CIS 490 / 730

Principles of Artificial Intelligence

Midterm Exam (Closed-Book, Closed-Notes, Open-Mind)

Monday, 16 Oct 2006

Instructions and Notes

- You have 60 minutes for this exam. Budget your time carefully.
- No calculators or computing devices are need or permitted on this exam.
- You are permitted 2 pages of notes (front and back). Turn your notes in with your exam.
- Your answers on short answer and essay problems shall be graded for originality as well as for accuracy.
- You should have a total of 8 pages; ***write your name on each page***.
- Use only the printed side of pages for your answers; you should not need additional pages.
- Show your work on problems and proofs.
- In the interest of fairness to all students, no questions shall be answered during the test concerning problems. If you believe there is ambiguity in any question, ***state your assumptions***.
- There are a total of 200 possible points in this exam.

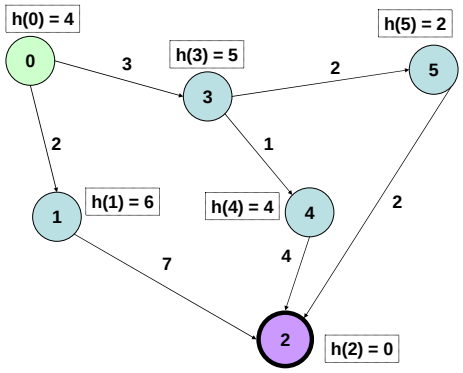
Instructor Use Only

1. _____ / 40
2. _____ / 40
3. _____ / 40
4. _____ / 40
5. _____ / 40

Total _____ / 200

1. Search (3 parts, 40 points total).

a) (3 points each, 6 points total) Data structures for graph search. Write down the adjacency list **and** the adjacency matrix for the following graph.



b) (16 points) Uninformed and Heuristic Search. Simulate the behavior of Branch and Bound and A/A* search for the above graph with start node **0** and goal node **2**. Show the evolution of the OPEN and CLOSED lists **and the path found**, with costs. *Break ties in ascending order of node number (lower-numbered nodes are expanded first in case of a tie).*

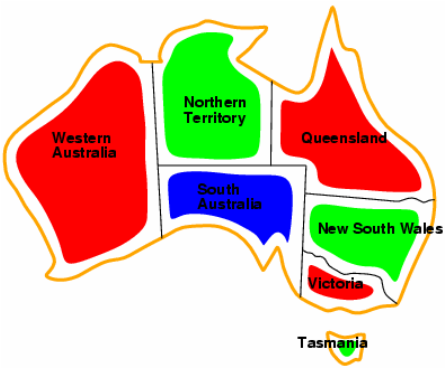
(8 points) Branch and Bound:

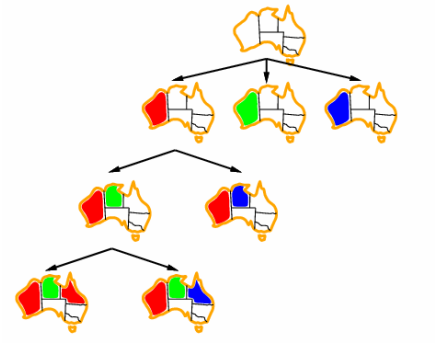
(8 points) A/A* search:

c) (6 points each, 18 points total) Monotonicity/Consistency vs. Admissibility. Circle one choice for each question.

- o Is the heuristic above admissible? Yes No
- o Is it monotonic/consistent? Yes No
- o Does one imply the other? No
  Yes, Admissible → Consistent only
  Yes, Consistent → Admissible only
  Yes, Consistent ↔ Admissible

2. Constraint Satisfaction Problems (2 parts, 40 points total). Consider the following map coloring problem:





a) (10 points) CSP graph representation. Draw a graph representation of the above CSP and specify what the edges (links or neighborhood function) and vertices (nodes) mean.

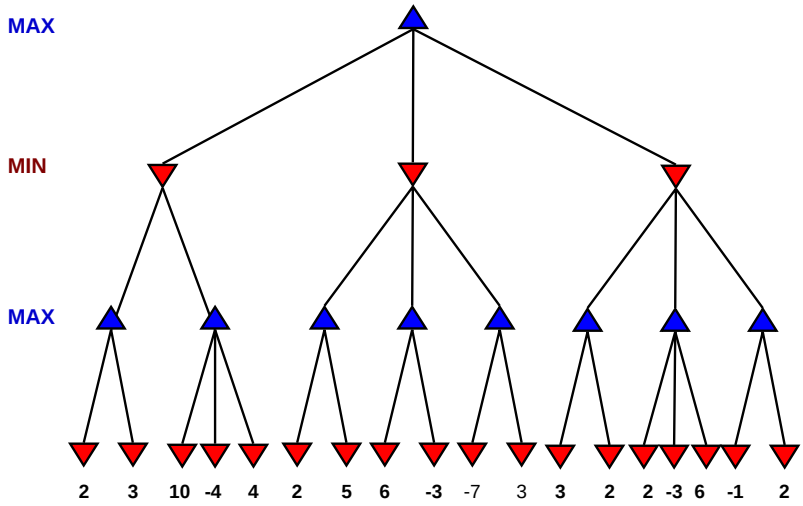
b) (10 points) CSP Solutions. What graph properties must does a solution have, given the above representation?

c) (20 points) CSP Methods. Define **one** of the following and illustrate it with an example using the above graph.

i) *Most constrained variable / Minimum remaining values (MRV) heuristic* for variable selection
ii) *Least constraining value* for value ordering
iii) Forward checking for speeding up constraint checking

3. Game Tree Search (2 parts, 40 points total).

Consider this game tree:



i. (10 points) Simulate the behavior of the ***minimax algorithm*** on the above game tree.

ii. (30 points) Simulate the behavior of minimax with **alpha-beta (α-β) pruning** on the above game tree. Show your work: mark the ~~pruned branches~~ by crossing them out, **indicate which values are α and which are β**, and number the static evaluations and all value updates and inequality tests versus α and β, in order.

4. First-Order Logic (3 parts, 40 points total).

a) (10 points) Clausal form. Write down the steps for converting an arbitrary first-order logic (FOL) sentence into clausal form, and apply them to the following sentence:

For every pair of Foos x and y, there is a Bar z such that z is not a Baz of x but it is a Quidditch of y.
$\forall$ x, y . Foo(x, y) $\rightarrow \exists$ z . Bar(z) $\wedge \neg$Baz(x, z) $\wedge$ Quidditch(y, z)

b) (10 points) Sentences in FOL. Write the following English sentences in FOL. (Specify your predicates and give their meaning in your own words.)

i. (5 points) For every trio of Blings x, y, and z, there is a Blang w that is a Boom of at least two out of the three Blings.

ii. (5 points) ♬ They laughin' and rollin' their eyes 'cause I'm so white n' nerdy ♬ ("*Weird Al" Yankovic*) **Hint**: formalize this sentence as an implication, so that "they" are quantified and identified as people.

c) (20 points) Complexity of First-Order Satisfiability and Validity: In terms of a first order logical sentence α, define the formal languages $L_{FOL\text{-}SAT}$ and $L_{FOL\text{-}VALID}$ along with their complements, and specify the *decision problem* for membership in each. Indicate which languages are *duals* and which are *complements.* Given that membership in $L_{FOL\text{-}SAT}$ is undecidable (i.e., that $L_{FOL\text{-}SAT}$ is not recursive enumerable), state the decidability properties for the other three.

5. Resolution theorem proving (3 parts, 40 points total).

(Based on a logic problem by Lewis Carroll.) Consider the following knowledge base:

i) None of the Others are good people.
ii) Every person from Oceanic Flight 815 is on the Island by design.
iii) All of the people who are stranded on the Island like mangoes.
iv) No one who is on the island by design is a bad person.
v) No person who is not from Oceanic Flight 815 likes mangoes.

a) (10 points) Write down all of the sentences above in implicative form.

b) (20 points) **Prove:** Everyone who is stranded on the Island is not an Other.

Hint: Convert every sentence above into an CNF propositional logic statement, e.g., $\neg O \vee \neg G$ for part c, where O denotes "The person is one of the Others" and G denotes "The person is a good person". Write out the direct statement (e.g., $A \rightarrow B$) and contrapositive statement. Show the proof using **resolution only**. You need not negate the target sentence; just show that you are able to prove it by forward chaining.

c) (10 points) What kind of resolution strategy (input, unit, linear, set of support) is applicable for answering the **query** "is no one stranded on the Island an Other"? How is the strategy applied?