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National University of Computer and Emerging Sciences, Lahore Campus

	Course:	**Evolutionary Computations**	**Course Code:**	**CS-566**
	Program:	**MS (Computer Science)**	**Semester:**	**Fall 2018**
	Duration:	**180 Minutes**	**Total Marks:**	**42**
	Paper Date:	**21-Dec-18**	**Weight**	
	Section:	**N/A**	**Page(s):**	**12**
	Exam:	**Final**		

Instruction/Notes: Attempt the examination on the question paper and write concise answers. You can use extra sheet for rough work. Do not attach extra sheets used for rough with the question paper. Don't fill the table titled Questions/Marks.

Question	1	2	3	4	5	6	7	Total
Marks	/ 5	/ 4	/ 5	/ 5	/6	/8	/9	/ 42

Q1: [1+4 marks] MOEA/D: Suppose you have 4 solutions and their weight vectors and randomly generated solutions are given in the table given below. You have to use Tchebycheff approach.

$$\text{minimize} \quad g^{te}(x|\lambda, z^*) = \max_{1 \le i \le m} \{\lambda_i |f_i(x) - z_i^*|\}$$

Soln# (i)	Weight vector (λ)	Solution $x^{(i)}$	Minimize $F1(x^{(i)})$	Maximize $F2(x^{(i)})$
1	$[0.3, 0.7]^T$	{0, 1, 1, 0, 1, 0}	3	7
2	$[0.7, 0.3]^T$	{1, 1, 0, 1, 1, 1}	5	13
3	$[0.5, 0.5]^T$	{0, 0, 1, 1, 1, 1}	4	14
4	$[0.2, 0.8]^T$	{1, 1, 1, 0, 0, 0}	3	3

Consider the following two fitness functions:

- F1(x) = the number of ones in bit string x
- F2(x) = $\sum_{j=0}^{5} (j * x(j))$, where x(j) is gene at index j

a) Fill in last 2 columns of the table above. As an example, F1 and F2 values for solution $x^{(1)}$ have been already populated.

b) Execute one complete iteration for solution# 1 ($x^{(1)}$), assuming T = 2 (parameter for closest weight vectors). You have to apply single point crossover (assuming crossover point = 3, its means child will inherit 50% of the genes from each parent). For mutation, swap first and last gene. You have to do all the working on this answer sheet. At the end fill in the 2nd column of the table given below.

B(1)	{ }
Child after crossover	

Child after mutation	
Fitness of mutated child	F1 = ----------------------------, F2 = -----------------------------
Write all Updated solutions :	

Solution (working here):

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Q2: [4 marks] Non-dominated sorting GA-II (Multi-Objective Optimization)

Let P = { (3, 3, 7), (3, 1, 6), (2, 1, 6), (0, 4, 6), (0, 4, 8), (5, 4, 9) } denote the objective function vectors of a population of individuals in an evolutionary algorithm for Pareto optimization.

1. Assuming all the objectives need to be minimized, apply non-dominated sorting procedure used in NSGA-II as shown below and answer the following questions. [1+2+1]

   a) Write solutions of Front 1 (F_1):

   b) In order to create F_1, write the updated values of S_p and n_p for each solution in the following table.

Soln# (p)	Objective function vectors	S_p	n_p
1	(3, 3, 7)		
2	(3, 1, 6)		
3	(2, 1, 6)		
4	(0, 4, 6)		
5	(0, 4, 8)		
6	(5, 4, 9)		

```
fast-non-dominated-sort(P)
for each p ∈ P
   S_p = ∅
   n_p = 0
   for each q ∈ P
      if (p ≺ q) then
         S_p = S_p ∪ {q}
      else if (q ≺ p) then
         n_p = n_p + 1
   if n_p = 0 then
      p_rank = 1
      F_1 = F_1 ∪ {p}
i = 1
while F_i ≠ ∅
   Q = ∅
   for each p ∈ F_i
      for each q ∈ S_p
         n_q = n_q − 1
         if n_q = 0 then
            q_rank = i + 1
            Q = Q ∪ {q}
   i = i + 1
   F_i = Q
```

   c) Write solutions for other fronts (other than F_1).

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Q3: NSGA-III (Many-Objective Optimization) [5 marks]

Suppose you have to optimize three objectives: (i) Maximize F_1, (ii) Maximize F_2 and (iii) Minimize F_3. Suppose there are total 10 solutions (initial population + generated offsprings) in generation 1 and consider 3 reference points (R1, R2, R3).

Sol #	Maximize F_1	Maximize F_2	Minimize F_3	**Distance from R1**	**Distance from R2**	**Distance from R3**
1	10	10	6	10	9	8
2	8	15	5	4	10	12
3	14	6	4	5	15	9
4	20	20	2	18	15	22
5	20	5	2	12	8	13
6	15	14	5	12	16	3
7	15	30	8	13	5	6
8	3	20	7	9	7	8
9	15	30	3	8	14	10
10	16	20	10	9	10	7

(i) Assume you apply NSGA-III to the problem, what will be the ideal point? [0.5 marks]
Solution:

(ii) Associate each solution with a Ref point [1 mark]

Soln#	1	2	3	4	5	6	7	8	9	10
Ref point										

(iii) Suppose we want to take 6 solutions to the next generations, which 6 solutions out of 10 will be part of next generation? Apply NSGA-III niching, and write down those 6 solutions and the updated niche count of the Reference points at the end. [3.5 marks]

Solution:

Solutions which will be part of next generation are:

Solution #						

Niche Count of Reference Points:

Ref. Point	R1	R2	R3
Initial Niche count			

Ref. Point	R1	R2	R3
Updated Niche count			

Q4: Hyper-heuristics [5 marks]

Suppose an AI-based company wants to solve an optimization problem with two objectives: (i) Minimize F1, (ii) Minimize F2. The chief scientist investigates and found that results of the problem can be improved if somehow we can combine the strengths of different already proposed multi-objective evolutionary algorithms. He looks at the latest papers of “IEEE transactions on Evolutionary computation” and suggests “Learning Automata based Hyperheuristic”, to solve the problem. In first set of experiments he considers only 3 well-known EAs, which are NSGA-II, SPEA2, and MOEA/D.

(i) **Ranking Scheme Initialization:** If we use ranking scheme in initialization, which MOEAs are eliminated? Updated population of each MOEA (for stage 1) is given in the following table.

STAGE 1: objective function vectors of the population

MOEA/D	SPEA-2	NSGA-II
[5, 2]	[11, 20]	[5, 2]
[15, 10]	[8, 10]	[15, 10]
[3, 4]	[5, 12]	[3, 4]

[10, 15]	[12, 13]	[10, 15]

HV and SPREAD values for all 3 stages (Here you need to write calculated HV values for stage 1)

STAGE#	MOEA/D	SPEA-2	NSGA-II
1	HV= ---------------------	HV= ---------------------	HV= ---------------------
	Spread = 0.1	Spread = 0.2	Spread = 0.1
2	HV = 0.8	HV = 0.6	HV = 0.5
	Spread = 0.1	Spread = 0.05	Spread = 0.1
3	HV = 0.9	HV = 0.7	HV = 0.8
	Spread = 0.01	Spread = 0.1	Spread = 0.07

Which MOEAs are eliminated? ---

(ii) Generate the initial Transition matrix

(iii) **Update the Transition matrix using Reinforcement Learning scheme:** Suppose first we apply the top-ranked algorithm to the combined best population (obtained after first 3 initialization stages). After g generations, we need to switch to another metaheuristic. Using "$\in -$¿RouletteGreedy Selection" method, we select one of the available metaheuristics. Suppose the selected metaheuristic is the one with 2^{nd} rank. We execute the selected metaheuristic for g generations. The HV values for both metaheuristics are given below in the table.

Previous metaheuristic (top-ranked in initialization)	New metaheuristic (2^{nd} rank in initialization)
HV = 0.9	HV = 0.85

Update the transition matrix using the following equations (Assume λ = 2):

- If a successor metaheuristic h_j of h_i is selected,

$$p_{(i,j)}(t+1) = p_{(i,j)}(t) + \lambda_{(i,j)}(t)\beta(t)(1 - p_{(i,j)}(t)) - \lambda_{(i,j)}(t)(1 - \beta(t))p_{(i,j)}(t) \quad (1)$$

- For the rest of metaheuristics that are not chosen,

$$p_{(i,l)}(t+1) = p_{(i,l)}(t) - \lambda_{(i,l)}(t)\beta(t)p_{(i,l)}(t) + \lambda_{(i,l)}(t)(1 - \beta(t))\left[\frac{1}{r-1} - p_{(i,j)}(t)\right] \quad (2)$$

where $\beta(t) = [0,1]$, $\lambda_{(i,j)}(t)$ is Reward/Penalty Rates, $p_{(i,j)}(t)$ is the probability and r is no. of metaheuristics

Updated Matrix:

Q5: **Multi-criteria Decision Making (MCDM) [6 marks]**

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A recent graduate from a well-reputed university wants to join a university in Pakistan as an Assistant professor/Lecturer. He has to select one from 5 alternatives (Universities): A, B, C, D, and E. The criteria for selection are: (i) Research support, (ii) students quality, (iii) salary, (iv) teaching work-load.

Use TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution) method to select the best alternatives.

(i) Generate weight vector using Analytic Hierarchy Process (AHP) method.

Pairwise Comparisons of different criteria's:

Research support is strongly to very strong preferred (6) over **salary,** and moderately to strong important (4) over **teaching work-load**; also, **Research support** is equally to moderately important (2) over **students' quality**. **Students' quality** is strongly to very strongly preferred (5) over **salary**. **Teaching work-load** is equally to moderately important (2) over **salary**; also, **Students' quality** is moderately preferred (3) over **Teaching work-load**.

(ii) Score of each option with respect to each criterion are shown in the table below. Use TOPSIS method for the following 3 parts.

	Research support	students quality	salary	teaching work-load
A	10	7	8	5
B	5	10	6	7
C	2	5	10	7
D	7	10	8	6
E	8	8	5	5

a) Construct normalized decision matrix: $\mathbf{r_{ij} = x_{ij}/(x^2_{ij})^{1/2}}$ **for i = 1, …, m; j = 1, …, n**

b) Construct weighted normalized decision matrix: $\mathbf{v_{ij} = w_j\, r_{ij}}$

c) Determine ideal and negative ideal solutions

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Q6: MCQs [8 marks]

1) The class NP is the set of all decision problems that:
    a. Can be solved by polynomial-time algorithms.
    b. Can definitely not be solved by polynomial-time algorithms.
    c. Have polynomial-time algorithms that can verify potential solutions.
    d. All of the above.
    e. None of the above.

2) If you could prove, for some problem X, that problem X is NP-complete and also problem X is in class P, then:
    a. The instructor would give you an A+ in CS 566 regardless of your marks.
    b. You would be ready to write your dissertation and claim your PhD in computer science.
    c. You would receive job offers to join the computer science faculties at MIT and Stanford.
    d. The ACM would honor you with a Turing Award for your outstanding research contributions.
    e. All of the above.

3) One at a time Design of experiment fails when factors are

    a) Independent b) confounded c) continuous-valued d) discrete-valued

4) In SPEA2, which fitness assignment strategies are used

    a) Dominance depth b) dominance rank c) dominance count d) All

5) If you want to build an intelligent system to recognize the vehicle type on highway, which of the following will be preferred

    a) Genetic algorithm b) Hill climbing c) Simulated annealing d) Genetic programming

6) Which of the following performance indicators are used to measure both convergence and diversity

    a) Generated Distance b) Hyper Volume c) Inverted Generated Distance d) Spread

7) The followings are examples of NP-hard problems

    a) Travelling salesman problem b) Factoring problem c) Knapsack problem d) All mentioned

8) Which of the followings are not True

a) Schema with Higher order are more likely to survive under crossover operator
b) probability of survival under mutation is higher for short-length schemas.
c) probability of survival under crossover is higher for shorter schemas.
d) schemas are implicitly the building blocks that the GA process effectively under the operations of selection, mutation and single-point crossover.

Q7: Short questions [9 marks]

1) Generate Random Latin Hypercube Design for 3 factors, assuming 5 levels for each factor. You need to generate total 10 design points. Moreover also generate Coarse Grid factorial designs for 3 factors. [2 mark]

Random Latin Hypercube Design	**Coarse Grid factorial design**

2) What is Elitism in Environmental Selection? [1 mark]

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3) When we say that two objectives are conflicting, what does it mean? Does it mean that one of the objective need to be minimized and the other one should be maximized? Explain your answer with a real-world example with two conflicting objectives. [1 mark]

4) Genetic Programming: Given some points in R^2, $(x_1, y_1), \dots, (x_n, y_n)$
The function f(x) such that. For all $i = 1, \dots, n : f(x_i) = y_i$.
Suppose you also want to fix the bloating issue, and your formulate your problem as Multi-objective optimization problem. What will be your two objectives, also write if you will minimize or maximize the objectives? [2 marks]

Solution:

Objective function 1: --

Objective function 2: --

5) . GA Theory: For schema **H = 1****1*,** what will be the total number of instances (candidate solutions) which belong to this schema? Also write general formula. [1 mark]

6) . GA Theory: For schema **H = 1**1**0**,** what will be the probability that crossover occurs within the defining length of the schema? [1 mark]

7) . GA Theory: For schema **H = 1**1**0**,** what will be the probability that schema will not survive under mutation? [1 mark]

Good Luck ☺