COMP 5660/6660 Fall 2025 Exam 3 Key

This is a closed-book, closed-notes exam. The sum of the max points for all the questions is 66, but note that the max exam score will be capped at 62 (i.e., there are 4 bonus points, but you can't score more than 100%). You have exactly 50 minutes to complete this exam. Good luck!

Multiple Choice Questions

1. Which of the following is not a way that (canonical) Cartesian Genetic Programming differs from typical genetic programming variants? [4 pts]

   (a) Population size of 1
   (b) No recombination
   (c) GP nodes can form cycles
   (d) Bloat control is unnecessary

   Select one of:

   - a [0]
   - b [0]
   - **c**
   - d [0]
   - a and b [0]
   - a and c [2]
   - a and d [0]
   - b and c [2]
   - b and d [0]
   - c and d [2]
   - a, b, and c [1]
   - a, b, and d [0]
   - a, c, and d [1]
   - b, c, and d [1]
   - a, b, c, and d [0]
   - none of a, b, c, nor d [0]

2. Which mechanisms does the quality-diversity algorithm MAP-Elites use to promote diversity? [4 pts]

   (a) Fitness is divided between all individuals that are close by in phenotype space
   (b) A grid of cells in phenotype space, where each cell stores a single individual
   (c) A penalty function measures the Manhattan distance between individuals in genotype space
   (d) The phylogenetic history of each gene is tracked in order to form distinct species

   Select one of:

   - a [1]
   - **b**
   - c [0]
   - d [0]
   - none of a, b, c, nor d [0]

3. When representing a multivariate normal distribution of solutions in CMA-ES, what role does the covariance matrix play? [4 pts]

   (a) Encodes the location of the distribution
   (b) Encodes the scale of the distribution
   (c) Encodes the orientation of the distribution

   Select one of:

   - a [0]
   - b [2]
   - c [2]
   - a and b [1]
   - a and c [1]
   - **b and c**
   - a, b, and c [2]
   - none of a, b, nor c [0]

4. An asynchronous parallel EA (APEA) inherently leverages heterogeneous fitness evaluation times for: [4 pts]

   (a) genotype size diversity
   (b) phenotype size diversity
   (c) computational scalability
   (d) elitist parsimony pressure

   Select one of:

   - a [0]
   - b [0]
   - c [2]
   - d [2]
   - a and b [0]
   - a and c [1]
   - a and d [1]
   - b and c [1]
   - b and d [1]
   - **c and d**
   - a, b, and c [0]
   - a, b, and d [0]
   - a, c, and d [3]
   - b, c, and d [3]
   - a, b, c, and d [2]
   - none of a, b, c, nor d [0]

5. Machine learning models alone would be unfit for evolving new proteins because... [4 pts]

   (a) Evolutionary algorithms are the only thing that can model the process by which existing proteins were designed.
   (b) Proteins are an example of an extremely high-dimensional space, which machine learning models struggle with.
   (c) Even the most advanced machine learning models, such as AlphaFold 3, struggle to fold proteins accurately.
   (d) Machine learning models will be biased by their own training data.

   Select one of:

   - a [1]
   - b [0]
   - c [1]
   - **d**
   - none of a, b, c, nor d [0]

6. Koza's Automatically Defined Functions (ADFs) are: [4 pts]

   (a) the application of GP to automate the creation of functions in computer programs
   (b) the standard method of evolving reusable components in GP
   (c) the use of GP to create functions with a high AI ratio

   Select one of:

   - a [2]
   - **b**
   - c [1]
   - a and b [3]
   - a and c [1]
   - b and c [2]
   - a, b, and c [2]
   - none of a, b, nor c [0]

7. Some Interactive EAs allow the user to directly modify the evolving genes and place the modified individuals back in the population. This is an example of: [4 pts]

   (a) Lamarckian Evolution
   (b) Baldwin Effect
   (c) Hyper-heuristics
   (d) Self-generating Memetic Algorithms

   Select one of:

   - **a**
   - b [2]
   - c [0]
   - d [1]
   - none of a, b, c, nor d [0]

8. Learning Classifier Systems (LCS) have the following differences with classic expert systems in order to improve performance: [4 pts]

   (a) storing knowledge in the form of rules
   (b) improving accuracy through reinforcement learning
   (c) gaining new knowledge by generating rules employing evolutionary computation

   Select one of:

   - a [1]
   - b [2]
   - c [2]
   - a and b [2]
   - a and c [2]
   - **b and c**
   - a, b, and c [3]
   - none of a, b, nor c [0]

9. In Fitness Sharing: [4 pts]

   (a) new individuals replace similar population members, resulting in the population sharing niches equally
   (b) the fitness of individuals immediately prior to selection is adjusted according to the number of individuals falling within some prespecified distance of each other
   (c) individuals share the fitness of similar population members immediately prior to selection, resulting in the number of individuals per niche being dependent on the niche fitness

   Select one of:

   - a [0]
   - b [2]
   - c [2]
   - a and b [1]
   - a and c [1]
   - **b and c**
   - a, b, and c [3]
   - none of a, b, nor c [0]

10. In the hybridization of the GPS-EA and ELOOMS, the Limiting Cases are detected by: [4 pts]

    (a) none of the individuals desiring to mate with any individual who reciprocates that desire
    (b) the average fitness of the mating pool being higher than the average population fitness
    (c) the average fitness of the mating pool being lower than the average population fitness
    (d) none of the individuals desiring to mate with any other individual

    Select one of:

    - **a**
    - b [0]
    - c [0]
    - d [2]
    - none of a, b, c, nor d [0]

11. Increasing primitive granularity in hyper-heuristics is: [4 pts]

    (a) a terrible idea, because we want more sophisticated algorithms, not more primitive
    (b) a sensible idea, because you can represent more fine-grained solutions thus increasing the chance of representing the true global optimum
    (c) a problematic idea, because it expands the search space, so the expected run time to find the global optimum increases
    (d) a wonderful idea, because as the granularity approaches Turing completeness, the hyper-heuristic performance will converge on GP optimality

    Select one of:

    - a [0]
    - b [2]
    - c [2]
    - d [0]
    - a and b [1]
    - a and c [1]
    - a and d [0]
    - **b and c**
    - b and d [1]
    - c and d [1]
    - a, b, and c [3]
    - a, b, and d [1]
    - a, c, and d [1]
    - b, c, and d [3]
    - all of a, b, c, and d [2]
    - none of a, b, c, nor d [0]

12. In the context of John Holland's Schema Theorem, which of the following statements are true: [4 pts]

    (a) The Building Block Hypothesis is that a genetic algorithm seeks near-optimal performance through the juxtaposition of short, low-order, high-performance schemata, called the building blocks.
    (b) Short, low-order, above-average schemata receive exponentially decreasing trials in subsequent generations of a genetic algorithm.
    (c) The result that a population of size μ will usefully process $O(\mu^3)$ schemata is known as Implicit Parallelism.

    Select one of:

    - a [3]
    - b [1]
    - c [2]
    - a and b [2]
    - **a and c**
    - b and c [2]
    - all of a, b, and c [3]
    - none of a, b, nor c [0]

Open Questions

13. Assume a generational genetic algorithm with $\mu = 5$, $\lambda = 35$, and max fitness of 4. Given the following population v_1 through v_5 and schema S

$$
\begin{aligned}
v_1 &= (\texttt{11111111111111}) & \quad & fitness(v_1) = 1 \\
v_2 &= (\texttt{00000000000000}) & & fitness(v_2) = 1 \\
v_3 &= (\texttt{00000001111111}) & & fitness(v_3) = 2.5 \\
v_4 &= (\texttt{11111110000000}) & & fitness(v_4) = 4 \\
v_5 &= (\texttt{10101010101010}) & & fitness(v_5) = 4 \\
S &= (\texttt{1*****1******0}) & &
\end{aligned}
$$

(a) Compute the *order* of S. [2 pts]

3

(b) Compute the *defining length* of S and show your computation. [2 pts]

14-1=13

(c) Compute the fitness of S and justify your answer. [2 pts]

The strings that match S are v_4 and v_5, so the fitness of S at the current generation is $\frac{4+4}{2} = 4$.

(d) Do you expect the number of strings matching S to increase or decrease in subsequent generations? Explain your answer! [4 pts]

Average population fitness $= \frac{1+1+2.5+4+4}{5} = 2.5$

Increase, because while S has a high defining length so a significant chance of destruction during crossover, the fitness of S is well-above the average population fitness and S is low-order, so has a small chance of destruction from mutation.

14. The n-bit multiplexer function consists of k address bits a_i followed by 2^k data bits d_j where $n = k+2^k$ and the function is defined as $a_{k-1}, \ldots, a_1, a_0, d_{2^k-1}, \ldots, d_1, d_0$. Assume a Michigan-style Learning Classifier System (LCS) to solve a 6-bit multiplexer problem with the following rule set:
Rule 1: 101### : $1 \rightarrow 10$
Rule 2: 0#1110 : $1 \rightarrow 30$
Rule 3: #01##0 : $0 \rightarrow 60$
Rule 4: ##1##0 : $1 \rightarrow 20$
Rule 5: #11010 : $1 \rightarrow 10$
Rule 6: 10#0#0 : $0 \rightarrow 50$
Rule 7: 0##### : $0 \rightarrow 25$

If the input string 011000 is presented to this LCS:

(a) which rules will the match set consist of? [2 pts]

Rules 4 and 7

(b) which rules will the action set consist of and what action will the LCS execute? Show how you computed this. [6 pts]

Group them by advocated action and compute predicted action payoff:
Action 0: Rule 7: Mean predicted action payoff: 25/1=25
Action 1: Rule 4: Mean predicted action payoff: 20/1=20
Highest predicted payoff action: Action 0
Action set: Rule 7
LCS executes Action 0