Introduction to
Artificial Intelligence

Challenge Q7 HW2

- **Due:** Friday 9/16 at 11:59pm.

- **Policy:** Can be solved in groups (acknowledge collaborators) but must be submitted individually.

- **Make sure to show all your work and justify your answers**.

- **Note:** This is a typical exam-level question. On the exam, you would be under time pressure, and have to complete this question on your own. We strongly encourage you to first try this on your own to help you understand where you currently stand. Then feel free to have some discussion about the question with other students and/or staff, before independently writing up your solution.

- Your submission on Gradescope should be a PDF that matches this template. Each page of the PDF should align with the corresponding page of the template (page 1 has name/collaborators, question begins on page 2.). **Do not reorder, split, combine, or add extra pages**. The intention is that you print out the template, write on the page in pen/pencil, and then scan or take pictures of the pages to make your submission. You may also fill out this template digitally (e.g. using a tablet.)

First name	
Last name	
SID	
Collaborators	

For staff use only:

Q7. [18 pts] Challenge Problem (CSP)

Pacman has reconciled with 4 of the ghosts Bubbly, Kozy, Irresistible and Cuddly and he wants to invite them to live with him and Ms. Pacman in their 6 bedroom house. To figure out who sleeps in which bedroom, Pacman wants to solve a CSP with the variables being Pacman (P), Ms. Pacman (M), Bubbly (B), Kozy (K), Irresistible (I) and Cuddly (C). The values are the different room numbers, from 1 to 6 and the constraints that must be satisfied are as follows:

A. Only one person can take up a room.

B. $P > 3$

C. $K < P$

D. M is either 5 or 6

E. $P > M$

F. B is even

G. I is not 1 or 6

H. $|I - C| = 1$

I. $|P - B| = 2$

7.1) (2pts) If we enforce unary constraints, which of the following values will be eliminated from each domain? Cross them out.

```
P   1̶   2̶   3̶   4   5   6
B   1̶   2   3̶   4   5̶   6
C   1   2   3   4   5   6
K   1   2   3   4   5   6
I   1̶   2   3   4   5   6̶
M   1̶   2̶   3̶   4̶   5   6
```

The unary constraints are B, D, F, and G. B crosses out 1,2, and 3 for P. D crosses out 1,2,3,4 for M. F crosses out 1,3, and 5 for B. G crosses out 1 and 6 for I. K and C have no unary constraints, so their domains remain the same.

7.2) (1pts) If we follow the Minimum Remaining Value (MRV) method, which variable will be assigned first?

M has the fewest value remaining in its domain (2), so it should be selected first for assignment.

7.3) (2pts) Now let's assume that we choose to assign P first with the value of 6. If we enforce unary constraints (from 7.1)) and run forward checking, what will the new domains look like? Cross out the values that will be removed.

```
P                       6
B   1̶   2̶   3̶   4   5̶   6̶
C   1   2   3   4   5   6̶
K   1   2   3   4   5   6̶
I   1̶   2   3   4   5   6̶
M   1̶   2̶   3̶   4̶   5   6̶
```

In addition to enforcing the unary constraints from part 7.1), the domains are further constrained by all constraints involving P. This includes constraints A, B, E, and I. A removes 6 from the domains of all variables. C removes 6 from the domain of K (already removed by constraint A). E removes 6 from the domain of M (also already removed by A). I removes 2 and 6 from the domain of B.

7.4) (3pts) We no longer want to run backtracking search, and so we decide to start over and run iterative improvement with min-conflicts heuristic for value selection. Let's assume that the starting assignment is P:6, M:5, B:4, C:3, K:2, I:1.

First fill out the left table with the number of constraint violations per variable. Next, in the table on the right, put for each variable an X in the box corresponding to each value that that variable could take following the min-conflicts method. Do not mark the current value of each variable with an X.

Variable	# violated
P	0
B	0
C	1
K	0
I	2
M	0

	1	2	3	4	5	6
P						
B						
C		x				
K						
I		x		x		
M						

Both I and C violate constraint H, because $|I - C| = 2$. I also violates constraint G. No other variables violate any constraints. According to iterative improvement, any conflicted variable could be selected for assignment, in this case I and C. According to min-conflicts, the values that those variables can take on are the values that minimize the number of constraints violated by the variable. Assigning 2 or 4 to I causes it to violate constraint A, because other variables already have the values 2 and 4. Assigning 2 to C also only causes C to violate 1 constraint.

Now let's consider a different problem. In our usual CSPs, our goal is to find a constraint satisfying assignment. For this new problem our task is to try and find all possible assignments instead! This new CSP solving algorithm is similar to the backtracking algorithm we saw in class with the only difference being that once it finds a solution, it appends it to a list instead of returning it. After that, the algorithm backtracks and once it cannot backtrack anymore, it returns the aforementioned list.

In the following parts, for each of the given constraint graphs, determine whether using the MRV and LCV methods might cause a change to the number of nodes that will be expanded in our search tree using our modified algorithm. Remember to justify your answer.

The remaining parts all have a similar reasoning. Since every value has to be checked regardless of the outcome of previous assignments, the order in which the values are checked does not matter, so LCV has no effect. In the general case, in which there are constraints between variables, the size of each domain can vary based on the order in which variables are assigned, so MRV can still have an effect on the number of nodes expanded for the new "find all solutions" task. The one time that MRV is guaranteed to not have any effect is when the constraint graph is completely disconnected, as is the case for part 7.5) . In this case, the domains of each variable do not depend on any other variable's assignment. Thus, the ordering of variables does not matter, and MRV cannot have any effect on the number of nodes expanded.
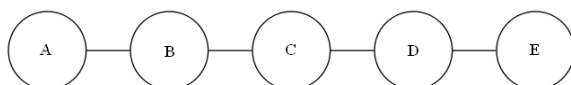
7.5) (2pts)
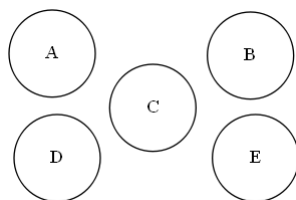
A. No possible change from MRV and LCV

B. Change possible only from MRV

C. Change possible only from LCV

D. Change possible from both

A.

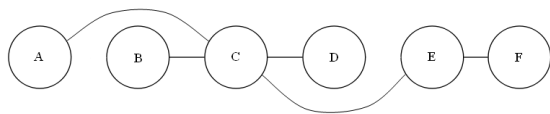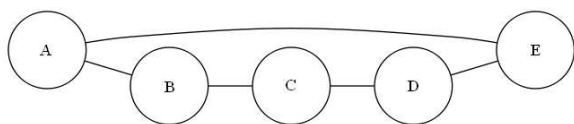**7.6)** (2pts)

A. No possible change from MRV and LCV

B. Change possible only from MRV

C. Change possible only from LCV

D. Change possible from both

B.

7.7) (2pts)

3

A. No possible change from MRV and LCV

B. Change possible only from MRV

C. Change possible only from LCV

D. Change possible from both

B.

7.8) (2pts)

A. No possible change from MRV and LCV

B. Change possible only from MRV

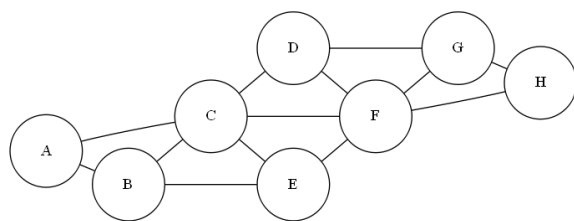C. Change possible only from LCV

D. Change possible from both

B.

7.9) (2pts)

A. No possible change from MRV and LCV

B. Change possible only from MRV

C. Change possible only from LCV

D. Change possible from both

B.