CIS 530/730

(Introduction to) Artificial Intelligence
Fall, 2011

Final Exam (Open-Book, Open-Notes, Open-Mind)

Instructions and Notes

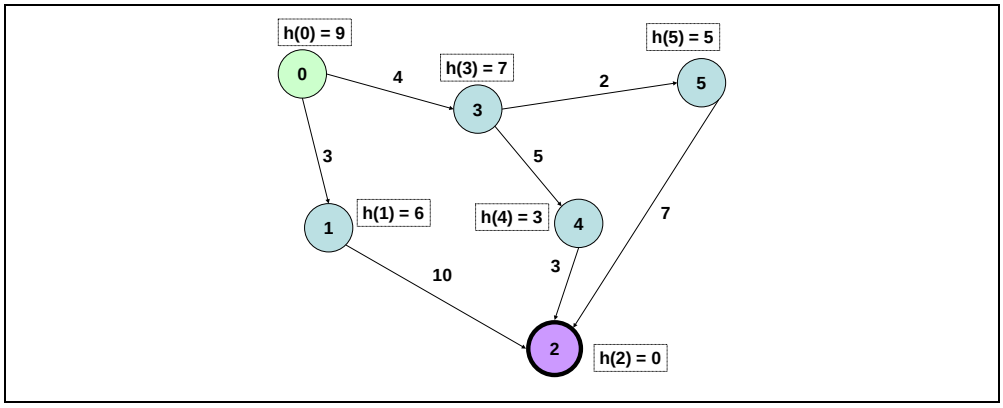
- You have 120 minutes for this exam. Budget your time carefully.
- **CIS 530 students: Choose any four** of the six problems to work. Your highest four scores will be counted. Circle "530" in the large, boldface title above.
- **CIS 730 students: Choose any five** of the six problems to work. Your highest five scores will be counted. Circle "730" in the large, boldface title above.
- Basic scientific calculators (with logarithms) are permitted on this 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 14 pages; write your name on **each** page.
- Use only the front 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 300 possible points in this exam.

Instructor Use Only

	Score	Counted
1.	_____ / 60 or 75	_____
2.	_____ / 60 or 75	_____
3.	_____ / 60 or 75	_____
4.	_____ / 60 or 75	_____
5.	_____ / 60 or 75	_____
6.	_____ / 60 or 75	_____

Total _____ / 300

1. Heuristic Search: Problem Solving, Proof, Discussion (3 parts)



a) (24 or 30 points) Heuristic Search. Simulate the behavior of A/A* and greedy search for the above graph with start node **0** and goal node **2**. **Show all work,** including 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).*

A/A* search:

Greedy search:

b) (24 or 30 points) Admissibility and Consistency (Monotone Restriction).

i. Is the above heuristic admissible? Why or why not?
ii. Is it consistent (*i.e.*, is h(*parent*) ≤ h(*child*) + c(*parent*, *child*) for every *parent* and *child*)? Why or why not?
iii. Are all consistent heuristics admissible? Why or why not?

c) (12 or 15 points) Algorithm A/A*, Optimality, and Optimal Efficiency. How come A* is *optimally efficient* but still explores a suboptimal path? What does this say about the heuristic?

2. Definitions (5 parts, 12 or 15 points each).

a) Global Optimization and the Foothill Problem. Define *global optimization* in your own words and relate it to the problem of foothills (local optima). What kind of problems have foothills and what kind have *relative minima*? Illustrate your answer to give an example.

b) Alpha-Beta (α-β) Pruning. Define alpha (α) and beta (β) in minimax game tree search (what the values actually stand for) and explain in your own words how they can help in pruning. Use an illustration if needed.

c) Logic. Explain, in terms of logical representation and possible worlds, what it means for a knowledge base KB to *entail* a sentence α. What does it means for α to be *derivable* or *provable* from the knowledge base KB? What is the difference between these two properties? (**Hint:** On what does provability depend besides KB and α?)

d) Conditional planning. In your own words, explain the method of *conditional* or *contingent planning* in robust planning, and give an example of conditional planning (specify which one and give a definition of the one you chose) in a problem-solving domain such as Angband or the Wumpus World.

e) Entropy. Define *entropy* in decision tree induction as a function of a class label (give the formula and define all variables).

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3. Logic and Resolution (3 parts, 60 or 75 points total).

a) Converting to clausal form (24 or 30 points). Convert the following sentence to clausal form. List out the steps and show your work.

$\forall$ a . P(a) $\Rightarrow$ [$\forall$ b $\exists$ c . Q(a, b) $\wedge$ $\neg$R(b, c)]

b) Sentences in FOL (16 or 20 points total) Translate the following sentences to FOL. Write your interpretation of each sentence first, **explaining the semantics** of all predicates used, and state any assumptions you use to resolve ambiguity.

i. *(8 or 10 points) Someone who loves no one is loved by no one.*

ii. *(8 or 10 points) ♬ I pity the fool who falls in love with you ♬* (Cee Lo Green) **Hint:** A literal interpretation of this sentence is "any one who is a person and falls in love with you is a fool and I pity him".

c) Proof (25 points). (Based on a logic problem by Lewis Carroll.) Consider the following knowledge base:

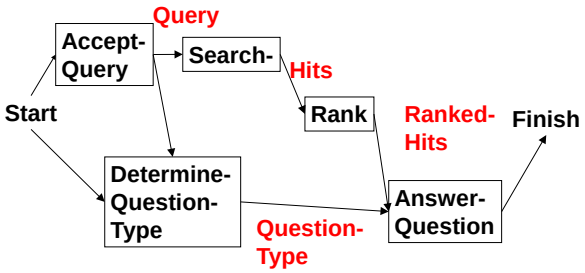
A. No program has ever beaten Rinzler.
B. Everyone who is scanned by the Digitalizer is a digital human.
C. Everyone who tries to hack ENCOM has escaped the Grid.
D. No digital human has ever lost to (not beaten) Rinzler.
E. No one who was not scanned by the Digitalizer has ever escaped the Grid.

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

b. (20 points) **Prove:** No one who tries to hack ENCOM is a program.

4. **Planning and Learning: Problem Solving, Short Essay (3 parts, 60 or 75 points total).** HAL 3000, a large software corporation, hires you to develop a hierarchical abstraction planning system for question answering in the game show *Peril!*

a) (16 or 20 points) Hierarchical Decomposition Planning (Section 12.2, R&N 2e). Consider the following abstract plan:



Answer-Question

Suppose you have a database of question types that, once determined by classification, can be used to re-rank candidate answers or filter out those that do not match a template form (*e.g.*, "contains the word `green'"). Give a refinement of the "Answer-Question" step of ths abstract plan into concrete steps and indicate examples of the following by marking them:

- Action
- Causal link
- Open precondition

b) (12 or 15 points) Planning based upon Past Experiences. Explain the concept of *continual* or *lifelong* planning in your own words and discuss how a lifelong planner might make use of information gathered from past games played, past searches that have produced cached hits, or documents crawled from the web.

c) (12 or 15 points). Handling Indeterminacy in HTN Planning. Consider the four approaches towards bounded indeterminacy in planning:

i. Sensorless planning
ii. Conditional planning
iii. Execution monitoring and replanning
iv. Continual planning

Select *one* of these approaches and, in a couple of paragraphs, explain how hierarchical abstraction simplifies your chosen robust planning approach or makes it more difficult **for the search agent task given in part (a)**. Give one aspect where abstraction simplifies planning and one aspect where it complicates the planning process.

d) (20 or 25 points) Decision Tree Induction. Show all work.

The principal of a high school in Spoons, Washington is alarmed by the number of students who have recently been murdered in acts of inexplicable violence. He enlists your help to look into the background of students.

The input variables are:

1. Gender
2. Is a klutz
3. Class (junior or senior)
4. Plays baseball

(Index) Apprentice	Gender	Klutz?	Class	Baseball?	(Output) Family?
1	Male	No	Senior	Yes	Vampire
2	Male	Yes	Junior	No	Human
3	Male	No	Junior	Yes	Werewolf
4	Male	No	Senior	Yes	Vampire
5	Male	Yes	Junior	Yes	Human
6	Male	No	Junior	No	Werewolf
7	Male	No	Senior	Yes	Vampire
8	Female	No	Senior	Yes	Vampire
9	Female	Yes	Junior	No	Human
10	Female	No	Junior	Yes	Human
11	Female	No	Senior	No	Werewolf
12	Female	No	Senior	No	Human
13	Female	No	Junior	No	Werewolf
14	Female	No	Junior	Yes	Human

i. **(4 or 5 points)** What is the conditional entropy H(*Family* | *Baseball* = Yes)?

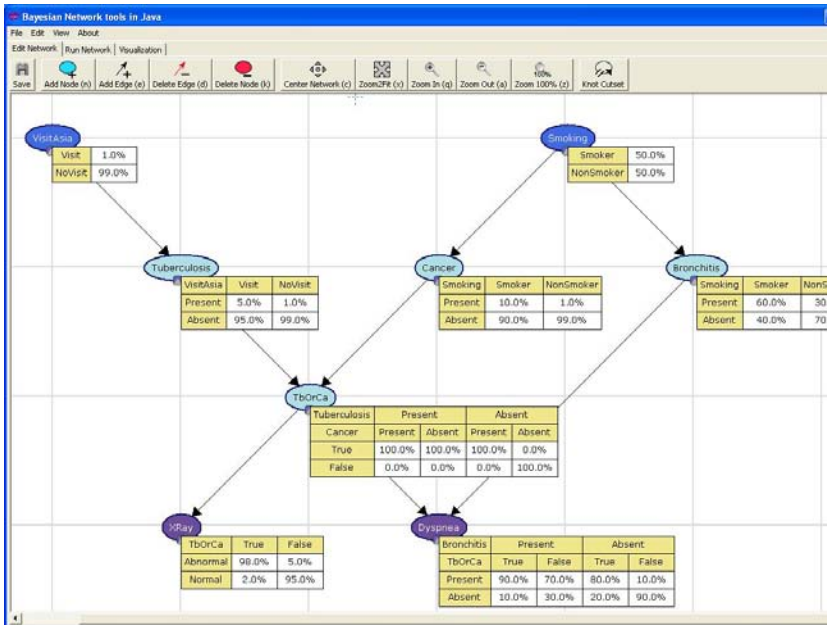
ii. **(4 or 5 points)** What is H(*Family* | *Class* = Senior)?

iii. **(12 or 15 points)** What attribute would the decision tree-building algorithm choose to use as the root of the tree (assume no pruning)? **Show your work.**

(scratch space for d)

5. Bayesian Networks: Problem Solving (3 parts, 60 or 75 points total). Choose any <u>three</u> of the following four parts.

Consider the following Bayesian network:



a) (20 or 25 points) Conditional Probability Tables. Explain what the tables stand for by labeling each one with a conditional probability $P(X_i \mid X_1, X_2, \ldots, X_n)$.

b) (20 or 25 points) Evidence, Hidden, and Query Variables. Define *evidence, hidden,* and *query variables* and give a partition classifying each of the above seven nodes Bayesian network above as one of these.

c) (20 or 25 points) Hierarchy of Bayesian network topologies. State the hierarchy of topologies: polytree, multiply-connected network, tree, singly-connected network, star. Circle or draw examples of each that are **subgraphs** of the above network.

d) (20 or 25 points) Conditional Independence and Markov Neighborhoods. Explain what it means for a random variable *X* to be conditionally independent of another random variable *Y* given a third random variable *Z*. What is the Markov neighborhood of a node and what does it have to do with conditional independence?

6. Neural Networks, Genetic and Evolutionary Computation (GEC), Natural Language, and Vision (3 parts, 75 points total). Choose any <u>three</u> of the following four parts.

a) (20 or 25 points) Perceptrons. Define *linear separability* and explain why a perceptron cannot represent non-linearly separable concepts. What happens when a non-linearly separable **data** is presented to a perceptron?

b) (20 or 25 points) Genetic and Evolutionary Computation (GEC): Genetic Programming. List out and define the five basic steps in designing a GP.

c) (20 or 25 points) Machine Translation. List and explain three of the four computational advances that led to the breakthroughs in machine translation in the early 2000s.

d) (20 or 25 points) Segmentation and Edge Detection in Computer Vision. Define an *edge* in computer vision and discuss how the task of *edge detection* relates to the task of *segmentation* in computer vision.