CIS604: Techniques in Artificial Intelligence
Final Exam, Fall, 2013

Duration: 120 minutes

Instructions:

- This is a closed-book exam.
- Answer *all* questions.
- You may use a calculator.
- Start with the easy questions, and don't spend too much time on one question until you covered the others.
- If you are caught cheating, you will be asked to leave and will receive 0 for this exam.

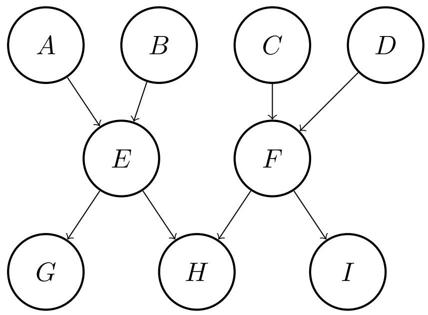
Student Name: –

Student ID: –

Problem	Points Obtained	Points Possible
1		5
2		6
3		14
4		10
5		8
6		7
Total		50

1 Bayesian Networks: D-Separation (5 points)

Consider the following Bayesian network.



$A \perp B$ means A is independent of B. $A \perp B | C$ means A is independent of B given C. For each of the following, indicate whether the statement is true or false.

1. $C \perp D$
2. $C \perp D | F$
3. $C \perp D | I$
4. $C \perp D | E$
5. $B \perp C | I$

<u>**ANSWER:**</u>

1. True. They are d-separated by common unobserved effect.
2. False. The triple $A - E - B$ is activated (explaining away effect).
3. False. Observing G gives information about E, which in turn breaks the d-separation between A and B.
4. True. F is not on any path not already covered.
5. True. Again, G is not on any path.

2 Constraint Satisfaction Problems (6 points)

	1	2	3	4	5	6	7	8	9
A			3		2		6		
B	9			3		5			1
C			1	8		6	4		
D			8	1		2	9		
E	7								8
F			6	7		8	2		
G			2	6		9	5		
H	8			2		3			9
I			5		1		3		

Consider the sudoku board above. When filling in the gaps with digits (1-9), no digit can appear twice in a row, column or 3x3 block.

2.1 Remaining values

Write down remaining values for the open positions of the central block (D5, E4, E5, E6, F5).

2.2 Arc consistency and MRV

Based on the Minimal Remaining Value strategy and arc consistency, solve column 6.
ANSWER:

Remaining Values

D5	3,4,5,6
E4	4,5,9
E5	3,4,5,6,9
E6	4
F5	3,4,5,9

Arc consistency and MRV

	A6	E6	I6
Remaining	1,4,7	**4**	4, 7
Remaining	1,7		**7**
Remaining	**1**		

3 Hidden Markov Models (14 points)

Given three states A, B and C. From A it is possible to go to B with probability 0.8 or stay in A with probability 0.2. In B and C it is only possible to go to C and A, respectively. Observations can be Red, Green or Blue. The probabilities in A are 3/4, 1/4 and 0 for Red, Green, Blue, respectively. The probabilities in B are 1/4, 1/4 and 1/2 for Red, Green, Blue, respectively. The probabilities in C are 1/6, 2/3 and 1/6 for Red, Green, Blue, respectively.

3.1

Provide a formal representation $M(\Sigma, Q, A, E)$ of the resulting Hidden Markov Model. Provide A and E in matrix form.

3.2

Provide a graphical representation of the resulting Hidden Markov Model (not including emission probabilities).

3.3

Draw the simplified edit graph (used for the Viterbi algorithm) up to level 3, in which only edges are drawn that represent non-zero transition probabilities.

3.4

Assume that each state is equally likely to start from. Assume we observe the sequence with the single observation $\{Red\}$. Calculate the most likely Hidden state.

3.5

Assume we observe the sequence $\{Red, Green\}$. Calculate the most likely path of Hidden states.

3.6

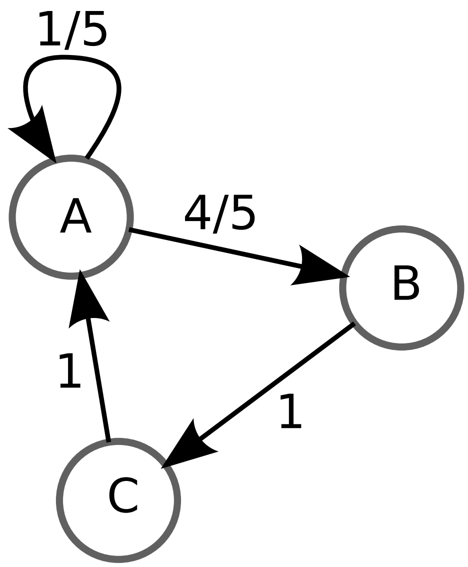
Assume we observe the sequence $\{Red, Green, Blue\}$. Calculate the most likely path of Hidden states.

Remember, the Viterbi algorithm uses the Dynamic Programming matrix s:

$$s_{l,i+1} = e_l(x_{i+1}) \max_{k \in Q'}(s_{k,i} a_{kl})$$

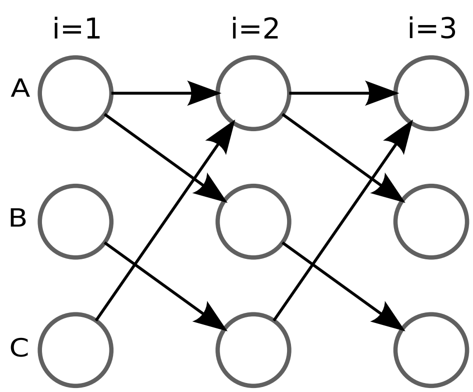
where Q' is the set of states that link into l
ANSWER:

Graphical representation



Formal representation: $M(\Sigma, Q, A, E)$ with $\Sigma = \{Red, Green, Blue\}$, $Q = \{A, B, C\}$,

$$A = \begin{bmatrix} & A & B & C \\ A & 1/5 & 4/5 & 0 \\ B & 0 & 0 & 1 \\ C & 1 & 0 & 0 \end{bmatrix} E = \begin{bmatrix} & Red & Green & Blue \\ A & 3/4 & 1/4 & 0 \\ B & 1/4 & 1/4 & 1/2 \\ C & 1/6 & 2/3 & 1/6 \end{bmatrix}$$



4 PageRank algorithm (10 points)

4.1

Consider the attempt to calculate page ranks of a fully connected link farm: 1000 pages, each linking to each other (a clique).
Remember the recursive function for the PageRank PR:

$$PR(p) = \frac{1-d}{N} + \Sigma_i \frac{PR(in_i)}{C(in_i)}$$

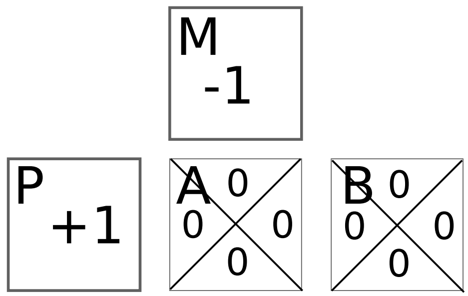
where N are total number of pages in the corpus, d is a damping factor and C are the outlinks for a respective page. Assume N to be 10^{10} and $d = 0.8$. The PageRank algorithm initializes each page rank to 1. Calculate the first three iterations for each node. You can provide estimates.

4.2

Assume the above process converges to a $PR(p) = 0$ for all pages in the link farm. Afterwards, assume it was possible to get a high quality page p_0 with $PR(p_0) = 500$ and $C(p_0) = 10$ to link to one of the link farm pages p_1. Calculate what happens to the page rank of p_1 as well as the other pages of the link farm. Provide the first two iterations.
<u>**ANSWER:**</u>

5 Q-Learning (8 points)

Consider the actions state space given below:



M and P are terminal states. States A and B contain the initial Q-values for actions "East", "North", "West", "South". Sample transitions are defined by tuples of the form (s, a, r, s'). The following sample observations are given: (A, "West", 0, P), (B, "West", 0, A), (A, "West", 0, P), (A, "West", 0, M). Express the relevant Q-value updates (using model-free Q-learning) for each sample in terms of γ and α (discount factor and learning rate, respectively).
Remember the formula for Q-value updates:

$$Q(s,a) \leftarrow (1-\alpha)Q(s,a) + \alpha[r + \max_a \gamma Q(s', a')]$$

ANSWER:

6 Planning (7 points)

Consider the following planning problem:

- Start state: $\neg open, \neg painted, \neg haveKeys$
- Goal: $open, painted$
- Actions:
  - $GetKeys$: (Pre: $\neg haveKeys$), (Eff: $haveKeys$)
  - $OpenDoor$: (Pre: $\neg open$, $haveKeys$), (Eff: $open$)
  - $PaintDoor$: (Pre: $\neg open$, $\neg Painted$), (Eff: $painted$)

Answer the following questions about the graphplan graph of the above problem.

1. List the nodes in level S_0
2. List the nodes in level A_0
3. List the nodes in level S_1
4. List the nodes in level A_1
5. List the nodes in level S_2
6. What is the first level in which the goal appears?
7. List a plan for achieving the goal.