CS5401 FS2018 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 "cs5401fs2018 exam1". 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 53, but note that the max exam score will be capped at 50 (i.e., there are 3 bonus points but you can't score more than 100%). You have exactly 75 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. Mutation has the potential to modify an individual's: [2]
   (a) genotype
   (b) phenotype
   (c) alleles
   (d) fitness
   (e) all of the above
   (f) a, b, and c, but not d

2. Mutation has the potential to increase population diversity by: [2]
   (a) increasing the number of unique fitness values without increasing the number of unique alleles *(true, a different distribution of the same set of alleles over the genes can result in a different phenotype and fitness value)*
   (b) increasing the number of unique alleles without increasing the number of unique phenotypes *(true, for instance if the decoder function skips a particular gene then changing that gene's allele to a unique value will not effect the phenotype)*
   (c) increasing the number of unique phenotypes without increasing the number of unique genotypes *(true, for instance if two different genotypes decoded to the same phenotype, then replacing one of those genotypes with a unique genotype which decodes to a unique phenotype doesn't increase the number of unique genotypes but does increase the number of unique phenotypes)*
   (d) a, b, and c
   (e) a and b, but not c

3. Which is the odd one out: [2]
   (a) Random resetting mutation
   (b) Uniform mutation
   (c) Creep mutation *(the only one of the four which employs a non-uniform distribution)*
   (d) Bit-flipping mutation

4. To increase selective pressure for an EA employing tournament parent selection one can: [2]
   (a) switch from truncation survivor selection (i.e., deterministically replacing the worst individuals) to an elitist stochastic survivor selection
   (b) decrease the tournament size used in parent selection
   (c) both of the above
   (d) none of the above

5. In an EA which utilizes truncation survival selection: [2]
   (a) the chance of premature convergence is lower than other elitist EAs *(false because truncation survival has the highest selective pressure of all the regular elitist survival mechanisms)*
   (b) the parent selection may not be elitist because that would cause premature convergence *(elitist means that the fittest solution is guaranteed to survive which by itself doesn't caise premature convergence)*
   (c) the parent selection should be stochastic to decrease the chance of premature convergence
   (d) all of the above
   (e) none of the above

Open Questions - write your answer on your answer paper

6. (a) What is the binary gray code for the standard binary number 0100111011? [2]
   0110100110
   (b) What is the standard binary number encoded by the binary gray code 11100001? [2]
   10111110

7. Given the following two parents with permutation representation:
   $p1 = (147628539)$
   $p2 = (193465872)$
   (a) Compute the first offspring with Cycle Crossover. [4]
   Cycle 1: 1, cycle 2: 4-9-2-6, cycle 3: 7-3, cycle 4: 8-5
   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: $1 \cdots\cdots\cdots$
      ii. Add cycle 2 from parent 2: $19 \cdot 46 \cdots 2$
      iii. Add cycle 3 from parent 1: $19746 \cdot \cdot 32$
      iv. Add cycle 4 from parent 2: **197465832**
   (b) Compute the first offspring with PMX, using crossover points between the 3rd and 4th loci and between the 6th and 7th loci. [4]
      i. $\cdots 628 \cdot \cdot\cdot$
      ii. $\cdots 628 \cdot \cdot 4$
      iii. $\cdots 6285 \cdot 4$
      iv. **193628574**
   (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	9+,4,2	6	7,2,4,5
2	6,8,7,1	7	4,6,8,2
3	5,9+,4	8	2,5+,7
4	1,7,3,6	9	3+,1+
5	8+,3,6		

Construction Table:

Element selected	Reason	Partial result
1	Lowest	1
9	Common edge	19
3	Only element	193
4	Equal list size, so lowest	1934
6	Equal list size, so lowest	19346
5	Shortest list	193465
8	Only element	1934658
2	Equal list size, so lowest	19346582
7	Last element	**193465827**

Edge Table After Step 1:

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

Edge Table After Step 2:

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

Edge Table After Step 3:

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

Edge Table After Step 4:

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

Edge Table After Step 5:

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

Edge Table After Step 6:

Element	Edges	Element	Edges
2	8,7	7	8,2
		8	2,7
5	8+		

Edge Table After Step 7:

Element	Edges	Element	Edges
2	7	7	2
		8	2,7

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

i. Child 1: $\cdot\cdot$ 76285 $\cdot\cdot$

ii. Child 1: **347628519**

The last four questions are about the Light Up Puzzle assignment assuming that the genotype representation is any set of coordinate pairs (coordinates merely need to map to the dimensions of the grid) for bulb placements and the decoder function maps these sets to bulb placements in white cells on Light Up puzzle grids where no two bulbs shine on each other, black cell adjacency constraints are met, and fitness is determined by the number of cells lit up.

8. Explain whether this problem is unimodal or multimodal. [4]

This depends on the neighborhood structure imposed by the variation operators one chooses to employ. For example, if mutation has the ability to transform any genotype to any other genotype, for instance by replacing any set of coordinate pairs with any other set of coordinate pairs, then the problem is per definition unimodal. On the other hand, if for instance mutation was restricted to moving a bulb to an adjacent cell, then given a 3 by 3 board of all white cells except for center cell (2,2) and corner cell (3,1) which are black but without any number constraints and a single bulb has been placed in (1,1), then that start position is a local optimum and there are additional local optima such as placing the bulb in (1,3), so therefore the problem is multimodal.

9. Explain whether this encoding is pleitropic and/or polygenetic. [2]

Both, because, for example, a bulb has the potential to light up multiple cells (pleitropy) and a cell has the potential to be lit up by different bulbs (polygeny).

10. Explain whether this decoding function is surjective and/or injective. [4]

It is surjective, because the placement of bulbs in a phenotype always is a valid genotype which will be decoded to that phenotype. It is not injective, because multiple genotypes can be decoded to the same phenotype; for example, if genotype g decodes to a phenotype where all cells are lit, and g' is created by adding a uniquely placed bulb coordinate pair to g, then the decoder may decode g' to the same phenotype as g because the added bulb either is on a black cell or is shining on another bulb.

11. Say that constraint satisfaction techniques are to be employed in regard bulbs shining on each other.

(a) Explain whether it would be better to (I) ignore the constraints, (II) upon generating an infeasible solution immediately kill it and generate a new solution, or (III) employ a penalty function. [4]

Option (I) is poor because if the constraint that bulbs should not shine on each other is not being enforced during evolution, then because the easiest way to light up all white cells is to keep adding bulbs to unlit white cells until they are all lit, the final population will almost certainly contain all invalid solutions. Option (II) is poor because as in most Light Up puzzles the majority of unconstrained bulb placements result in bulbs shining on each other, generating and killing infeasible solutions will result in the majority of computational time being wasted. Option (III) is the better solution 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.

(b) Describe a possible instance of the decoder function given its description. [3]

Iterate through all coordinate pairs in the genotype, adding coordinate pairs to the phenotype unless they violate a constraint. If this is insufficient to satisfy all black cell adjacency constraints, then brute-force all combinations of bulb placements adjacent to black cells with unsatisfied constraints where bulbs that shine on these placements are removed.

(c) Propose a high-quality repair function. [3]

For each bulb in the phenotype not adjacent to a black cell with an adjacency constraint, build a list of bulbs it shines on. Iteratively remove the bulb from the genotype with the longest list until either the phenotype has been repaired or there are no more. In case of the latter, for each remaining bulb in the phenotype, build a list of bulbs it shines on, and iteratively remove the bulb from the genotype with the longest list until the phenotype has been repaired or there are no more. Brute-force all combinations of bulb placements adjacent to black cells with unsatisfied constraints where bulbs that shine on these placements are removed.