UNIVERSITY OF SOUTHAMPTON COMP6026W1

SEMESTER 1 EXAMINATION 2008/09

EVOLUTION OF COMPLEXITY

Duration: 90 mins

Answer the question in Section A and
TWO questions from Section B.
(25 marks each, 75 marks total)

University approved calculators MAY be used.

 Number of Pages: 6

SECTION A

Question 1.

a) Describe in detail (e.g. using pseudo-code) an algorithm for mutating a bit-string individual. (2 marks)

b) Describe in detail (e.g. using pseudo-code) an algorithm for uniform crossover between two bit-string individuals. (3 marks)

c) Assuming the mutation and crossover operators above, a fitness function and initialisation procedures are all provided, describe in detail (e.g. using pseudo-code) an algorithm for a steady state, tournament selection genetic algorithm. Replacement may be done at random. (10 marks)

d) Describe in detail (e.g. using pseudo-code) how to pick a parent for reproduction with probability proportional to their fitness (instead of the tournament selection requested in part c). Assume that an array of individuals and a corresponding array of their fitnesses is provided. (6 marks)

e) What are the advantages and disadvantages of rank-based selection compared to fitness proportionate selection? Use an example to describe the differences in selective pressure that these selection schemes create. (4 marks)

SECTION B

Question 2.

a) “Every living thing has fitness dependencies with at least one other living thing, so all life is coevolving.” Is this statement accurate? Explain briefly. (3 marks)

b) Describe one example of asymmetric competitive coevolution from the artificial evolution literature. What do the members of the two populations represent. (2 marks)

c) Using examples, describe 2 potential benefits of using competitive coevolution in artificial evolution. (6 marks)

d) Describe what intransitivity means and name 3 sports where intransitivity may occur in the ranking of players, and 3 sports where intransitivity cannot occur. (2 marks)

e) Why is intransitivity a potential problem for coevolutionary algorithms? Among the members of a large diverse populations there is more potential for intransitive relationships than there is among the members of small converged populations. So, if we used small converged populations would this solve the problem of intransitivity? Explain. (6 marks)

f) Describe, using both biological and engineering examples, two different types of modularity (4 marks)

g) Which type of modularity might cooperative coevolution be useful for? Explain briefly (2 marks)

Question 3.

Consider a two-player game with two possible strategies, Up and Down. Here is the payoff matrix for the game, which shows the payoff to a player using the strategy in the appropriate row against an opponent using the strategy in the appropriate column.

	Up	Down
Up	-50	50
Down	0	25

For example, if player 1 plays "Up" and player 2 plays "Down", player 1 will receive a payoff of 50, and player 2 will receive a payoff of 0. If both players play "Down", each would receive a payoff of 25.

a) Of the notable games covered in the lectures, which one is this game most similar to? (2 marks)

b) Imagine a population of players playing this game, repeatedly matched up at random. If the whole population of players played the strategy "Up", would that be an evolutionarily stable strategy (ESS)? Why or why not? (4 marks).

c) If the whole population of players played the strategy "Down", would that be an ESS? Why or why not? (2 marks).

d) Suppose that players were not locked into playing a single strategy consistently, but could randomly choose to play either "Up" or "Down" with a given probability. Would this make a mixed-strategy equilibrium possible? Why or why not? If a mixed-strategy equilibrium is possible, show your working in calculating what it would be. (8 marks).

e) Describe, with appropriate illustrations, an aggregation and dispersal model of the evolution of co-operation of the type proposed by D. S. Wilson. Explain how it operates to suppress cheats in a population. (9 marks).

Question 4.

a) How long will random search, searching in the space of character strings, take to find the string "evolution"? (1 mark).

b) Give an upper bound on the expected time for a mutation hill-climber to find this string assuming fitness is proportional to the number of correct characters. (2 marks).

c) What does the comparison in parts (a) and (b) tell us about the following argument: "The genome of organisms, even for bacteria, is at least 10^6 nucleotides long each of which can be one of 4 bases (A, C, T or G). The number of possible genomes is therefore at least $4^{1000000}$. A single mutation to any of the bases in an organism can be fatal or produce non-viable offspring. It is therefore inconceivable that a random trial and error process like evolution could have produced the genomes of living organisms." (4 marks)

d) Consider the following four two-allele genotypes and their fitnesses. Are they epistatic? Explain. (1 mark).
   - fitness(ab)=1
   - fitness(Ab)=1.1
   - fitness(aB)=2
   - fitness(AB)=2.8

e) What epistasis is described in part (b) where fitness is proportional to the number of correct characters, and what influence does epistasis have on your answer to part (c)? (2 marks).

f) What is the probability of creating the string 1111111111 from the string 1111101101 using:
   1. a two-point mutation? (1 mark).
   2. uniform crossover with a second string 0011111111? (1 mark).
   3. one-point crossover with a second string 0011111111? (1 mark).

g) In the ‘hurdles problem’ the fitness of an individual is a function of the number of 1s in the genotype and, for any individual with an even number of 1s, an additional 1 causes a fitness decrease but two additional 1s provides a fitness increase. Why is a sexual population with uniform crossover able to solve the hurdles problem faster than an asexual population? (2 marks).

h) Student A says “Crossover can take the good parts of one individual and combine them with the good parts of another individual. That’s why crossover is good.” Student B says, “Sure, but more often than not, crossover will disrupt good combinations of alleles by mixing them with the alleles of other individuals. So crossover is generally bad.” Which student is right? Discuss using the concepts of building-blocks, linkage disequilibrium, and the Fisher-Muller benefit of sex. (10 marks).

END OF PAPER