Christopher Reed

COGS 125 / CSE 175
Introduction to Artificial Intelligence
Midterm Examination

900

David C. Noelle

October 27, 2016

Instructions

This examination is to be completed during the normal class meeting period on Thursday, October 27, 2016. It is to be completed *without* the assistance of any material other than these test pages. In particular, you may *not* reference course textbooks, any lecture slides, or any of your notes before completing and submitting your examination booklet for evaluation. Neither may you make use of the assistance of any other person during the examination period, with the exception of the individual who is proctoring the exam. If needed, please approach the proctor quietly to present any questions of clarification, so as not to disturb others in the classroom.

Responses to questions are to be written directly on these test pages. Please show all of your work, demonstrating how you derived your responses to these questions. Clearly indicate continuations of responses onto the back sides of test pages. Additional blank pages are also available at the end of the test packet.

Please be sure that your name appears on every page of the exam before you submit it for evaluation.

Scoring

This examination contains ten (10) questions, many of which contain multiple parts. Each part of each question is labeled with the maximum number of points which will be awarded for a correct response to that part. The sum of these point values — the total number of points for the entire exam — is 1500.

Questions

The next page contains a collection of logical equivalences that may be useful to you as you complete this examination. Examination questions begin on the subsequent page.

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Logical Equivalences

$$
\begin{aligned}
(\alpha \land \beta) &\equiv (\beta \land \alpha) \\
(\alpha \lor \beta) &\equiv (\beta \lor \alpha) \\
((\alpha \land \beta) \land \gamma) &\equiv (\alpha \land (\beta \land \gamma)) \\
((\alpha \lor \beta) \lor \gamma) &\equiv (\alpha \lor (\beta \lor \gamma)) \\
\neg(\neg\alpha) &\equiv \alpha \\
(\alpha \Rightarrow \beta) &\equiv (\neg\beta \Rightarrow \neg\alpha) \\
(\alpha \Rightarrow \beta) &\equiv (\neg\alpha \lor \beta) \\
(\alpha \Leftrightarrow \beta) &\equiv ((\alpha \Rightarrow \beta) \land (\beta \Rightarrow \alpha)) \\
\neg(\alpha \land \beta) &\equiv (\neg\alpha \lor \neg\beta) \\
\neg(\alpha \lor \beta) &\equiv (\neg\alpha \land \neg\beta) \\
(\alpha \land (\beta \lor \gamma)) &\equiv ((\alpha \land \beta) \lor (\alpha \land \gamma)) \\
(\alpha \lor (\beta \land \gamma)) &\equiv ((\alpha \lor \beta) \land (\alpha \lor \gamma)) \\
(\alpha \land \alpha) &\equiv \alpha \\
(\alpha \lor \alpha) &\equiv \alpha \\
(\alpha \land \neg\alpha) &\equiv \mathit{False} \\
(\alpha \lor \neg\alpha) &\equiv \mathit{True} \\
(\alpha \land (\mathit{True})) &\equiv \alpha \\
(\alpha \land (\mathit{False})) &\equiv \mathit{False} \\
(\alpha \lor (\mathit{True})) &\equiv \mathit{True} \\
(\alpha \lor (\mathit{False})) &\equiv \alpha
\end{aligned}
$$

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1. *History & Philosophy*

For each the following multiple choice questions, circle the single best answer from among the listed options.

(a) [20 points] The first official use of the phrase "artificial intelligence" to describe this field, marking the "birth of artificial intelligence" as a field, happened ...

i. ... in the writings of Aristotle in the Fourth Century BCE.

ii. ... in the writings of Charles Babbage in the 19th Century.

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iii. ... in a scientific paper written by Warren McCulloch and Walter Pitts in 1943.

iv. ... in an essay written by Alan Turing in 1950.

v. ... in John McCarthy's proposal for a meeting at Dartmouth College in 1956.

(b) [20 points] The first demonstration of a formal relationship between propositional logic and the functioning of simple neural network models appeared ...

i. ... in the writings of Aristotle in the Fourth Century BCE.

ii. ... in the writings of Charles Babbage in the 19th Century.

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iii. ... in a scientific paper written by Warren McCulloch and Walter Pitts in 1943.

iv. ... in an essay written by Alan Turing in 1950.

v. ... in John McCarthy's proposal for a meeting at Dartmouth College in 1956.

(c) [20 points] Which of the following is *not* true of Marvin Minsky?

i. He attended the Dartmouth workshop in 1956.

ii. He produced one of the first neural network computers.

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iii. He helped to write a book that contributed to nearly halting neural network research for many years.

iv. He proved that a complete inference procedure exists for first-order logic.

v. He supervised many students who built programs that addressed problems in *microworlds*.

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(d) [20 points] One argument for the claim that we will never be able to know if a system possesses strong artificial intelligence is ...

i. ... the intentional stance.
ii. ... the mathematical objection.
iii. ... the symbol grounding problem.
iv. ... the argument from informality.
v. ... the problem of philosophical zombies.

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(e) [20 points] The *Weak AI* hypothesis claims that ...

i. ... a machine could be conscious.
ii. ... a machine could never be conscious.
iii. ... a machine could act as if it were conscious.
iv. ... a machine could never act as if it were conscious.
v. ... only machines modeled on the human brain can be conscious.

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(f) [20 points] The "brain prosthesis" thought experiment, advocated by Hans Moravec, is intended to support the claim that ...

i. ... a machine could be conscious.
ii. ... a machine could never be conscious.
iii. ... a machine could act as if it were conscious.
iv. ... a machine could never act as if it were conscious.
v. ... only machines modeled on the human brain can be conscious.

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(g) [20 points] John Searle intended his "Chinese room" thought experiment to be a convincing argument that ...

i. ... understanding a natural language is needed for true knowledge and intelligence.
ii. ... understanding a natural language is not necessary for true knowledge and intelligence.
iii. ... symbol manipulation can produce true knowledge and intelligence.
iv. ... symbol manipulation is insufficient for true knowledge and intelligence.
v. ... only machines modeled on the human brain can be conscious.

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2. *Agent Architectures*

For each the following multiple choice questions, circle the single best answer from among the listed options.

(a) [20 points] What is rational at any given time depends on four of the things listed below, but it does *not* depend on ...

i. ... the performance measure.

ii. ... the agent's memory capacity.

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iii. ... the agent's percept sequence to date.

iv. ... the agent's prior knowledge of the environment.

v. ... the actions that the agent can perform.

(b) [20 points] In general, simple reflex agents are to be preferred over utility-based agents when ...

i. ... the environment is episodic.

ii. ... the enviornment is only partially observable.

20

iii. ... the environment involves multiple agents.

iv. ... costs and benefits must be carefully weighed.

v. ... the agent must choose actions quickly.

(c) [20 points] In general, utility-based agents are to be preferred over goal-based agents when ...

i. ... the environment is episodic.

ii. ... the enviornment is only partially observable.

20

iii. ... the environment involves multiple agents.

iv. ... costs and benefits must be carefully weighed.

v. ... the agent must choose actions quickly.

(d) [20 points] The primary problem with the `TABLE-DRIVEN-AGENT` architecture is that ...

i. ... it cannot, even in principle, implement important classes of *agent functions*.

ii. ... it cannot, even in principle, take into account the *utility function* of the agent.

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iii. ... it cannot, even in principle, leverage the power of parallel computation.

iv. ... it can result in unacceptably slow performance.

v. ... it can require an unacceptably large amount of memory.

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(e) [20 points] In a general *learning agent*, the *learning element* receives performance feedback from the . . .

i. . . . *critic.*
ii. . . . *utility function.*
iii. . . . *problem generator.*
iv. . . . *performance element.*
v. . . . *performance standard.*

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(f) [20 points] Which one of the following problem environments are *not* usually seen as *deterministic*?

i. go
ii. chess
iii. checkers
iv. backgammon
v. battleship

20

(g) [20 points] Which one of the following problem environments are *not* usually seen as *fully observable*?

i. go
ii. chess
iii. checkers
iv. backgammon
v. battleship

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Great!

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3. *Heuristic Search*

You are writing a route planning program for a robot that is to navigate through a maze. The maze is laid out on a square grid so that, on each time step, the robot has the choice of moving North, South, East, or West, though some directions might be blocked by walls. The robot is equipped with a camera mounted on a tall pole which rises well above the maze walls, allowing the robot to see the whole maze in order to plan its route before it begins moving. You want to find the route that minimizes the number of "moves" from one grid square to an adjacent grid square (i.e., path cost is measured in grid squares). You decide to use A* search to plan this route, using the city-block distance (i.e., Manhattan distance) heuristic function, measured in grid squares. You are in a hurry, however, so you do *not* implement repeated state checking.

(a) [30 points] Will your search program be *complete*?

30

The program will be complete.

(b) [30 points] Will your search program be *optimal*?

30

It will also be optimal.

(c) [60 points] You discover that some grid squares in the maze contain clearly visible pits. If the robot were to enter one of these squares, it would surely fall into the pit and be unable to escape. In terms of the route planning search tree, these states have no successors. If you persist in using the A* search algorithm and the same heuristic function as described above, without any modification, will your search program be *complete*? Will it be *optimal*?

Pits have no successors

0

If the robot views the pits as it would a normal square, the search program would not be complete nor would it be optimal since the robot could just fall into a pit.

Yes, complete

Yes, optimal

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(d) [40 points] A friend suggests that you modify your heuristic function. She recommends using city-block distance, as before, for all grid squares except for those containing pits. She suggests that grid squares containing pits should be assigned a heuristic value equal to the total number of grid squares in the whole maze, regardless of the location of the pit. Would you take this suggestion? If so, why? If not, why do you think this modification is a bad idea?

20

I would take this suggestion. Since the heuristic value would be a lot higher on pits than the normal squares adjacent to pits, the robot will never go into a pit. Rather, it would go to a different adjoining normal square.

fewer nodes expanded

More accurate heuristic function than city-block. So, fewer nodes expanded and better.

because it's closer to the true path cost of the pit squares (infinity)
since it's greater than the heuristic function

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4. *Optimization Search*

[140 points] Consider an optimization search problem in which almost all of the states have the same very low goodness value. There are a small number of very different "solution" states, however, and these states all have about the same high value of goodness. There are virtually no states that have intermediate levels of goodness. Now, consider the following two optimization search algorithms:

- *Algorithm A* — local beam search
- *Algorithm B* — genetic algorithm with two-point crossover and mutation

For this optimization problem, do you think that Algorithm A will find a "solution" state much more quickly than Algorithm B? Do you think that Algorithm B will find a solution much more quickly than Algorithm A? Or, do you think that the two algorithms would perform similarly? Why?

No Intermediate state between global maxs.

Algorithm B will find a solution more quickly than Algorithm A since the crossovers and mutations provide a random effect to the algorithm. With a random effect, there is more chance of finding a solution state.

0

Both perform similarly and poorly. Both would generate and test for random points. They both suck

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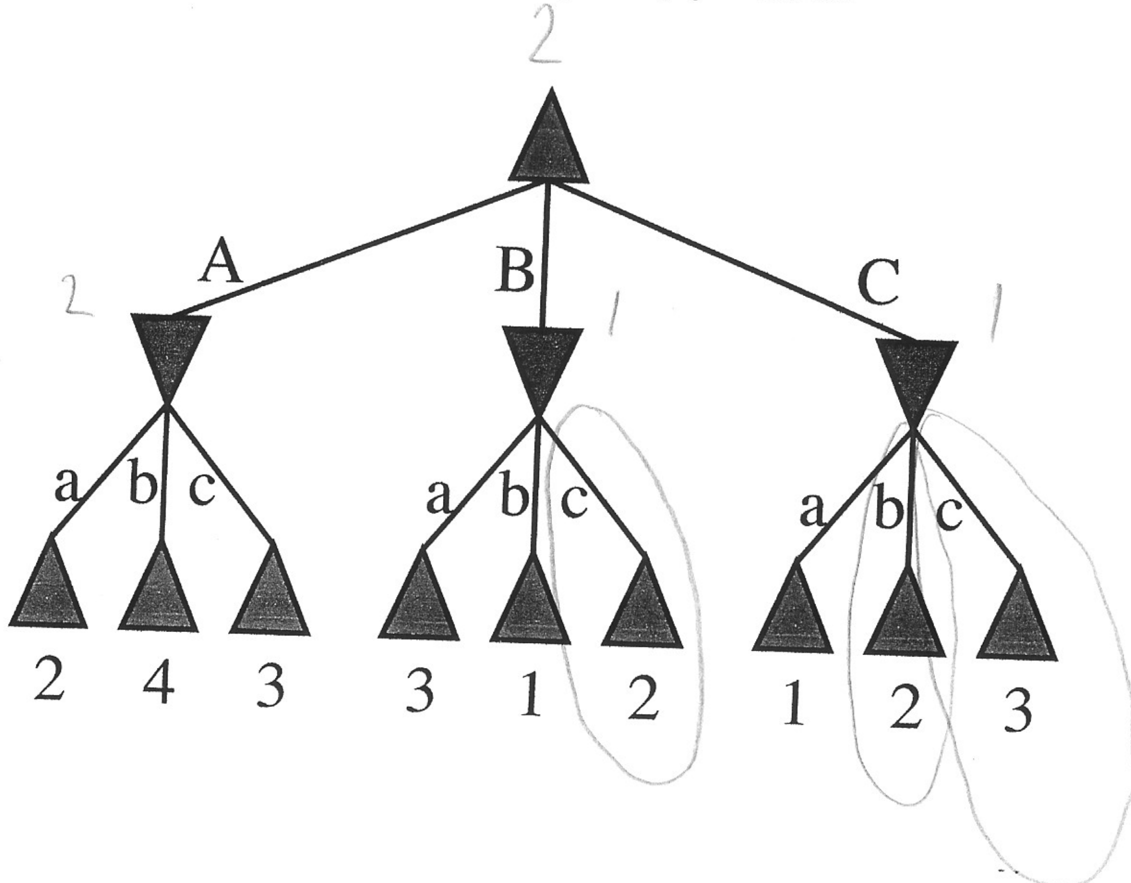
5. *Adversarial Search*

[140 points] Consider the complete game tree, below. In this diagram, upward pointing nodes are MAX nodes, and downward pointing nodes are MIN nodes. The letters labeling arcs correspond to *moves* or *actions*. The leaves of this tree are terminal states, with the corresponding payoffs listed next to the nodes. **Circle all nodes that would be pruned** if alpha-beta pruning were applied to this game tree, assuming that actions are considered in alphabetical order. **Also, clearly indicate, below, which action should be selected by the MAX player and what the minimum expected payoff will be.**



140

SELECTED ACTION: A

MINIMUM PAYOFF: 2

140

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6. *Propositional Logic*

(a) [40 points] In terms of logical entailment and inference, what does it mean for an inference procedure to be *complete*?

40 It is complete when if a knowledge base can entail it, then it follows that the base can infer it.

if $KB \models \alpha$, then $KB \vdash_i \alpha$

(b) [40 points] In terms of logical entailment and inference, what does it mean for an inference procedure to be *sound*?

40 It is sound when if a knowledge base can infer it, then it follows that the base can entail it.

if $KB \vdash_i \alpha$

then $KB \models \alpha$

(c) [20 points] Is the following sentence *valid*, *unsatisfiable*, or *neither*?

20 $\neg Smart \Leftrightarrow Smart$ Unsatisfiable

(d) [20 points] Is the following sentence *valid*, *unsatisfiable*, or *neither*?

20 $\neg Smart \Rightarrow Smart$ Neither

(e) [20 points] Is the following sentence *valid*, *unsatisfiable*, or *neither*?

20 $\neg Lazy \Rightarrow (\neg Smart \lor \neg(Lazy \lor \neg Smart))$ Valid

(f) [20 points] Is the following sentence *valid*, *unsatisfiable*, or *neither*?

20 $((\neg Smart \Rightarrow Smart) \Leftrightarrow (Smart \land (Lazy \Rightarrow Lazy)))$ Valid

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7. *First-Order Logic*

Consider the following set of constants, functions, and predicates for the world of unsettled people ("iff" is shorthand for "if and only if"):

- *Tamika* — a constant referring to a person named Tamika
- *Fred* — a constant referring to a person named Fred
- *Merced* — a constant referring to the city of Merced
- *Fresno* — a constant referring to the city of Fresno
- *Move(x, y, z)* — a function referring to the action of person x moving from location y to location z
- *Person(x)* — a predicate which is true iff x is a person
- *Location(x)* — a predicate which is true iff x is a location
- *Resident(x, y, s)* — a predicate which is true iff x is in location y in situation s
- *Neighbor(x, y, s)* — a predicate which is true iff both x and y are residents of the same location in situation s

Use this ontology to answer the following questions.

(a) [50 points] Write a first-order logic sentence that provides a definition for the *Neighbor* predicate.

exists x exists y exists z ((Person(x) ∧ Person(y) ∧ Location(z) ∧ Resident(x, z, s) ∧ Resident(y, z, s)) → Neighbor(x, y, s))

$\forall x, y, s \ \ Neighbor(x, y, s) \Leftrightarrow \exists z \ Resident(x, z, s) \wedge Resident(y, z, s)$

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(b) [40 points] Translate the following English sentence into first-order logic: "There was a time when Fred and Tamika resided in the same location."

exists x, s (Location(x) ∧ Resident(Fred, x, s) ∧ Resident(Tamika, x, s))

(CK I put exists s, 40 points)

30

$\exists s \exists x$ Resident(Fred, x, s) ∧ Resident(Tamika, x, s)

(c) [40 points] Translate the following English sentence into first-order logic: "Everybody always has a neighbor."

all x all y all z ((Person(x) ∧ Person(y) ∧ Location(z) ∧ Resident(x, z, s) ∧ Resident(y, z, s)) → Neighbor(x, y, s))

$\forall x \forall s$ Person(x) → $\exists y$ Person(y) ∧ Neighbor(x, y, s)

0

(d) [50 points] Without using the uniqueness quantifier, translate the following English sentence into first-order logic: "Every person resides in exactly one location."

all x exists y (((Person(x) ∧ Location(y)) → Resident(x, y, s)) ∧ exists z (Location(z) ∧ (z = y)))

$\forall x \forall s$ Person(x) → [$\exists y$ Resident(x, y, s) ∧ ($\forall z$ Resident(x, z, s) → (z = y))]

10

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(e) [80 points] Convert the following first-order logic sentence into conjunctive normal form:

$$\exists s\ \forall x\ (Person(x) \wedge Resident(x, Merced, s)) \Rightarrow (\exists z\ Resident(x, Fresno, z))$$

Becomes skolem constant

Since stuff is left of z, becomes a function, not constant

∃s ∀x ¬(Person(x) ∧ Resident(x, Merced, s)) ∨ (∃z Resident(x, Fresno, z))

∃s ∀x (¬Person(x) ∨ ¬Resident(x, Merced, s)) ∨ (∃z Resident(x, Fresno, z))

∀x (¬Person(x) ∨ ¬Resident(x, Merced, A)) ∨ (Resident(x, Fresno, B))

(¬Person(F(x)) ∨ ¬Resident(F(x), Merced, A)) ∨ (Resident(F(x), Fresno, B))

Should've been a skolem function

¬Person(F(x)) ∨ ¬Resident(F(x), Merced, A) ∨ Resident(F(x), Fresno, B)

function

60 $\neg Person(x) \vee \neg Resident(x, Merced, A) \vee Resident(x, Fresno, B(x))$

60

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8. *Rule Chaining* {Variable / Constant}

(a) For each of the following sentence pairs, provide the most general unifier for the two sentences, or indicate that none exists. (Retain the given variable names. Do *not* standardize variables apart.)

i. [20 points] $P(A, B, A)$ and $P(x, y, z)$

0

P(X, Y, X) {X/A, Y/B, Z/A}

ii. [20 points] $Q(G(A, B), y)$ and $Q(y, G(x, x))$ Variable can only take on one value. Can't do {x/A, x/B}

20

None exist

iii. [20 points] $Wiser(Father(y), y)$ and $Wiser(Father(x), John)$

0

Wiser(Father(John), John) {x/John, Y/John}

iv. [20 points] $Knows(Father(y), y)$ and $Knows(x, x)$ x is Father(y)

0

~~Knows / Father~~ Knows(Father(x), x) none exist

Cannot bind Y / Father(Y)

(b) [20 points] Does forward chaining over definite clauses form a *sound* inference procedure?

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Forward chaining over definite clauses can form a sound inference procedure.

(c) [20 points] Does forward chaining over definite clauses form a *complete* inference procedure?

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Forward chaining over definite clauses forms a complete inference procedure.

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9. *Resolution Theorem Proving*

[120 points] What clause results from applying the binary resolution inference rule to the following two sentences? Apply any required substitutions to the resulting clause.

$$\neg Person(x) \vee Neighbor(x, Tamika, Result(Move(x, Fresno, Merced), s))$$

$$Resident(x, y, s) \vee \neg Neighbor(Fred, x, Result(Move(Fred, y, Merced), s))$$

¬ Person(Fred) ∨ Resident(Tamika, Fresno, s)

120 great!

Person (x)

Resident (a, b, z) {x/Fred, a/Tamika, b/Fresno, z/s}

¬ Person(x) ∨ Resident (a, b, z)

120

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10. *The Situation Calculus*

[120 points] Using the ontology from Question 7, write the successor-state axiom for the predicate *Resident*.

~~exists x exists y (Resident (x, y, s)~~

Resident (x, y, s, a) $\Leftrightarrow$ exists x exists y ((Person(x) $\wedge$ Location (y)) $\to$ Resident(x, y)) $\wedge$

0

a = Resident (x, y, S))

$$\forall x, y, a, s \quad Resident(x, y, Result(a, s)) \Leftrightarrow$$

Either the action made it true $\to$

$$(\exists z \; Resident(x, z, s) \wedge (a = Move(x, z, y)))$$

They moved from z to y

OR

$$\vee$$

OR

it was already true and the action did not make it untrue.

$$(Resident(x, y, s) \wedge \neg(\exists z \; \neg(z = y) \wedge (a = Move(x, y, z)))$$

They were already in y and did not move.

0