PLEASE HAND IN

UNIVERSITY OF TORONTO
FACULTY OF ARTS AND SCIENCES

DECEMBER 2010 EXAMINATIONS

CSC384H1F

Duration – 3 hours

Examination Aids: Non-Programmable Calculators, 1-Sided A4 Aid-Sheet

Name: ____
Surname   Given Names

Student Number: ______________________________________

Q1	/ 25
Q2	/ 5
Q3	/ 18
Q4	/ 30
Q5	/ 28
Q6	/ 14
Total	/ 120

Question 1 – Search (25 Total Marks)

A basic Brio railway set contains the pieces shown in Figure 1. The task is to connect *all* these pieces into a *single* railway that has *no loose ends* where a train could run off onto the floor and no *overlapping* tracks.

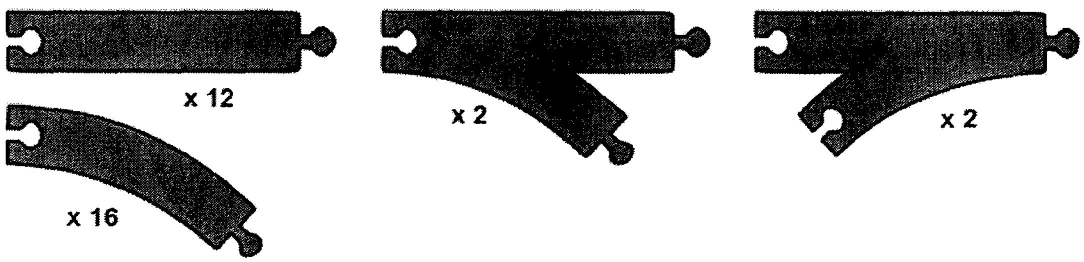


Fig. 1: The track pieces in a basic Brio set. Note that curved pieces and "fork" pieces ("switches" or "points") can be flipped over, so they can curve in either direction. Each curve subtends 45 degrees.

a. **(10 marks)** Suppose that the pieces fit together *exactly* with no slack. Give a precise formulation of the task as a search problem.

b. **(5 marks)** Identify a suitable uniformed search algorithm for this task and explain your choice.

c. **(5 marks)** Explain briefly why removing any one of the "fork" pieces makes the problem unsolvable.

d. **(5 marks)** Give an upper bound on the total size of the state space defined by your formulation. (Hint: think about the maximum branching factor for the construction process and the maximum depth, ignoring the problem of overlapping pieces and loose ends. Begin by pretending that every piece is unique.)

Question 2 – CSPs (5 Total Marks)

A latin square of size m is an $m \times m$ matrix containing the numbers 1 to m such that no number occurs more than once in any row or column. For example

$$\begin{matrix} 1 & 2 & 3 & 4 \\ 4 & 1 & 2 & 3 \\ 3 & 4 & 1 & 2 \\ 2 & 3 & 4 & 1 \end{matrix}$$

is a latin square of size 4. Formulate the problem of constructing an $m \times m$ latin square as a Constraint Satisfaction Problem. That is, specify the variables, domains of these variables, and constraints of the problem.

Question 3 – Knowledge Representation and Reasoning (18 Total Marks)

Consider the following:

Iguanas are lizards. Lizards eat flies. People feed their pets the food they eat. Corky is Fred's pet iguana.

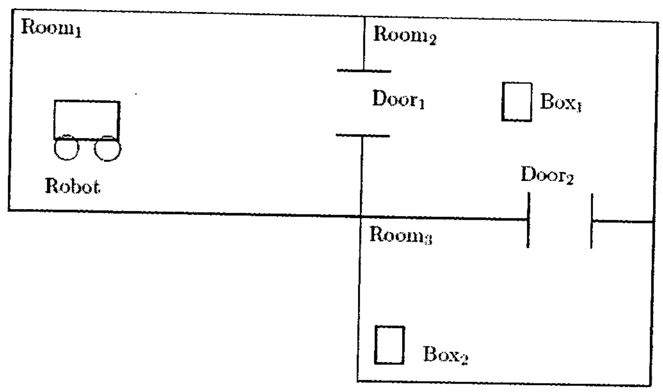
(a) **(8 marks)** Encode the above knowledge in causal form. For each clause indicate which part of this knowledge it encodes. You must use the following symbols in your clauses.

- Constants: Fred, Corky, Flies
- Predicates:
  Lizard(X), Iguana(X), Person(X)
  Pet(X,Y) – X is Y's pet
  Eats(X,Y) – X eats Y
  Feeds(X,Y,Z) – X feeds Y to Z

(b) **(10 marks)** Encode the question "What does Fred feed Corky?" as a query, and construct a resolution proof to answers it.

Question 4 – Planning (30 Total Marks)

1. **(12 marks)** Consider the following planning domain consisting of a robot pushing boxes between connected rooms.



We will represent this domain with the following symbols

- b1, b2 the two boxes; r1, r2, r3 the three rooms, d1, d2 the two doors.
- open(X)—door X is open.
- in(X,Y)—box X is in room Y.
- robin(X)—the robot is in room X.
- join(X,Y,Z)—door X joins rooms Y and Z.

Give a STRIPS representation of the following actions. In all cases use the above symbols to specify sensible preconditions and effects for each of the actions.

i. gothru(D,R1,R2) the robot goes from room R1 to R2 via door D.

ii. pushthru(B,R1,R2,D) the robot pushes the box B from room R1 to room R2 via door D.

iii. close(D) the robot closes door D.

2. **(18 marks)** Consider the set of STRIPS actions:

Name	Pre	Adds	Del
T	c	b	c
S	b	a	b
R	a	b, c	

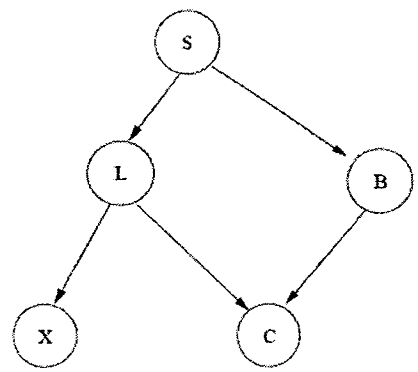
And the start state $S_0 = \{c\}$, and goal $G = \{a, b, c\}$.

a. **(9 marks)** Show the reachability graph from S_0 grown until the final state layer includes the goal G.

b. **(9 marks)** If CountActions is being used as heuristic, what will be the heuristic value of S_0. (That is, what is CountActions(G, S_f) in the reachibility graph you just built, where S_f is the final state layer.)

Question 5 – Bayesian Network (28 Total Marks)

1. Consider the following Bayes Network:



In this network B = *bronchitis*, S = *smoker*, C = *cough*, X = *positive X-ray*, and L = *lung cancer*.

a. **(2 marks)** If we use variable elimination on this network, what would be a better elimination order: (a) L, C, S, B, X, or (b) S, B, X, C, L? (Answer a or b)

b. Using d-separation, list the pairs of individual nodes that are conditionally independent in this network

   i. **(2 marks)** When there is no evidence.

   ii. **(2 marks)** When the patient has *lung cancer* and *bronchitis*.

   iii. **(2 marks)** When the patient is a *smoker*.

2. **(20 marks)** Using the same Bayes Net as the previous question. Let the variables *B*, *L*, *C*, and *X* be Boolean (with values true/false), while *S* has 3 values (0 = non-smoker, 1 = light smoker, 2 = heavy smoker).
Let the conditional probability tables parameterizing this network be as follows (in these tables, e.g., *c* means that cough is true, while $-c$ means that cough is false).

$Pr(s=0) = 6/10$ $Pr(s=1) = 2/10$ $Pr(s=2) = 2/10$	$Pr(b\|s=0) = 0$ $Pr(-b\|s=0) = 1$ $Pr(b\|s=1) = 2/10$ $Pr(-b\|s=1) = 8/10$ $Pr(b\|s=2) = 5/10$ $Pr(-b\|s=2) = 5/10$	$Pr(l\|s=0) = 0$ $Pr(-l\|s=0) = 1$ $Pr(l\|s=1) = 2/10$ $Pr(-l\|s=1) = 8/10$ $Pr(l\|s=2) = 4/10$ $Pr(-l\|s=2) = 6/10$
$Pr(x\|l) = 1$ $Pr(-x\|l) = 0$ $Pr(x\|-l) = 0$ $Pr(-x\|-l) = 1$	$Pr(c\|l,b) = 1$ $Pr(-c\|l,b) = 0$ $Pr(c\|l,-b) = 8/10$ $Pr(-c\|l,-b) = 2/10$ $Pr(c\|-l,b) = 8/10$ $Pr(-c\|-l,b) = 2/10$ $Pr(c\|-l,-b) = 0$ $Pr(-c\|-l,-b) = 1$	

HINT. In the following questions first check if independence or relevance can make answering the question easier.

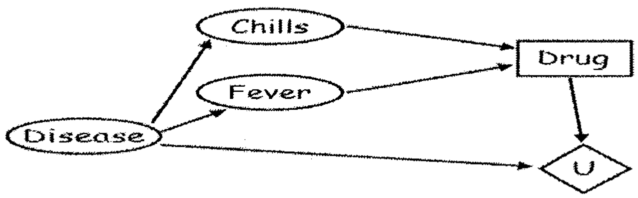
(a) **(5 marks)** Given that the patient has *bronchitis* and *lung cancer* give the 3 values of $\Pr(S|b, l)$.

(b) **(10 marks)** Give the two values of $\Pr(X|S = 1)$.

(c) **(5 marks)** What is the relationship between the quantities $\Pr(x|l, S = 1, c, -b)$ and $\Pr(-x|l, S = 2, -c, -b)$.

Question 6 – Decision Making (14 Total Marks)

Consider the influence diagram



where the utility node is parameterized by the following table

Disease	Drug	Utility
flu	flu_drug	-10
flu	malaria_drug	-100
flu	no_drug	-40
malaria	flu_drug	-300
malaria	malaria_drug	-50
malaria	no_drug	-300
none	flu_drug	-10
none	malaria_drug	-100
none	no_drug	30

In order to minimize the computations you need to do, the following table specifies the value of the product Pr(*Disease*)Pr(*Fever* | *Disease*)Pr(*Chills* | *Disease*) for different values of *Disease*, *Fever*, and *Chills*.

Chills	Fever	Disease=none	Disease=flu	Disease=malaria
yes	yes	0	0.1	0.9
yes	no	0	0.4	0.6
no	yes	0	1	0
no	no	.95	0.05	0

Give the policy we should associate with the *Drug* decision node. Specify the policy as a function that maps each setting of the nodes *Drug* depends on to a choice for what drug to administer.

End of Examination
Total Pages = 13
Total Marks = 120