COMP 5970/6970/6976 Fall 2019 Exam 1 Key

This is a closed-book, closed-notes exam. The only items you are allowed to use are writing implements. Mark each sheet of paper you use with your name and the string "COMP 5970/6970/6976 Exam 1". If you are caught cheating, you will receive a zero grade for this exam. The max number of points per question is indicated in square brackets after each question. The sum of the max points for all the questions is 38, but note that the max exam score will be capped at 36 (i.e., there are 2 bonus points, but you can't score more than 100%). You have exactly 50 minutes to complete this exam. Keep your answers clear and concise while complete. Good luck!

Multiple Choice Questions - write the letter of your choice on your answer paper

1. In Evolution Strategies with uncorrelated mutation with n step sizes, the conceptual motivation for updating the mutation step sizes with the formula $\sigma_i' = \sigma_i \cdot e^{\tau' \cdot N(0,1) + \tau \cdot N_i(0,1)}$ is: [2]
   - (a) the sum of two normally distributed variables is also normally distributed [$\frac{1}{2}$]
   - (b) the common base mutation $e^{\tau' \cdot N(0,1)}$ allows for an overall change of the mutability, guaranteeing the preservation of all degrees of freedom [1]
   - (c) the coordinate-specific $e^{\tau \cdot N_i(0,1)}$ provides the flexibility to use different mutation strategies in different directions [1]
   - (d) **all of the above**
   - (e) none of the above [0]

2. In the hybridization of the GPS-EA and ELOOMS, the Limiting Cases are detected by: [2]
   - (a) **none of the individuals desiring to mate with an individual who reciprocates that desire**
   - (b) the average fitness of the mating pool being higher than the average population fitness [0]
   - (c) the average fitness of the mating pool being lower than the average population fitness [0]
   - (d) none of the individuals desiring to mate with any other individual [1]
   - (e) none of the above [0]

3. If we employ self-adaptation to control the value of penalty coefficients for an EA with an evaluation function which includes a penalty function, then: [2]
   - (a) the penalty coefficients will be self-adapted to cause fitness improvement just like, for instance, mutation step sizes [1]
   - (b) this cannot be done because it is inherently impossible to self-adapt any part of the evaluation function [$\frac{1}{2}$]
   - (c) **the penalty coefficients will be self-adapted, but the increase in fitness achieved may not be correlated with better performance on the objective function**
   - (d) none of the above [0]

The final multiple choice questions are about this semester's Cutting Stock assignment.

Assume that:

- the genotype representation is a sequence of triples consisting of a coordinate pair of the form (x, y) where x is the length offset and y is the width offset, with the origin being bottom left, followed by a 0, 1, 2, or 3, indicating clockwise 90 degree rotation multipliers, and the k^{th} triple corresponds to the k^{th} shape of the problem instance,
- the phenotype representation is a 2-d grid showing the stock layout of all the shapes to be cut,
- constraint satisfaction is achieved by immediately eliminating offspring which do not satisfy all constraints and regenerating offspring until a valid offspring has been created,
- mutation is restricted to moving shapes to adjacent grid cells, and
- fitness is inversely proportional to the length of the material needed in order to accommodate all the shapes provided.

4. For this semester's cutting stock assignment, is the encoding: [2]
   (a) pleitropic, but not polygenic [1]
   (b) polygenic, but not pleitropic [1]
   (c) **both pleitropic and polygenic** [because a shape has the potential to cover multiple grid cells (pleitropy) and a grid cell has the potential to be covered by different shapes (polygeny), although not simultaneously]
   (d) neither pleitropic nor polygenic [0]

5. For this semester's cutting stock assignment, is the decoding function: [2]
   (a) **surjective, but not injective** [It's surjective, because during initialization all feasible phenotypes can be generated; it's not injective, because the same shapes with different starting coordinates, but appropriately chosen rotations, map to the same phenotype
   (b) injective, but not surjective [0]
   (c) surjective, injective, and bijective [1]
   (d) surjective and injective, but not bijective [$\frac{1}{2}$]
   (e) bijective, but not both surjective and injective [0]
   (f) neither surjective, injective, nor bijective [1]

6. For this semester's cutting stock assignment, is in general (i.e., do there exist instances of) this problem: [2]
   (a) unimodal, but not multimodal [$\frac{1}{2}$]
   (b) **multimodal, but not unimodal** [for example, given a shape containing a 2 x 2 grid cell hole, and a shape consisting of a 2 x 2 grid cell square, the optimal solution is to fit the square in the hole, but due to the mutation operator being limited to adjacent moves, that would require moving the square through the other shape to get to the hole, which is not possible due to the type of constraint satisfaction employed, so it cannot be unimodal, but it is multimodal]
   (c) both unimodal and multimodal [2] this wasn't supposed to be a correct answer, but the i.e., clarification of "in general" is ambiguous
   (d) neither unimodal nor multimodal [0]

7. For this semester's cutting stock assignment, for harder instances is it generally better to: [2]

   (a) ignore the constraints [0; this is a poor solution, because selective pressure will favor placing all shapes at the start of the stock with massive overlaps, just about guaranteeing converging on invalid solutions]

   (b) upon generating an infeasible solution immediately kill it and generate a new solution [$\frac{1}{2}$; this is a poor solution, because selective pressure will favor placing all shapes at the start of the stock, thus increasingly generating invalid solutions as evolution progresses, thus causing the majority of computational time to be wasted]

   (c) **employ a penalty function** [because while it will prefer valid solutions, by penalizing rather than eliminating invalid ones, it will facilitate invalid regions of the search space to be crossed

8. Alice is writing an EA to solve the binary knapsack constraint satisfaction problem. The sum of the item costs is 37, while the total cost is constrained to be below 36. Should she: [2]

   (a) Ignore the constraints under the motto: all is well that ends well. [0]

   (b) **Upon generating an infeasible solution, immediately kill it and generate a new solution; repeat this step until a feasible solution is generated.**

   (c) Employ a penalty function that reduces the fitness of infeasible solutions, preferably so that the fitness is reduced in proportion to the number of constraints violated, or to the distance from the feasible region. [$\frac{1}{2}$]

   (d) Employ a repair function that takes infeasible solutions and "repairs" them by transforming them into a related feasible solution, typically as close as possible to the infeasible one. [$1\frac{1}{2}$]

   (e) Employ a closed feasible solution space which guarantees that the initial population consists of feasible solutions only and all evolutionary operations on feasible solutions are guaranteed to result in feasible solutions. Typically a combination of custom representation, initialization, recombination, and mutation is employed to achieve this. [$\frac{1}{2}$]

   (f) Employ a decoder function that maps genotype space to phenotype space such that the phenotypes are guaranteed to be feasible even when the genotypes are infeasible. Typically this involves mapping multiple different genotypes to the same phenotype. [1]

open questions start on the next page

Open Questions - write your answer on your answer paper

9. (a) What is the binary gray code for the standard binary number 00011100110101? [2]
   00010010101111

   (b) What is the standard binary number encoded by the binary gray code 00011100110101? [2]
   00010111011001

10. Given the following two parents with permutation representation:
    $p1 = (135792468)$
    $p2 = (614879532)$

    (a) Compute the first offspring with Cycle Crossover. [4]
    Cycle 1: 1-6-3
    Cycle 2: 5-4
    Cycle 3: 7-8-2-9
    Construction of first offspring by scanning parents from left to right, starting at parent 1 and alternating parents:

    i. Add cycle 1 from parent 1: **13.....6.**
    ii. Add cycle 2 from parent 2: **134...56.**
    iii. Add cycle 3 from parent 1: **134792568**

    (b) Compute the first offspring with PMX, using crossover points between the 2nd and 3rd loci and between the 7th and 8th loci. [4]

    i. $\cdot\cdot 57924 \cdot\cdot$
    ii. $\cdot\cdot 57924 \cdot 8$
    iii. **615792438**

    (c) Compute the first offspring with Edge Crossover, except that for each random choice you instead select the lowest element. [8]

Original Edge Table:

Element	Edges	Element	Edges
1	8,3,6,4	6	4,8,2,1
2	9,4,3,6	7	5,9+,8
3	1,5+,2	8	6,1,4,7
4	2,6,1,8	9	7+,2,5
5	3+,7,9		

Construction Table:

Element selected	Reason	Partial result
1	Lowest	1
3	Shortest list size	13
5	Common edge	135
7	Equal list size, so lowest	1357
9	Common edge	13579
2	Only element	135792
4	Equal list size, so lowest	1357924
6	Equal list size, so lowest	13579246
8	Last element	**135792468**

Edge Table After Step 1:

Element	Edges	Element	Edges
1	8,3,6,4	6	4,8,2
2	9,4,3,6	7	5,9+,8
3	5+,2	8	6,4,7
4	2,6,8	9	7+,2,5
5	3+,7,9		

Edge Table After Step 2:

Element	Edges	Element	Edges
		6	4,8,2
2	9,4,6	7	5,9+,8
3	5+,2	8	6,4,7
4	2,6,8	9	7+,2,5
5	7,9		

Edge Table After Step 3:

Element	Edges	Element	Edges
		6	4,8,2
2	9,4,6	7	9+,8
		8	6,4,7
4	2,6,8	9	7+,2
5	7,9		

Edge Table After Step 4:

Element	Edges	Element	Edges
		6	4,8,2
2	9,4,6	7	9+,8
		8	6,4
4	2,6,8	9	2

Edge Table After Step 5:

Element	Edges	Element	Edges
		6	4,8,2
2	4,6		
		8	6,4
4	2,6,8	9	2

Edge Table After Step 6:

Element	Edges	Element	Edges
		6	4,8
2	4,6		
		8	6,4
4	6,8		

Edge Table After Step 7:

Element	Edges	Element	Edges
		6	8
		8	6
4	6,8		

(d) Compute the first offspring with Order Crossover, using crossover points between the 6th and 7th loci and between the 8th and 9th loci. [2]

i. Child 1: $\cdot\cdot\cdot\cdot\cdot\cdot 46\cdot$

ii. Child 1: **187953462**