CIS 530 / 730
Principles of Artificial Intelligence

Midterm Exam (Open-Textbook, Closed-Notes, Open-Mind)
Wed 17 Oct 2012

<u>Instructions and Notes</u>

- CIS 530 students: choose any **4 out of the 6 problems** to work.
- 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 11 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.

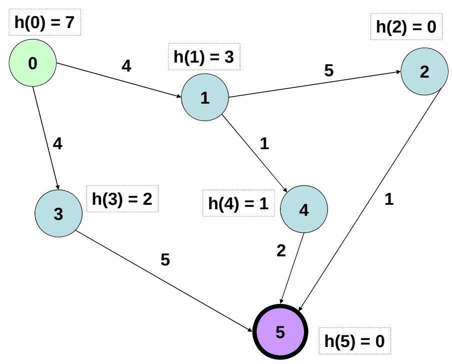
<u>Instructor Use Only</u>

1. ______ / 40 (730) or 50 (530)
2. ______ / 40 (730) or 50 (530)
3. ______ / 40 (730) or 50 (530)
4. ______ / 40 (730) or 50 (530)
5. ______ / 40 (730) or 50 (530)
6. ______ / 40 (730) or 50 (530)

Total ______ / 200

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

a) (5 points) Data structures for graph search. Write down the adjacency matrix for the following graph. (You do **not** have to write the adjacency list.)



b) (20 points) Uninformed and Heuristic Search. Simulate the behavior of Greedy and A/A* search for the above graph with start node **0** and goal node **5**. Show the evolution of the OPEN and CLOSED lists **and the path found**, with costs. For each search, *indicate whether the solution is optimal.* Break ties in ascending order of node number (lower-numbered nodes are expanded first in case of a tie).

(10 points) Branch-and-Bound:

Path found: ____

Optimal path cost in this case? Y / N

(10 points) A/A* search:

Path found: ____

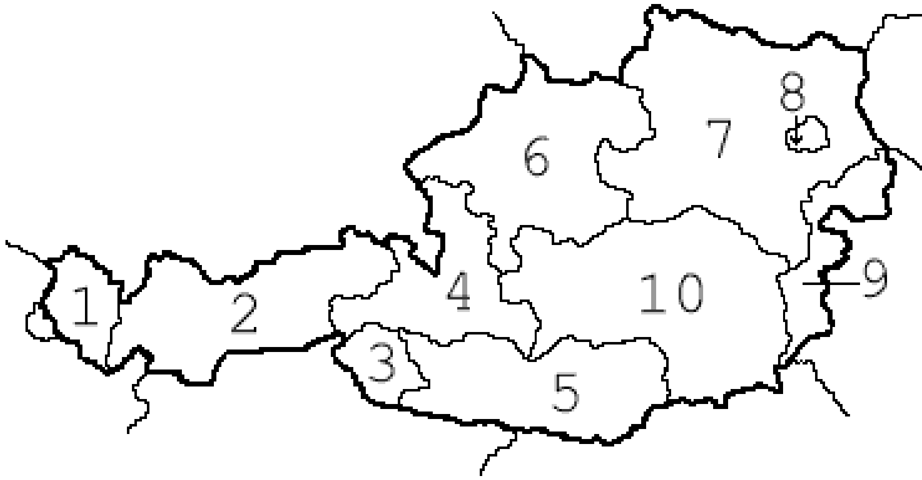
Optimal path cost in this case? Y / N

c) **(5 points) Branch-and-Bound Search.** Would your solution to part (b) for Branch-and-Bound change if the edge cost from Node 3 to Node 5 was 2 instead of 5? How so?

d) **(5 points) Best-First Search.** Explain in your own words the relationship between A* search and Branch-and-Bound search.

e) **(5 points) 530 only. Hill-Climbing vs. Greedy Search.** Does hill-climbing expand a different path than greedy search?
(5 points) 730 only. Consistency. Is the heuristic consistent? Why or why not?

2. Constraint Satisfaction Problems (2 parts, 40 points total). Consider the problem of coloring each node in the 10-node map of Austria (© 2004 About.com, http://bit.ly/TuSZAV) with one of three colors (**R**, **G**, **B**):



a) (10 points) Constraint graph representation. Draw the constraint graph for the above map and explain what the edges and vertices (nodes) mean.

b) (20 points) CSP Methods. Suppose Node 1 (Vorarlberg) is colored **Red**. **530 students:** Define **one** of the following and illustrate it with an example using the above graph. **730 students**: Define any **two** and illustrate them with examples.

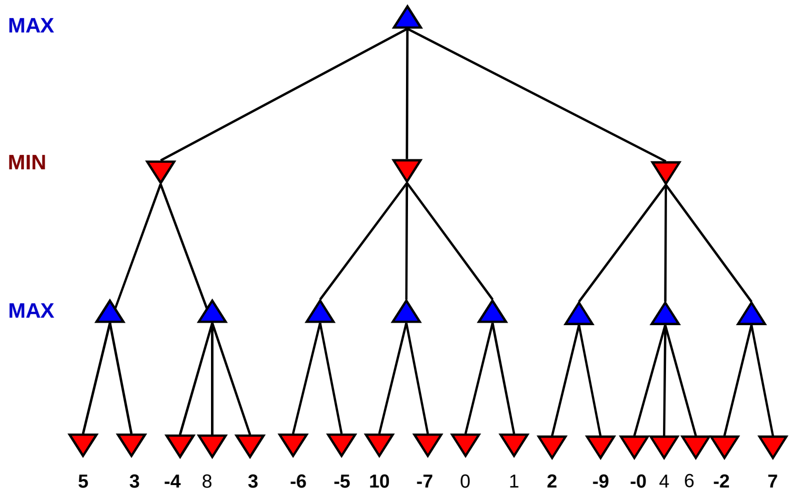
i) *Most constrained variable / Minimum remaining values (MRV) heuristic* for variable selection
ii) *Least constraining value* for value ordering
iii) *Forward checking* for speeding up constraint checking

(Scratch space)

a) **(10 points) 3-coloring.** Show that the graph **is** 3-colorable by finding a 3-coloring consistent with part (b). You need not use any of the above heuristics, but they should help.

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. (20 points for 530, 10 points for 730) 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,

iii. **(10 points, 730 only)** Indicate **which values are α and which are** β and show the tests and backing up of values, 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:

Not every student who has no questions can answer any question.

$\neg \forall$ s,

{ [Student (s) $\wedge$ $\neg\exists$ q . Has-Question (s, q)] $\rightarrow$

$\forall$ q . Can-Answer (s, q) }

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

i. (5 points) Everyone envies all people who envy no one. **Predicates:** Person (x), Envies (x, y).

ii. (5 points) ♬ All the other kids with the pumped up kicks / You'd better run, better run, outrun my gun ♬ (*Foster the People,* "Pumped Up Kicks")

Predicates: Kid (k), Has (k, p), Pumped-Up-Kicks (p), Need-to-Run (k, speed), Greater-Than (x, y) or >

Functions: speed-of (x), gun-of (k),

Constant: ME

Hint: Use equality where needed to enforce "other".

c) **(10 points) Decidability of First-Order Validity and Unsatisfiability:** In terms of a first order knowledge base KB and logical sentence α, define the formal languages $L_{FOL\text{-}VALID}{}^{C}$ (the language of non-valid sentences) and $L_{FOL\text{-}SAT}{}^{C}$ (the language of unsatisfiable sentences), and explain the *decision problem* for membership in each in terms of what entails or does not entail $\perp$ (and from what resolution does or does not derive $\perp$). Are these languages *duals*, *complements,* or related in some other way? State the decidability properties for these two languages (decidable, *i.e.*, recursive; semi-decidable, *i.e.,* recursive enumerable but not recursive; or undecidable, *i.e.*, not recursive enumerable). Is the decidability class the same for $L_{FOL\text{-}VALID}{}^{C}$ and $L_{FOL\text{-}SAT}{}^{C}$?

d) (10 points) Resolution theorem proving. (Based on a logic problem by Lewis Carroll.) Consider the following knowledge base:

i) $\neg C \rightarrow D$
ii) $C \rightarrow \neg B$
iii) $\neg E \rightarrow \neg F$
iv) $E \rightarrow \neg D$
v) $A \rightarrow B$

Prove the theorem $A \rightarrow \neg F$ by **refutation resolution**.
Indicate which resolution strategies (input, linear, unit) are being applied**. Use at least one such strategy.**
Hint: Convert every sentence above into a CNF propositional logic statement, e.g., $A \rightarrow \neg B \equiv \neg A \vee \neg B$ for part (i). Negate the query (theorem) and derive $\perp$.

5. Planning (2 parts, 40 points total).

a) (20 points) Sussman Anomaly. Illustrate the Sussman Anomaly in Blocks World and show how it can be solved using partial-order planning with promotion and demotion.

b) (20 points) Handling Indeterminacy in HTN Planning. Consider the four approaches towards bounded indeterminacy in planning:

1. Sensorless planning
2. Conditional planning
3. Execution monitoring and replanning
4. Continual planning

Select **one** of these approaches and, in a couple of paragraphs, give an example of it for the domain of selecting a term project in this course.

6. Abstract Data Types, Description Logics. and Ontologies (2 parts, 40 points total).

c) (10 points) Basic Inheritance. Illustrate one example of inheritance in any domain other than the Elephant domain covered in class.

d) (30 points) Defeasible Inheritance. Give an example of defeasible inheritance and explain using a counterexample why "minimum distance" may not work in determining what properties are inherited.