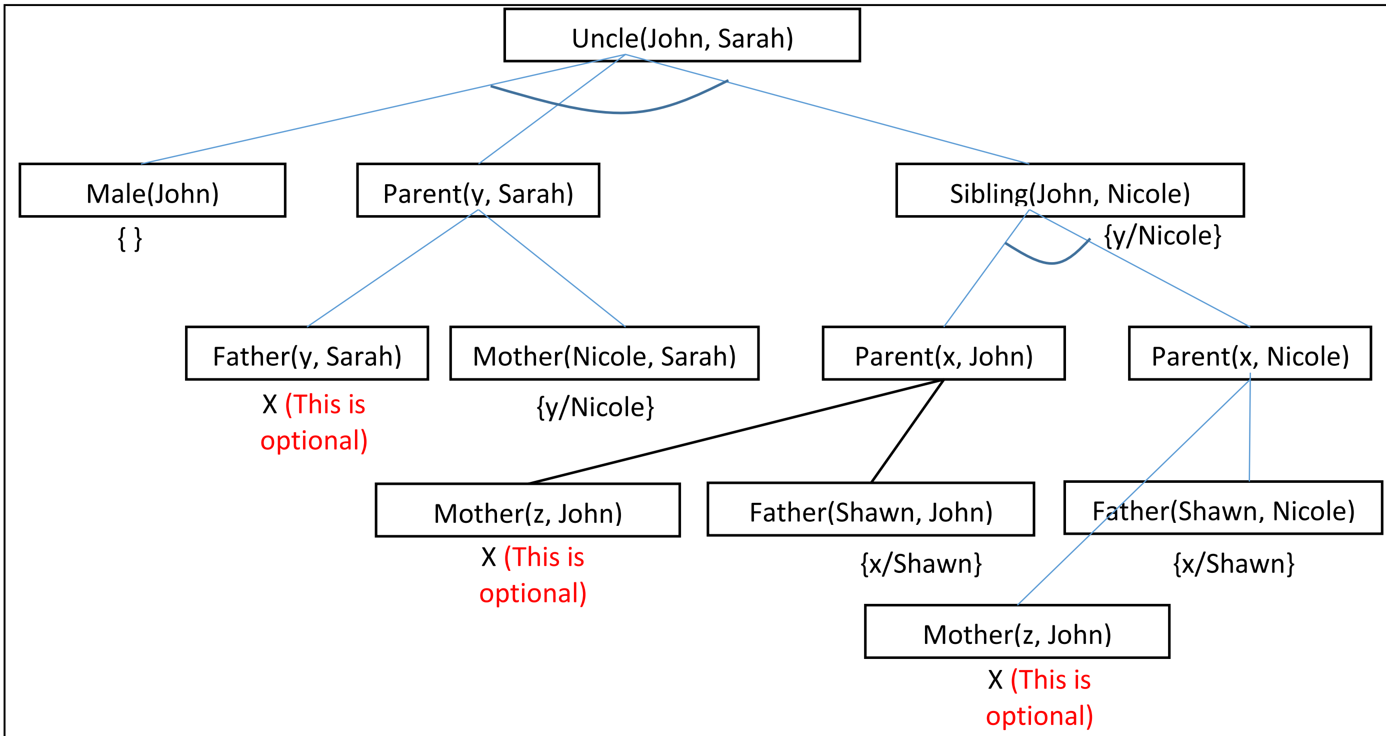
3.1. [15%] Backward Chaining

Consider the following sentences that are added
to a knowledge base in turn. ***Male***, ***Parent***, ***Father***,

Mother and ***Sibling*** are **predicates**, *John, Nicole, Sarah* and *Shawn* are constants, x, y, z, w, p are variables. Assume all sentences are implicitly universally quantified over all variables unless otherwise stated.

1. ***Male(x) ∧ Parent(y, z) ∧ Sibling(x, y) => Uncle(x, z)***
2. ***Father(x, y) => Parent(x, y)***
3. ***Mother(x, y) => Parent(x, y)***
4. ***∀ w,p w≠p (Parent(x, p) ∧ Parent(x, w) => Sibling(p, w))***
6. ***Male(John)***
7. ***Mother(Nicole, Sarah)***
8. ***Father(Shawn, Nicole)***
9. ***Father(Shawn, John)***

Given the KB above, show how ***backward chaining with GMP*** can be used to infer whether ***John*** is an ***Uncle*** of ***Sarah*** (i.e., ***Uncle(John, Sarah)***). Draw a backward-chaining inference graph. Be sure to show (1) a backward-chaining inference graph as studied in class, (2) all the substitutions used in unification at each stage, as relevant. Also mark if particular unification is not possible or fails. You will lose marks for any missing node or substitution. You will get 0 if you use any other method than backward chaining with GMP.



[2] Left Subtree (Male(John))
[3] Middle Subtree Parent(y, Sarah) and below
[5] Right Subtree Sibling(John, Nicole) and below (If the tree is partially correct, give partial points)
[2.5] Correct substitution of Nicole for **Mother(Nicole, Sarah) and Sibling(John, Nicole)**
[2.5] Correct substitution of Shawn for **Father(Shawn, John) and Father(Shawn, Nicole)**
NOTE to Students: See https://courses.uscden.net/d2l/le/8377/discussions/threads/5853/View for common errors and explanation before you contact TA.

3.2 [5%] Logic Sentences

Consider the following predicates:
A(x): x is an Animal
M(x): x is a Mammal
B(x): x is a Bird
MR(x): x is Marine (i.e. lives under water)
AR(x): x is Aerial (i.e. can fly)

Using the above predicates, translate the following English sentences into logic expressions:

1. **[1%]** All Mammals are animals

$\forall x\, M(x) \Rightarrow A(x)$

2. **[1%]** Some Birds Cannot Fly

$\exists x\, B(x) \wedge \neg AR(x)$
Also acceptable,
$\neg\forall x\, \neg B(x) \vee AR(x)$ **OR** $\neg\forall x\, B(x) \Rightarrow AR(x)$

3. **[1%]** Bat is the Only Mammal that can Fly

$\forall x\, M(x) \wedge AR(x) \Rightarrow (x = Bat)$ **(if students add M(bat) ∧ AR(bat) that is acceptable)**

4. **[2%]** Animals are either Marine or Aerial but not BOTH.

$\forall x\, A(x) \Rightarrow \big(MR(x) \wedge {\sim}AR(x)\big) \vee \big({\sim}MR(x) \wedge AR(x)\big)$

Note:

MR(X)	AR(x)	**R1**	**R2 = XOR**
0	0	**1**	**0**
0	1	**1**	**1**
1	0	**1**	**1**
1	1	**0**	**0**

AMEND: If student's expression evaluates to either R1 or R2, then SOLUTION is ACCEPTABLE for full 2 points.
It should be A(x) => XYZ (or equivalent. If the student does not mention A(x), give 0)

3.3. [15%] Resolution

Given the query

$\exists x\ E(x) \vee \neg B(x)$

And the following knowledge base:

$\forall x\ A(x) \Rightarrow (B(x) \wedge \neg C(x))$

$\exists x\ A(x) \wedge D(x)$

$\forall x\ C(x) \vee E(x)$

Convert each statement to CNF (hint: some of the given sentences may become split into several CNF sentences), and use **resolution** and a **proof by contradiction** to prove the query. Please show the complete resolution proof, including all substitutions used (you will lose points for any missing step or substitution).

(1) $Q = \exists x\ E(x) \vee \neg B(x)$

$\neg Q = \forall x\ \neg E(x) \wedge B(x) = \neg E(x) \wedge B(x) = \ \neg E(x), B(x)$ **[2]**

If they first converted it to CNF (i.e. skolemized) to Q = E(K)∨¬B(K). and then negate to ¬E(K)∧B(K) then give [1] point. If they negate it to $\neg E(x) \wedge B(x)$ give full [2] points.

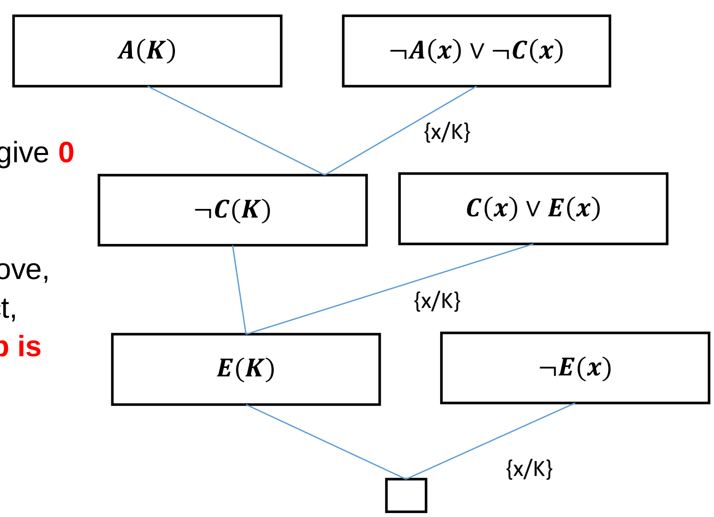
(2) $\forall x\ A(x) \Rightarrow \big(B(x) \wedge \neg C(x)\big) = \ \forall x\ \neg A(x) \vee \big(B(x) \wedge \neg C(x)\big) = \forall x\ \big(\neg A(x) \vee B(x)\big) \wedge \big(\neg A(x) \vee \neg C(x)\big) = \neg A(x) \vee B(x),\ \ \neg A(x) \vee \neg C(x)$ **[2]**

(3) $\exists x\ A(x) \wedge D(x) = A(K) \wedge D(K) = \ A(K), D(K)$ **– using Skolemization Constant [2]**

(4) $\forall x\ C(x) \vee E(x) = C(x) \vee E(x)$ **[2]**

NOTE: The resolution tree is for 7 points.
If students make any INCORRECT resolution, give **0 Points.**

If they used the incorrect query negation as above,
But ALL The shown resolution steps are correct,
Then give **3 points. But if any resolution step is Incorrect give 0.**



NOTE: Students may not have written the tree in different form. Check each resolution step.
NOTE to Students: See https://courses.uscden.net/d2l/le/8377/discussions/threads/5821/View for common errors and explanation before you contact TA.

4. [15%] Planning

4.1 [3%] STRIPS actions

Consider the slightly different block world problem than the one studied in class, where only one box can be placed onto each location A, B, or C on the table. As in the block world studied in class, boxes can be stacked onto other boxes.

Please describe the **STRIPS actions** required for a robot to rearrange the boxes in the Box world described in Fig. 1. (Hint: You may define an action that is to move the box from one place to another.)

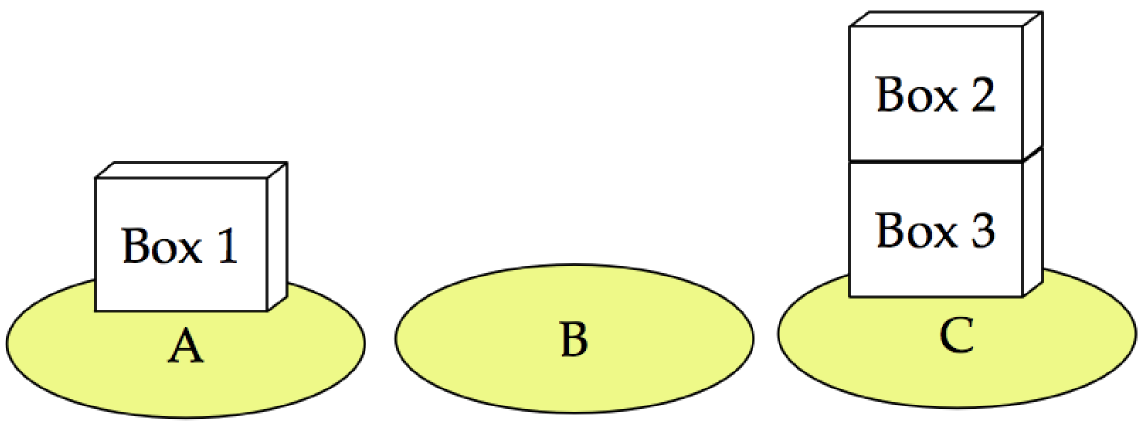


Figure 1: Box world

Action: moveFromTo(Box, X, Y)
Precondition: on(Box, X), clear (Box), clear(Y)
Postcondition: on(Box, Y), clear (X), NOT on(Box, X), NOT clear(Y)

Partial credit: 1 point for the action, precondition and postcondition respectively.

Different kinds of actions and their pre-/postconditions are acceptable as long as they take into account that the robot can only grab the topmost box and is not intelligent.

4.2 [4%] Initial (empty) plan

Your plan is to rearrange the boxes from the starting state in figure 1 so that Box 3 is in Place A, Box 2 is in Place B and Box 1 is in Place C.
Write down the initial condition and the goal of this plan using your STRIPS definitions from 4.1.

Initial condition:

on(Box1, A), on(Box3, C), on(Box2, Box3), clear(Box1), clear(B), clear(Box2).

Goal:

on(Box3, A), On(Box2, B), On(Box1, C), *clear(Box1), clear(Box2), clear(Box3) (Clear(x) are optional here)*

Partical credit: 2 points each for the initical condition and the goal.

4.3 [8%] Complete plan

Write down your plan to reach the goal
from the initial condition, using the initial
condition and goal that you specified in 4.2.

Diagram is Mandatory. With each state and preconditions, postconditions, actions. Promotion/Demotion list. (Dash arrows)

If it is text, text should mention all the details, preconditions/postconditions etc.

moveFromtTo(Box2, C, B)
moveFromTo(Box1,A,Box2)
moveFromTo(Box3, C, A)
moveFromTo(Box1,B,C)

2 Points for each step, or if the solution is based on a different set of actions which require more or fewer steps, split the points accordingly.

6. [10%] AI Applications

Circle the letter that corresponds
to the best answer for the question:

1. [2pts] In the debate between Neats vs Scruffies, this is home of the Scruffies.
    a. Stanford
    b. CMU
    c. MIT
    d. All of the above
    e. None of the above

2. [2pts] The creators of Prolog sacrifice soundness for efficiency by using:
    a. Inheritance
    b. **No Occurs-Check**
    c. Frame axioms
    d. All of the above
    e. None of the above

3. [2pts] This uses a type hierarchy/ontology:
    a. Semantic Network
    b. Amazon
    c. Facebook
    d. **All of the above**
    e. None of the above

4. [2pts] Knowledge sharing is hard because:
    a. Knowledge bases are too small
    b. Knowledge bases have the same query interface
    c. All knowledge bases use the same upper ontology
    d. All of the above
    e. **None of the above**

5. [2pts] Transitivity reasoning is supported by:
    a. OWL 2
    b. Wordnet
    c. **PartOf hierarchy [acceptable for 2 points]**
    d. **All of the above [both c and d are acceptable for 2 points]**
    e. None of the above