

Artificial Intelligence: Constraint Satisfaction Problems – Final Exam – March 26, 2017

Max Marks 100      Duration 180 minutes      Weight 75 %

MODULE - I

1. CSPs are – [1 mark]
  - a. an alternative formulation for general problem solving method <
  - b. ways of formulating problems using variables and constraints <
  - c. problems that come in the way of satisfying constraints
  - d. problems that arise after constraint satisfaction
  - e. none of the above
  
2. Which of the following conditions must hold for a solution to a CSP? [1 mark]
  - a. All relations in all constraints must hold.
  - b. At least one relation in all constraints must hold. <
  - c. More than one relation in all constraints must hold.
  - d. All relations in at least one constraint must hold.
  - e. It is sufficient that at least one relation in at least one constraint holds.
  
3. Consider the following constraint network  $R = \langle \{x_1, x_2, x_3\}, \{D_1, D_2, D_3\}, \{C\} \rangle$  where  $D_1 = D_2 = D_3 = \{a, b, c\}$  and  $C = \langle \{x_1, x_2, x_3\}, \{ \langle a, a, b \rangle, \langle a, b, b \rangle, \langle b, a, c \rangle, \langle b, b, b \rangle \}$ . How many solutions exist?  
**Ans: 4** [1 mark]
  
4. The Waltz algorithm is used to solve [1 mark]
  - a. N-Queens problem
  - b. Scheduling problem
  - c. Graph Colouring problem
  - d. Radio Link Frequency Assignment Problem
  - e. Crypto Arithmetic Puzzles
  - f. Crossword Puzzles
  - g. None of the above <
  
5. Each edge in a dual constraint graph represents [1 mark]
  - a. a variable
  - b. the scope of a constraint
  - c. that the constraint scopes in the 2 nodes share variables <
  - d. a relation

Given the following crypto-arithmetic puzzle.

$$\begin{array}{r} \text{GERALD} \\ + \text{DONALD} \\ \hline \text{ROBERT} \end{array}$$

6. The number of variables for which values have to be found in the network is \_\_\_\_\_. (answer in numeric form) [1 mark]  
**Ans: 16**
  
7. If a constraint  $D=5$  is enforced, then ROBERT will be encoded as \_\_\_\_\_. (answer in numeric form) [2 marks]

Ans: 723970

MODULE - II

8. An assignment to each variable in a subset of variables is called [1 mark]
- an instantiation  $\prec$
  - a consistent partial instantiation
  - a solution
  - a conflict set

9. Given the following constraint networks X,Y and Z with four variables  $x_1, x_2, x_3$  and  $x_4$  all defined on the same domain values {red,blue}. The constraints in the network are as follows: [1 mark]

X:  $R_{13}=R_{14}=R_{23}=R_{24}=\{(red,blue) (blue,red)\}$

Y:  $R_{13}=R_{14}=R_{23}=R_{24}=\{(red,blue) (blue,red)\}$  ,  $R_{12}=\{(red,red) (blue,blue)\}$

Z:  $R_{13}=R_{14}=R_{23}=R_{24}=\{(red,blue) (blue,red)\}$  ,  $R_{34}=\{(red,blue) (blue,red)\}$

Identify which of them are equivalent:

- Z and X
  - Z and Y
  - X and Y  $\prec$
  - All are equivalent
10. In the previous question, for network X, what is the result of composition of constraints  $R_{13}=R_{14}$ ? [1 mark]
- $R_{34}=\{(red,blue)(blue,red)\}$
  - $R_{34}=\{(red,red)(blue)(blue)\} \prec$
  - $R_{34}=\{(red,red)(blue,blue)(red,blue)(blue,red)\}$
  - None of the above

Given a constraint networks with three variables  $x_1, x_2$  and  $x_3$  with one constraint,  
 $p_{123}=\{(1,1,2) (1,2,2) (2,1,3) (2,2,2)\}$

11. The number of constraints in the projection network  $P(p)$  for the above network is \_\_\_\_\_ . [1 mark]
- Ans: 3

12. Given the above network with constraint  $p_{123}$ , which of the following tuple(s) will be present in the solution of projection network of  $p$ :
- (1,1,3)
  - (2,1,3)
  - (1,2,3)
  - (2,1,2)

Ans: (d)

[1 mark]

13. Given the following constraint networks X,Y and Z with three variables  $x_1, x_2$  and  $x_3$  all defined on the same domain values {red,blue}. The constraints in the network are  $R_{12}=R_{23}=\{(red,blue) (blue,red)\}$ . If you construct a minimal network for the given CSP, the number of edges in the matching diagram of the minimal network will be \_\_\_\_\_.

Ans: 6

[1 mark]

MODULE - III

14. Given a constraint satisfaction problem with two variables  $x$  and  $y$  whose domains are  $D_x=\{1,2,3\}$ ,  $D_y=\{1,2,3\}$  and constraint  $x < y$ . What happens to  $D_x$  and  $D_y$  after the REVISE( $x,y$ ) algorithm is called?
- Both  $D_x$  and  $D_y$  remain the same as before
  - $D_x=\{1,2\}$  and  $D_y=\{1,2,3\}$
  - $D_x=\{2,3\}$  and  $D_y=\{1,2\}$
  - $D_x=\{ \}$  and  $D_y=\{1,2,3\}$

[2 marks]

Ans: (b)

15. What are the complexities of the REVISE algorithm for arc consistency and AC-3 algorithm
- $O(ek^2)$  and  $O(ek^3)$
  - $O(k^2)$  and  $O(nek^3)$
  - $O(k^2)$  and  $O(ek^3)$
  - $O(k^2)$  and  $O(ek^2)$

[1 mark]

Ans: (c)

16. Which of the following statement(s) is/are true about the AC-4 algorithm?
- It does not use the REVISE algorithm
  - The best case performance of AC-4 is better than that of AC-1 and AC-3
  - A value from a domain is removed only if it has no support from the neighbouring variable
  - All of the above

[2 mark]

Ans: (a) and (c)

17. A network is said to be  $i$ -consistent if:
- a partial solution of  $i-1$  variables can be extended to  $i$  variables
  - a partial solution of  $i$  variables can be extended to  $i+1$  variables
  - a partial solution of  $i-1$  variables can be extended to  $i+1$  variables
  - None of the above

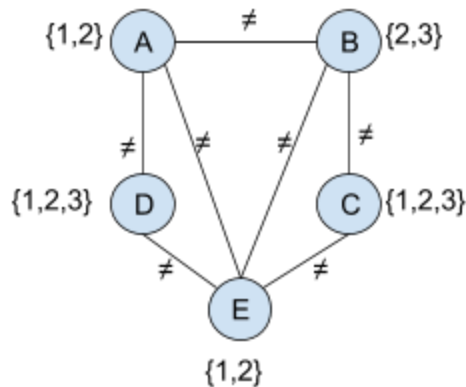
[1 mark]

Ans: (a)

MODULE - IV

18. Given a constraint graph with an ordering, the parent of a given node is - [1 mark]
- the node preceding the given node in the ordering.
  - the node succeeding the given node in the ordering.
  - the latest variable earlier in the ordering connected to the given variable. <
  - the earliest variable later in the ordering connected to the given variable.

Given the following constraint network



19. Which of the following are possible solution(s) for the above constraint network [2 marks]
- $A=1, B=3, C=1, D=1, E=2$
  - $A=1, B=3, C=1, D=3, E=2$  <
  - $A=1, B=3, C=2, D=3, E=2$
  - $A=2, B=3, C=2, D=2, E=1$
  - $A=2, B=3, C=2, D=3, E=1$
  - $A=2, B=3, C=1, D=3, E=2$  <
20. Given an ordering CDBAE. If you try to perform the bucket elimination algorithm over this network and ordering, what should be the initial constraints in Bucket C? [1 mark]
- $C \neq E, C \neq B$
  - $C \neq E$
  - $C \neq B$
  - empty bucket <
21. Given an ordering CDBAE. If you try to perform the bucket elimination algorithm over this network and ordering, what will be the constraints in bucket B after the variable A is processed? [2 marks]
- $B \neq C$
  - $R_{BCD}$
  - $B \neq C \parallel R_{BCD}$  <
  - empty bucket
22. In the previous question, if the ordering was EDCBA, what would be your answer [1 mark]

- a)  $B \neq C$
- b)  $B \neq C, B \neq E$
- c)  $B \neq A, B \neq C, B \neq E \parallel R_{CED}$
- d)  $B \neq C, B \neq E \parallel R_{CED} <$

23. When the constraint graph is a tree, the induced width of the graph is \_\_\_\_\_.

[1 mark]

Ans: 1

MODULE - V

24. In the Backtracking algorithm which of the following are true? [1 mark]
- a. The Select-Value procedure selects for the current variable a value that must be consistent with both the current partial instantiation, and the future variables.
  - b. If Select-Value finds no value for the current variable, a dead-end occurs. <
  - c. If Select-Value finds no value for the current variable, the algorithm terminates as no solution can be found.
  - d. None of the above.
25. The Generalized-Look-Ahead algorithm with Select-Value-Forward-Checking is applied to the CSP in [this](#) figure, for the ordering  $(x_1, x_2, x_3, x_4, x_5, x_6, x_7)$ . If the algorithm chooses the assignments  $x_1 = r$ ,  $x_2 = b$ , and  $x_3 = b$ , how many total values are pruned from the domains of the variables  $x_4, x_5, x_6$ , and  $x_7$ ? (Answer is a single number) [2 marks]  
**Ans: ???**
26. The Generalized-Look-Ahead algorithm with Select-Value-Arc-Consistency is applied to the CSP in [this](#) figure, for the ordering  $(x_1, x_2, x_3, x_4, x_5, x_6, x_7)$ . If the algorithm chooses the assignments  $x_1 = r$ ,  $x_2 = b$ , and  $x_3 = b$ , how many total values are pruned from the domains of the variables  $x_4, x_5, x_6$ , and  $x_7$ ? (Answer is a single number) [5 marks]  
**Ans: ???**
27. The Generalized-Look-Ahead algorithm with Select-Value-Partial-Look-Ahead is applied to the CSP in [this](#) figure, for the ordering  $(x_1, x_2, x_3, x_4, x_5, x_6, x_7)$ . If the algorithm chooses the assignments  $x_1 = r$ ,  $x_2 = b$ , and  $x_3 = b$ , how many total values are pruned from the domains of the variables  $x_4, x_5, x_6$ , and  $x_7$ ? (Answer is a single number) [3 marks]  
**Ans: ???**
28. The Generalized-Look-Ahead algorithm with Select-Value-Full-Look-Ahead is applied to the CSP in [this](#) figure, for the ordering  $(x_1, x_2, x_3, x_4, x_5, x_6, x_7)$ . If the algorithm chooses the assignments  $x_1 = r$ ,  $x_2 = b$ , and  $x_3 = b$ , how many total values are pruned from the domains of the variables  $x_4, x_5, x_6$ , and  $x_7$ ? (Answer is a single number) [3 marks]  
**Ans: ???**

The objective of a 4x4 Sudoku puzzle is to fill a 4x4 grid so that each column, each row, and each of the four disjoint 2x2 subgrids contains all of the digits from 1 to 4.

x1	x2	x3	x4
x5	x6	x7	x8
x9	x10	x11	x12
x13	x14	x15	x16

29. The following figure depicts the domains of the variables for the given 4x4 Sudoku problem. Note that some cells have only one value in their domain. Show the order in which Dynamic Variable Ordering With Forward Checking (DVFC) algorithm will fill in the values. Let the algorithm prefer variables in the order (x1, x2, ..., x16) at each tie break. [5 marks]

1	2	1	2	1	2	1	
3	4	3	4	3	4	1	
1	2	2		1	2	1	2
3	4	2		3	4	3	4
1	2	1	2	3		1	2
3	4	3	4	3		3	4
4		1	2	1	2	1	2
4		3	4	3	4	3	4

- a) x1, x2, x3, x4, x5, x6, x7, x8, x9, x10, x11, x12, x13, x14, x15, x16  
 b) x16, x15, x14, x13, x12, x11, x10, x9, x8, x7, x6, x5, x4, x3, x2, x1  
 c) x4, x6, x11, x7, x3, x8, x5, x13, x1, x2, x9, x10, x12, x14, x15, x16 <  
 d) x4, x6, x11, x7, x3, x8, x5, x13, x1, x12, x10, x9, x2, x14, x15, x16  
 e) none of the above
30. How many times does the DVFC algorithm backtrack? (Answer is a single number) [2 marks]  
**Ans: 0**

The Davis-Putnam, Logemann, and Loveland (DPLL) algorithm is applied to the following set of clauses:  
 $\{(\neg A \vee B), (\neg C \vee A), (A \vee B \vee D), (C)\}$ .

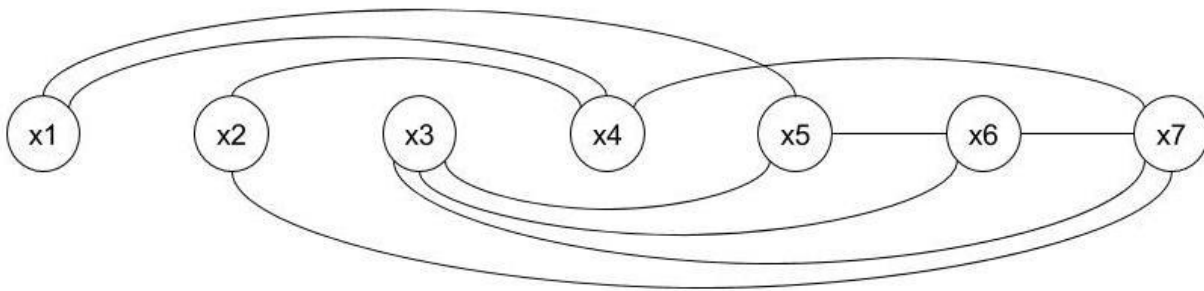
31. How many times is unit propagation done? [2 marks]  
**Ans: 3**
32. Which of the following statements are true about Look-Ahead Value Ordering (LVO)? [2 marks]
- It is not recommended to use LVO on small CSPs. <
  - The min-conflicts (MC) heuristic chooses the value that removes the smallest number of values from the domains of future variables. <
  - The max-domain-size (MD) heuristic prefers the value that creates the largest average domain size in the future variables.
  - The estimate-solutions (ES) heuristic selects the value that leads to the highest lower bound on the number of solutions.
  - It has been experimentally observed that the min-conflicts (MC) heuristic is the best among the 3 heuristics: MC, MD, and ES. <

MODULE - VI

33. Chronological backtracking in depth first search –

[1 mark]

- implies that the algorithm backtracks to a variable that with a new value will guarantee a solution to the CSP.
- ensures that the algorithm will never miss a solution. <
- implies that the algorithm may miss a solution for some variable orderings.
- implies that the algorithm may miss a solution for all variable orderings.
- may assign a new value to a variable that may not lead to a solution.



$D1 = \{w, r\}$

$D2 = \{b, r, g\}$

$D3 = \{r, b, g\}$

$D4 = \{b, w\}$

$D5 = \{r, b, g\}$

$D6 = \{g, b, y\}$

$D7 = \{b, r, w\}$

Figure Map-Colouring: Constraint graph for a map colouring problem. Each edge represents the not-equal relation.

34. Figure MAP-COLOURING is the constraint graph for a map colouring problem with the ordering  $(x_1, x_2, \dots, x_7)$ . An edge between two nodes means they should be assigned different colours. Backtracking arrives at a deadend on variable  $x_5$ . It will now assign a new value to the variable

[1

mark]

- $x_1$
- $x_3$
- $x_4$  <
- $x_6$

35. Let  $\bar{a}$  be a consistent assignment to a set of variables. We say that  $\bar{a}$  is a *nogood* iff –

[1 mark]

- The assignment  $\bar{a}$  cannot be extended to a solution.
- The assignment  $\bar{a}$  is conflict set for some variable  $X$ .
- The assignment  $\bar{a}$  is conflict set for any variable  $X$ .
- None of the above

36. Let  $\bar{a}$  be a consistent assignment to a proper subset of variables. Identify the true statements. [2 marks]

- If  $\bar{a}$  is a *nogood* then it is necessarily a conflict set with respect to some variable  $X$ .
- If  $\bar{a}$  is a conflict set with respect to some variable  $X$  then it is necessarily a *nogood*. <
- A *nogood*  $\bar{a}$  is not necessarily a conflict set with respect to some variable  $X$ . <



- d. A conflict set  $\bar{a}$  with respect to some variable  $X$  may not be a *nogood*.
- e. If  $\bar{a}$  is a *nogood* then there is no solution to the CSP. <
- f. If  $\bar{a}$  is a *nogood* then there may still be solution to the CSP.
37. An algorithm searching for a solution to a CSP on a ordered set of variables  $\{x_1, x_2, \dots, x_9\}$  reaches a deadend at variable  $x_7$ . The algorithm then jumps back to the variable  $x_3$  to assign a new value. This jump is safe iff - [marks 2]
- the domain  $D_3$  of  $x_3$  has at least one more value left.
  - if a new value assigned instead to a variable  $x_i$ ,  $3 < i < 7$ , could have led to a solution.
  - if no new value assigned instead to a variable  $x_i$ ,  $3 < i < 7$ , could have led to a solution. <
  - if the domain  $D_i$  of all variables  $x_i$ ,  $3 < i < 7$ , have at least one more value left.
38. An algorithm searching for a solution to a CSP on a ordered set of variables  $\{x_1, x_2, \dots, x_9\}$  reaches a deadend at variable  $x_7$ . This deadend is an *leaf deadend* if - [mark 1]
- the domain  $D_7$  of  $x_7$  has at least one more value left.
  - in the previous round it tried a value for the variable  $x_6$  and failed.
  - in the previous round it tried a value for the variable  $x_8$  and failed. <
  - in the previous round it tried a value for the variable  $x_9$  and failed. <
39. The set of relevant deadends in the context of Graph Based Backjumping [2 marks]
- includes all the deadends encountered by the algorithm since backtracking started from the latest node visited.
  - includes all the deadends encountered by the algorithm since the current internal deadend was revisited. <
  - must include at least one leaf deadend. <
  - can have more than one leaf deadend. <
40. Given a constraint graph in which the nodes are ordered on the depth first search ordering, on reaching a deadend the Graph Based Backjumping algorithm next needs to look only at [1 mark]
- the parent of the deadend in the ordering.
  - the induced parent of the deadend in the ordering.
  - the parent of the node in the DFS spanning tree. <
  - the earliest induced ancestor of the deadend that is earlier than the deadend.
41. Figure MAP-COLOURING is the constraint graph for a map colouring problem with the ordering  $(x_1, x_2, \dots, x_7)$  on the variables. An edge between two nodes means they should be assigned different colours. Let the domains be  $D_1=\{w,r\}$ ,  $D_2=\{b,r,g\}$ ,  $D_3=\{r,b,g\}$ ,  $D_4=\{b,w\}$ ,  $D_5=\{r,b,g\}$ ,  $D_6=\{g,b,y\}$ ,  $D_7=\{b,r,w\}$ . Graph Based Backjumping arrives at a deadend on variable  $x_4$  with the partial solution  $(w,b,r)$ . The culprit variable identified by the algorithm is - [2 marks]
- $x_1$
  - $x_2$  <
  - $x_3$
  - $x_4$
  - none of the above

42. Figure MAP-COLOURING is the constraint graph for a map colouring problem with the ordering  $(x_1, x_2, \dots, x_7)$  on the variables. An edge between two nodes means they should be assigned different colours. Let the domains be  $D_1=\{w,r\}$ ,  $D_2=\{b,r,g\}$ ,  $D_3=\{r,b,g\}$ ,  $D_4=\{b,w\}$ ,  $D_5=\{r,b,g\}$ ,  $D_6=\{g,b,y\}$ ,  $D_7=\{b,r,w\}$ . Gaschnig's Backjumping arrives at a deadend on variable  $x_7$  which is conflicting with  $(w,w,r,b,b,g)$ . The culprit variable identified by the algorithm is - [2 marks]
- $x_1$
  - $x_2$
  - $x_3$
  - $x_4$
  - $x_5$
  - $x_6$
  - $x_7$
  - none of the above.
43. After jumping back to the culprit variable identified in the previous problem, the Gaschnig's Backjumping algorithm finds that [1 mark]
- the culprit variable is a deadend. <
  - the culprit variable is not a deadend.
44. Continuing the above problem, the Gaschnig's Backjumping algorithm will next assign a new value to which variable? [2 marks]
- $x_1$
  - $x_2$
  - $x_3$
  - $x_4$
  - $x_5$
  - $x_6$
  - $x_7$
  - none of the above.
45. Figure MAP-COLOURING is the constraint graph for a map colouring problem with the ordering  $(x_1, x_2, \dots, x_7)$  on the variables. An edge between two nodes means they should be assigned different colours. Let the domains be  $D_1=\{w,r\}$ ,  $D_2=\{b,r,g\}$ ,  $D_3=\{r,b,g\}$ ,  $D_4=\{b,w\}$ ,  $D_5=\{r,b,g\}$ ,  $D_6=\{g,b,y\}$ ,  $D_7=\{b,r,w\}$ . Graph Based Backjumping arrives at a deadend on variable  $x_7$  which is conflicting with  $(w,w,r,b,b,g)$ . The culprit variable identified by the algorithm is - [2 marks]
- $x_1$
  - $x_2$
  - $x_3$
  - $x_4$
  - $x_5$
  - $x_6$
  - $x_7$
  - none of the above.

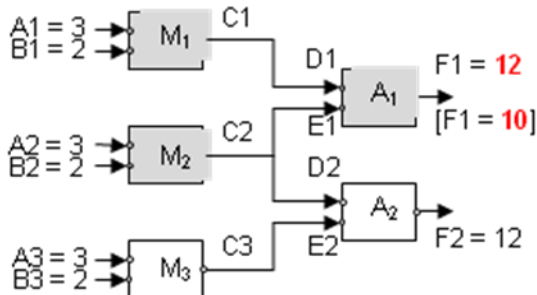
46. After jumping back to the culprit variable identified in the previous problem, the Graph Based Backjumping algorithm finds that [1 mark]
- the culprit variable is a deadend.
  - the culprit variable is not a deadend. <
47. Continuing the above problem, the Graph Based Backjumping algorithm will next assign a new value to which variable? [2 marks]
- $x_1$
  - $x_2$
  - $x_3$
  - $x_4$
  - $x_5$
  - $x_6$  <
  - $x_7$
  - none of the above.
48. Figure MAP-COLOURING is the constraint graph for a map colouring problem with the ordering  $(x_1, x_2, \dots, x_7)$  on the variables. An edge between two nodes means they should be assigned different colours. Let the domains be  $D_1=\{w,r\}$ ,  $D_2=\{b,r,g\}$ ,  $D_3=\{r,b,g\}$ ,  $D_4=\{b,w\}$ ,  $D_5=\{r,b,g\}$ ,  $D_6=\{g,b,y\}$ ,  $D_7=\{b,r,w\}$ . Conflict Directed Backjumping arrives at a deadend on variable  $x_7$  which is conflicting with  $(w,w,r,b,b,g)$ . The culprit variable identified by the algorithm is - [2 marks]
- $x_1$
  - $x_2$
  - $x_3$
  - $x_4$  <
  - $x_5$
  - $x_6$
  - $x_7$
  - none of the above.
49. After jumping back to the culprit variable identified in the previous problem, the Conflict Directed Backjumping algorithm finds that [1 mark]
- the culprit variable is a deadend. <
  - the culprit variable is not a deadend.
50. Continuing the above problem, the Conflict Directed Backjumping algorithm will next assign a new value to which variable? [2 marks]
- $x_1$
  - $x_2$  <
  - $x_3$
  - $x_4$
  - $x_5$
  - $x_6$
  - $x_7$
  - none of the above.

MODULE - VII

51. A model used in model based diagnosis constitutes of - [1 mark]
- behaviour models of individual components. <
  - physical models of the individual components.
  - a black box model of the device under consideration.
  - a set of connections that connect different components. <

52. A Truth Maintenance System (TMS) is [1 mark]
- keeps track of all the true statements in a story.
  - a program that does the book keeping and consistency management for a problem solver. <
  - a program that adds new values to maintain the truth value of the premises.
  - a program that routinely deletes false statements from a knowledge base.

53. A Truth Maintenance System (TMS) can [2 marks]
- keep a watch on the consistency of the beliefs of an agent. <
  - add new beliefs that are consistent with the beliefs held by the agent.
  - can help identify the source of inconsistency of beliefs held by an agent. <
  - can clean up the justifications to make all beliefs true.



54. For adder multiplier circuit given in the figure above – given the inconsistency in the value of F1 which of following are conflict sets, [2 marks]

- M1, M2, M3
- A1, A2
- M1, M2, A1 <
- M2, M3, A2
- A1, A2, M3

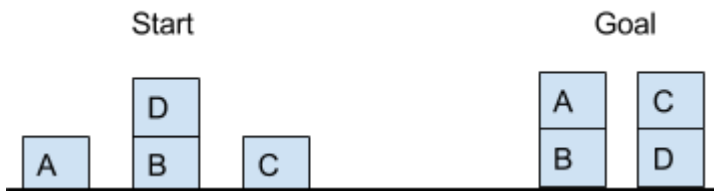
55. Given the above conflict set which of the following *cannot* be a single fault [2 marks]
- A1
  - A2 <
  - M1
  - M2
  - M3 <

56. Given the above conflict set which of the following *cannot* be a double fault [2 marks]
- A1,A2
  - A1,M1
  - A1,M2
  - M1,M2
  - A2,M2
  - A2,M3 <
  - M2,M3

57. For the above adder multiplier circuit and the data shown which of the following is another conflict set [2 marks]
- A1, A2, M1, M2
  - A1, A2, M1, M3 <
  - A1, A2, M2, M3
  - A1, M1, M2, M3
  - A2, M1, M2, M3

58. Given the conflict sets above which single faults are eliminated [2 marks]
- A1
  - A2 <
  - M1
  - M2 <
  - M3 <

Consider a planning problem in the blocks world domain.



59. If the above problem is solved as DCSP, which of the following are the initial set of constraints that denote the active propositions? [1 mark]
- Active  $\{On_0(A,B), On_0(C,D), Clear_0(A), Clear_0(C)\}$
  - Active  $\{On_4(A,B), On_4(C,D), Clear_4(A), Clear_4(C)\}$
  - Active  $\{On_0(D,B), OnT_0(A), OnT_0(C), Clear_0(D)\}$
  - Active  $\{On_4(D,B), OnT_4(A), OnT_4(C), Clear_4(D)\}$

Ans: (b)

60. Which of the following are true about the initial state in the state variable representation [1 mark]
- $On(A, S_0) = \text{table}$
  - $Clear(B, S_0) = 1$
  - $Clear(C, S_0) = 0$
  - $OnT(D, S_0) = 0$

Ans: (a), (d)

61. Which of the following constraints denote the frame axioms for the given domain

- a)  $\langle a_1 = \text{UnStack}(D,B), \text{Clear}(C,S_0)=1, \text{Clear}(C,S_1)=1 \rangle$
- b)  $\langle a_1 = \text{UnStack}(D,B), \text{Clear}(A,S_0)=1, \text{Clear}(A,S_1)=1 \rangle$
- c)  $\langle a_1 = \text{UnStack}(D,B), \text{On}(B,S_0)=1, \text{On}(B,S_1)=0 \rangle$
- d)  $\langle a_1 = \text{PickUp}(A), \text{Clear}(C,S_0)=1, \text{Clear}(C,S_1)=0 \rangle$

[1 mark]

Ans: (a), (b)

62. Which of the following formulas are valid encoding of actions as clauses in SAT

- a)  $\text{UnStack}(D,B,t) \supset \text{On}(D,B, t-1) \wedge \text{ArmEmpty}(t-1) \wedge \text{Clear}(B,t-1)$
- b)  $\text{Stack}(A,B,t) \supset \text{Holding}(A, t-1) \wedge \text{Clear}(B,t-1)$
- c)  $\text{UnStack}(D,B,t) \supset \text{On}(D,B, t-1) \wedge \text{ArmEmpty}(t-1) \wedge \text{Clear}(D,t-1)$
- d)  $\text{Stack}(A,B,t) \supset \text{On}(A,B, t-1) \wedge \text{ArmEmpty}(t-1) \wedge \text{Clear}(D,t-1)$

[1 mark]

Ans: (b), (c)

63. Which of the following formulas denote the action that are mutex while encoding the planning graph as SAT

- a)  $\text{UnStack}(D,B,0) \wedge \text{PickUp}(A,0)$
- b)  $\text{UnStack}(D,B,0) \wedge \text{PickUp}(C,0)$
- c)  $\neg \text{UnStack}(D,B,0) \vee \neg \text{PickUp}(C,0)$
- d)  $\neg \text{UnStack}(D,B,0) \vee \neg \text{PickUp}(A,0)$

[1 mark]

Ans: (c), (d)