National University of Computer and Emerging Sciences

FAST School of Computing **Spring-2023** **Islamabad Campus**

Question 1 [10 Marks]

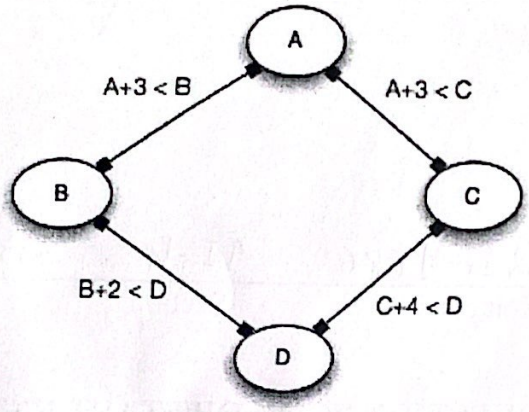
The constraint graph for four variables A, B, C, D is shown below. The nodes show the variables, and the arcs show the constraints. All the variables can have values from 0−11. You are required to solve this problem using backtracking table. Show all the working.

Formally:

Variables: A, B, C, D

Domains: {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11}

Constraints: A + 3 < B, B + 2 < D, C + 4 < D, A + 3 < C



Question 2 [15 Marks]

Suppose a genetic algorithm uses chromosomes of the form x = abcdefgh with a fixed length of eight genes. Each gene can be any digit between 0 and 9. Let the fitness of individual x be calculated as:

$$f(x) = (a + b) - (c + d) + (e + f) - (g + h),$$

and let the initial population consist of four individuals with the following chromosomes:

x1 = 6 5 4 1 3 5 3 2 9
x2 = 8 7 1 2 6 6 0 1 23
x3 = 2 3 9 2 1 2 8 5 -16
x4 = 4 1 8 5 2 0 9 4 -19

a) Evaluate the fitness of each individual, showing all your workings, and arrange them in order with the fittest first and the least fit last. [3]

$F(2) = (8+7) - (1+2) + (6+6) - (0+1) = 23$

$F(1) = (6+5) - (4+1) + (3+5) - (3+2) = 9$

$F(3) = (2+3) - (9+2) + (1+2) - (8+5) = -16$

$F(4) = (4+1) - (8+5) + (2+0) - (9+4) = -19$

$\Sigma F(0) = -3$

b) Perform the following crossover operations:

i. Cross the fittest two individuals using one–point crossover at the middle point. [1]

$x_2 = 8712|6601 \Rightarrow O_2 = 87123532$

$x_1 = 6541|3532 \Rightarrow O_1 = 65416601$

ii. Cross the second and third fittest individuals using a two–point crossover (points b and f). [1]

$x_3 = 23|9212|85 \Rightarrow O_3 = 23852085$

$x_4 = 41|8520|94 \Rightarrow O_4 = 41921294$

iii. Cross the first and third fittest individuals (ranked 1st and 3rd) using a *one-point* crossover at the middle point. [1]

$X_2 = 8712|6601 \Rightarrow 05 = 87121285$

$X_3 = 2392|1285 \Rightarrow 06 = 23926601$

c) Suppose the new population consists of the six offspring individuals received by the crossover operations in the above question. Evaluate the fitness of the new population, showing all your workings. Has the overall fitness improved? [4]

$F(O_1) = 65416601$

$= (6+5) - (4+1) + (6+6) - (6+1) = 17$

$F(O_2) = 87123532$

$= (8+7) - (1+2) + (3+5) - (3+2) = 15$

$F(O_3) = 23852085$

$= (2+3) - (8+5) + (2+0) - (8+5) = -19$

$F(O_4) = 41929294$

$= (4+1) - (9+2) + (1+2) - (9+4) = -16$

$F(O_5) = 87121285$

$(8+7) - (1+2) + (1+2) - (8+5) = 2$

$F(O_6) = (2+3) - (9+2) + (6+6) - (0+1) = 5$

$F(O) = 2$, hence fitness has improved

d) By looking at the fitness function and considering that genes can only be digits between 0 and 9 find the chromosome representing the optimal solution (i.e. with the maximum fitness). Find the value of the maximum fitness. [3]

maximum fitness $= (a+b) - (c+d) + (e+f) - (g+h)$

$= (9+9) - (0+0) + (9+9) - (0+0)$

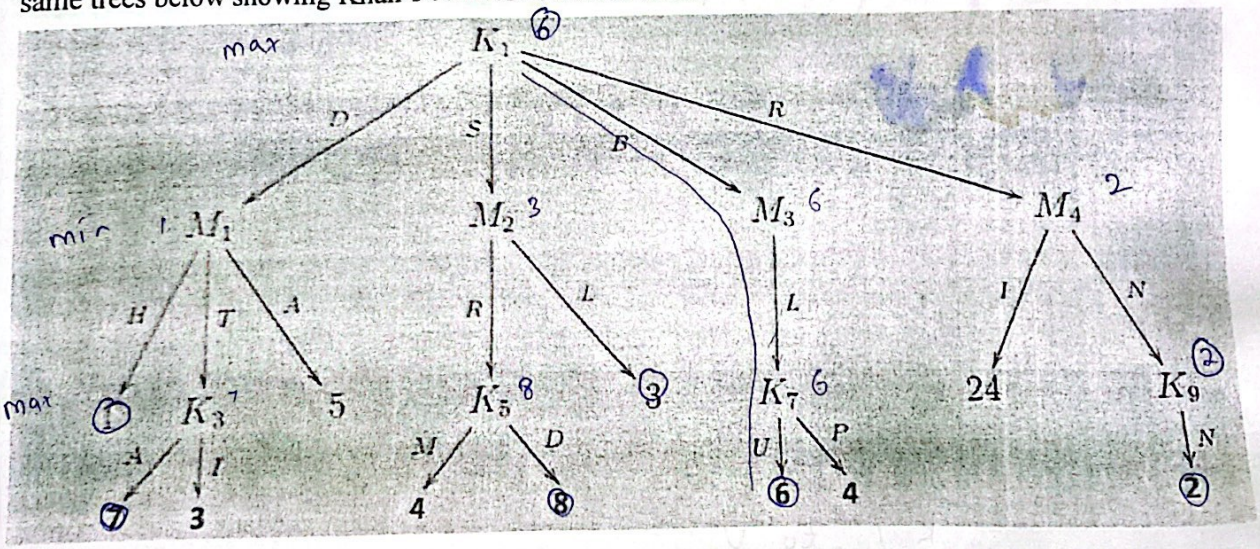
$= 36$

e) By looking at the initial population of the algorithm can you say whether it will be able to reach the optimal solution without the mutation operator? Gave the proper reason. There will be no marks for simple Yes/No. [2]

No, it will not be able to reach the optimal solution, as it would not be possible to place the highest digit (i.e '9') as the first digit of an offspring without using mutation. Using crossover will only swap the existing points and none of them currently possess the optimal solution.

Question 3 [15 Marks]

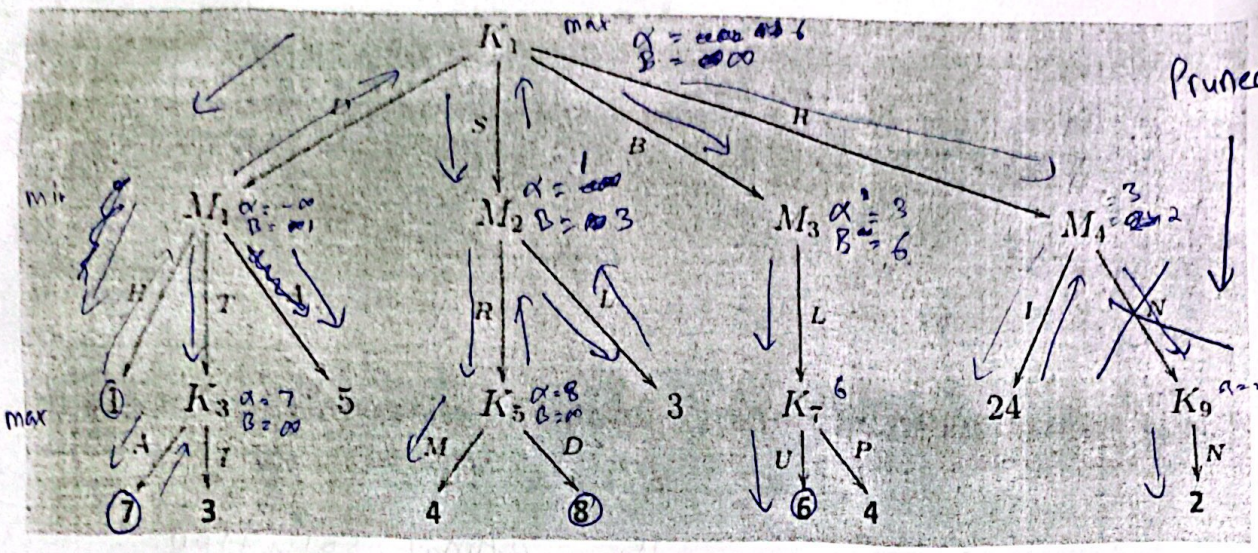
After the failed attempt to get worldwide attention in 2019, Narendra Modi, the supreme leader of Democratic People's Republic of India decided to launch an aerial attack on Pakistan Khan's nodes are market with K and Modi's with M. Once the attack was launched. Imran Khan, the Prime Minister of the Islamic Republic of Pakistan had the option of engaging in Dialogue (D), delivering one of his Daily Speeches(S), Bollywood Boycott(B) or a retaliatory strike (R). Modi can react accordingly, sometimes giving Khan another chance to make a second move. Consider the South Asian Crisis as the same trees below showing Khan's utilities at the leaf nodes.



a) Using minimax only (no αβ) indicate the values of all the decision nodes on the tree above. [5]

b) Using minimax only, what is the next best move from K1? [2]

B (towards M3)



c) Trace the steps of αβ pruning on the copy of the tree above. Circle and mark the leaf nodes in the order that they are statically evaluated. [5]

d) What the final α and β values at node M4? [3]

$\alpha = 3$

$\beta = 2$

Leaf nodes:

- M1 to H : sets $\beta = 1$
- K3 to A : sets $\alpha = 7$
- K3 to T : ignores $\alpha = 3$
- M1 to A : ignores $\beta = 5$
- K5 to M : sets $\alpha = 4$
- K5 to D : sets $\alpha = 8$
- K7 to U : sets $\alpha = 6$
- K7 to P : ignores $\alpha = 4$
- M4 to I : sets $\beta = 24$
- K9 to N : sets $\alpha = 2$
- M4 to N : sets $\beta = 2$

M4 to N : Pruned