

NAME: _____
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Computer Science and Engineering 151
Introduction to Artificial Intelligence
April 29, 2004

MIDTERM EXAM

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO START!!!!

- Please DO NOT put your name at the top of each page:
 - This should prevent residual sexism, racism, favoritism lurking in the unconscious of your professor & TA from biasing grading!!
- THE EXAM IS CLOSED BOOK. IN FACT, PLEASE LEAVE YOUR BOOKS AT THE FRONT OF THE CLASS!
- Once the exam has started, SORRY, NO TALKING!!!
- No, you can't even say "later, dude!"
- There are 6 problems: Make sure you have all of them - AFTER I TELL YOU TO START!
- Read each question carefully.
- Remain calm at all times!

Problem	Type	Points	Score
1	True/False	15	
2	Uncertainty	15	
3	Bayes' Rule	15	
4	Inference in Bayesian Networks	20	
5	More inference in Bayesian Networks	15	
6	Utility	20	
	Total	100	

True/False

1. (15 pts: +1 for correct, -1 for incorrect, 0 for no answer)

If you would like to justify an answer, feel free.

- _____ The $p(X = x|Y = y, Z = z, X = w)$ (where w is some value) must be 0 or 1
- _____ Exact inference in singly connected networks or polytrees is generally exponential in the size of the network.
- _____ State of the art for speech recognition involves generating a large number of features (on the order of 10,000), per 40 ms window of speech.
- _____ A node is conditionally independent of its descendants given its parents.
- _____ $p(X_1, X_2, \dots, X_n) = p(X_4)p(X_1, \dots, X_3, X_5, \dots, X_n|X_4)$ for $n > 5$
- _____ Given $x = [1 \ 2; 3 \ 4]$, $x[2, 1]$ will return 3.
- _____ Documentation strings in Matlab are just comments after the function definition.
- _____ For any distribution with n variables, if we use conditional probability tables, the best we can do is $2^n - 1$ entries.
- _____ $p(A, B) = p(A)p(B)$
- _____ $p(A \text{ or } B) = p(A) + p(B) - 2 p(A, B)$
- _____ The general form of Bayes rule is $p(A|B, e) = \frac{p(A, e|B)p(A|e)}{p(B|e)}$
- _____ In matlab,

 $[2 \ 2; 2 \ 2]^2 = [4 \ 4; 4 \ 4];$
- _____ For approximate inference algorithms, for two particular runs, a run for 10,000 iterations is guaranteed to be more correct than a run with 1,000 iterations.
- _____ The *Markov Blanket* of a node includes the parents of the node, the children of the node, and the parents of the parents of the node.
- _____ The Reverend Thomas Bayes's Rules are a set of rules concerning the development of morality of a population by showing how the conditions of a poor upbringing generating the morality of the children are propagated to their children, because the children's morality then generate the conditions for their children.

Uncertainty (15 points)

2(a) (6 pts, 2 each) Given the table below:

	toothache		$\neg$ toothache	
	catch	$\neg$ catch	catch	$\neg$ catch
cavity	0.108	0.012	0.072	0.008
$\neg$ cavity	0.016	0.064	0.144	0.576

- What is the marginal probability of a toothache?
- What is the probability of catch and not cavity?
- What is the probability of a toothache, given a cavity and a catch?

2(b) (3 pts) Explain the difference, if any, between a Boolean random variable, a discrete random variable, and a continuous random variable:

2(c) (2pts) How is the probability of a continuous random variable usually defined?

2(d) (4pts) List two of the properties of **atomic events**:

Bayes' Rule (15 pts)

3. (15 pts) Using the following probabilities and Bayes' rule, compute the probability that John has lung cancer given that he has a bad cough, and the probability that John has pneumonia given that he has a bad cough.

L = John has lung cancer

N = John has Pneumonia

C = John has a bad cough

$$P(L) = .0001$$

$$P(N) = .01$$

$$P(C|L) = .9$$

$$P(C|\sim L) = .5$$

$$P(C|N) = .9$$

$$P(C|\sim N) = .5$$

Recall Bayes' rule:

$$P(H|E) = P(E|H) * P(H)/P(E)$$

Show your work!

Inference in Bayesian Networks (20 pts)

4.(a) (8pts) Given a network with four nodes A, B, C, D . Draw the network with the following independence assumptions and only these independence assumption (i.e. no more assumptions):

$$A \perp B$$

$$A \perp C$$

$$A \perp D$$

$$B \perp C$$

(b) (8pts) Given the following definition of a Bayes net with binary variables:

A,

B with parent A,

C with parent B,

derive the expression for $p(B = 1 | C = 0)$ for this network, where each entry of the expression can be directly looked up in the conditional probability tables for this network.

(c) (4pts) We can view the inference enumeration algorithm as a tree as described in Russell and Norvig. Draw the tree for the query in (b). Label the edges for the entries in the conditional probability table (for example, $p(A = 1)$).

More Inference in Bayesian networks (15pts)

Describe three different **approximate** inference methods for Bayes nets. State precisely and concisely the advantages and disadvantages of using each approach. Feel free to compare/contrast approaches when describing advantages/disadvantages.

Utility theory (20 points)

6(a) (9 points). Define three of the six axioms of utility theory.

6(b) (6 points). Describe, in the notation of a lottery (you don't have to get the notation exactly right – just be sure it is clear what you mean), the situation where monty hall says, you can trade this bag of \$10,000 for the choice between these three doors. Behind one of the doors is a brand new Hummer (estimated value, \$100,000). Behind the one of the other door is a free subscription to *Reader's Digest*, valued at \$10, and behind the other, a year's worth of **Subway** sandwiches, worth about \$1,000.

6(c) (5 pts) How does Mutual Preferential Independence (MPI) in deterministic domains dictate the form of a multiattribute Utility (now a Value) Function? I.e., write down the form of the following 3 attribute utility function if MPI holds (2pts):

$$U(x_1, x_2, x_3) =$$

What if we are in a stochastic domain and we have Mutual Utility Independence (3pts)?

$$U(x_1, x_2, x_3) =$$