University of Waterloo
Department of Electrical and Computer Engineering

ECE 457A Cooperative and Adaptive Algorithms
Final Examination
August 2nd, 2016, 4:00-6:30. Location: M3 1006

Answer all questions

Question 1 [20 points]
Part 1: [12 points; 2 points each]

(a) What is the advantage of breadth-first search over depth-first search?

(b) Explain the difference between parameter tuning" and "parameter control"?

(c) Describe the difference between genetic programming and genetic algorithms

(d) What is the main difference between hill climbing and simulated annealing?

(e) Compare uniform crossover with 1-point crossover for binary string chromosomal representations! What is the main difference between the two operators?

(f) Explain concisely Rechenberg's 1/5 Success rule.

Part 2: [8 points; 1 point each] (True or False)

(a) Depth-First search using iterative deepening can be made to return the same solution as Breadth-First search.

(b) The solution path found by Uniform-Cost search *may change* if we add the same positive constant, *c*, to every arc cost.

(c) If *h* is a consistent heuristic, then *h* is also an admissible heuristic.

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(d) A* is a special case of uniform-cost search.

(e) Genetic algorithms are used for minimization problems while simulated annealing is used for maximization problems

(f) Genetic algorithms maintain several possible solutions, whereas simulated annealing works with one solution.

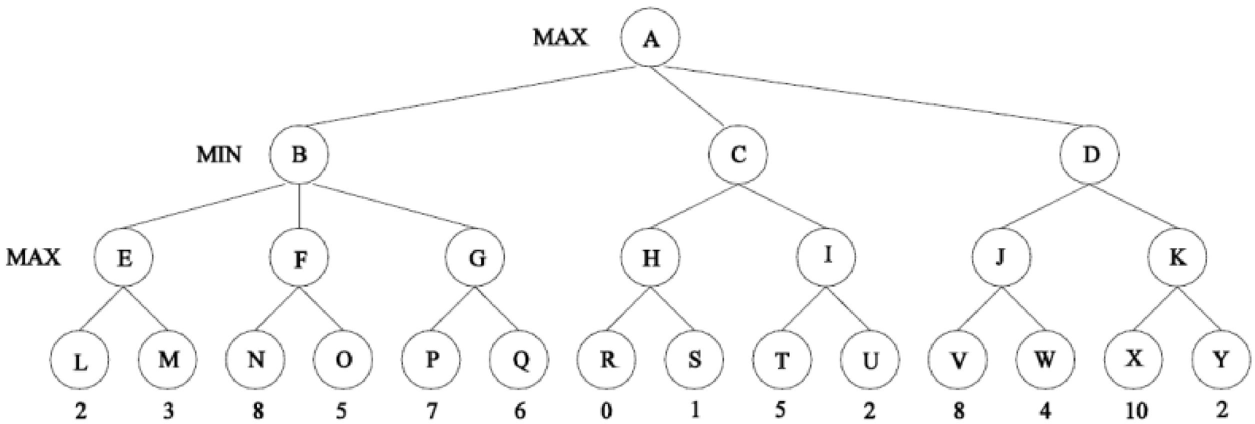
(g) Genetic algorithms maintain one solution, whereas simulated annealing maintains several possible solutions.

(h) Simulated annealing is guaranteed to produce the best solution, while genetic algorithms do not have such a guarantee.

Question 2 [20 points]

Part 1: [10 points]

(a) Consider the following game tree in which the root corresponds to a MAX node and the values of a static evaluation function, if applied, are given at the leaves.



(i) [3 points] What are the **minimax values** computed at each node in this game tree? Write your answers to the *LEFT* of each node in the tree above.

(ii) [3points] Is there a different ordering of the *children of the root* for which *more* pruning would result by Alpha-Beta? If so, give the order. If not, say why not.

(iii) [4 points] Now assume your opponent chooses her move ***uniformly at random*** (e.g., if there are two moves, ½ the time she picks the first move and ½ the time she picks the second) when it's her turn, and you know this. You still seek to maximize your chances of winning. What are the expected minimax values computed at each node in this case? Write your answers to the *RIGHT* of each node in the tree above.

Part 2: [10 points]

(a) [2 points] Describe the idea behind the simulated annealing algorithm making reference to its origins as an optimization methodology.

(b) [2 points] Describe a simulated annealing algorithm and why it can escape local minimum.

(c) (3 points) With regards to simulated annealing, what is the probability of accepting the following moves? Assume the problem is trying to maximise the objective function.

Current Evaluation	**Neighbourhood Evaluation**	**Current Temperature**
16	15	20
25	13	25
76	75	276
1256	1378	100

(d) [3 points] Explain how the Tab search algorithms works; and explain how it achieves exploration and exploitation.

Question 3: [20 points]

Part 1:[10 pints]

(a) [3 points] Explain the difference between the Ant Density Model and the Ant Quantity Model.

(b)[3points] In simple ACO algorithm, ant k located at node i **selects** the **next node** during its **forward** movement based on the below equation.

- When located at node i an ant k uses pheromone trails τ_{ij} to compute the prob. of choosing j as next node:

$$P_{ij}{}^{k} = \begin{cases} \dfrac{(\tau_{ij})^{\alpha}(\eta_{ij})^{\beta}}{\sum_{l \in N_i{}^k}(\tau_{il})^{\alpha}(\eta_{il})^{\beta}} & \text{if } j \in N_i{}^k \\ 0 & \text{if } j \notin N_i{}^k \end{cases}$$

where

$N_i{}^k$: Neighborhood of ant k when it is in node i,

η_{ij} : the heuristical desirability for choosing edge (i, j),

τ_{ij} : the amount of pheromone on edge (i, j),

α and β : relative influence of heuristics vs. pheromone.

Comment on **next node selection** behavior of simple ACO ant for case **α = 0**.

and explain the role of parameters α and β

(b) [4 points] Explain the Near Parameter Free ACS

Part 2: [10 points]

Consider below implementation of Particle Swarm Optimization (**PSO**) algorithm.

```
procedure [X] = PS(max_it,AC1,AC2,vmax,vmin)
    initialize X    //usually xi, ∀i, is initialized at random
    initialize Δxi //at random, Δxi ∈ [vmin,vmax]
    t ← 1
    while t < max_it do,
        for i = 1 to N do,           //for each particle
            if g(xi) > g(pi),
                then pi = xi,        //best indiv. performance
            end if
            g = i                    //arbitrary
            //for all neighbors
            for j = indexes of neighbors
                if g(pj) > g(pg),
                    then g = j,      //index of best neighbor
                end if
            end for
            Δxi ← Δxi + φ1⊗(pi − xi) + φ2⊗(pg − xi)
            Δxi ∈ [vmin,vmax]
            xi ← xi + Δxi
        end for
        t ← t + 1
    end while
end procedure
```

Algorithm 5.4: Standard particle swarm optimization (PS) algorithm.

(a) [4 points] In the above PSO implementation, which update mode (synchronous or asynchronous) for personal best and neighbors' best is adopted? Explain shortly.

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(b) [3 points] Comment on how to change the algorithm to work on asynchronous mode if your answer to part (a) is "synchronous" otherwise to work on synchronous if your answer to part (a) is "asynchronous".

(c) [3 points] Considering the effect of Parameters $w, c_1, c_2,$ in the PSO model

$$v_{t+1}^{id} = w * v_t^{id} + c_1 r_1^{id} \left(pbest_t^{id} \quad x_t^{id} \right) + c_2 r_2^{id} \left(Nbest_t^{id} \quad x_t^{id} \right)$$

- What happens when c_1 is set to zero ?

- What happens when c_2 set to zero ?

- What is the importance of the parameter w ?

Question 4: [20 points]

(a) [10 points] Assume that we use a genetic programming system to automatically evolve programs for regression problems such as fitting the following function

$$f(x) = \begin{cases} x^2 + \log_{10} x - x^4 & , \quad x \geq 0 \\ \cos x + \frac{1}{x} - 3.2 & , \quad x < 0 \end{cases}$$

(i) Determine an appropriate terminal set.

(ii) Determine an appropriate function set.

(iii) Suggest a good fitness function.

(iv) Determine the fitness cases.

(v) what is the “closure” property in GP?

(b) [4 points] For the problem in (a) sketch two solution candidates and show how mutation can be applied to generate two offsprings from these two candidates.

(c) [2 points] In ES (Evolutionary Strategies) we studied the (μ+λ)-selection and the (μ,λ)-selection operators. Which one is preferred and why?

(d) [2 points] Some ES approaches associate the variance σ with individuals in the population every object is mutated based on the mutation rate it is associated with it, which also changed by crossover and mutation operators. What advantage do you see in using such an approach?

(e) [2 points] What is the idea behind making co-variance matrices be part of mutation operators, such as in the ES evolutionary operators.

Question 5[20 points]

(a) [4 points] Given the following two parents with permutation representation:
P_1=(918273645)
P_2=(246813579)
(i) [2 points] Compute the Cycle Crossover of the two parents

(j) [2 points] Compute the Partially Mapped Crossover (PMX) of the two parents

(b) [4 points] What is evolutionary programming? How is it different from genetic programming (GP)?

(c) [4 points] How do we use evolutionary programming (EP) to solve the problem of control?

(d) [4 points]
a. [2 points] In genetic algorithms, the process of creating a new state, by combining parts of parent states is called

A) mutation	B) crossover
C) mating	D) expanding

b. [2 points] In genetic algorithms, the process of creating a new state, by randomly changing part of an old state, is called

A) mutation	B) crossover
C) mating	D) expanding

c. [4 points] Suppose the problem is to evolve a binary string of length n which is symmetric. If the string positions are numbered from 0, then a symmetric string will have a 1 in position i if and only if there is a 1 in position (n-1)-i. For example, 001100 is symmetric since it has a 1 at index 2 and a 1 at index (6-1)-2 = 3. Similarly, 110011 is symmetric, and 011011 is not. The initial population is a randomly generated set of binary strings of length n, where n is an even number.

   i. Give a suitable fitness function for this problem.

   ii. Will the offspring of parents with a high fitness value generally also have a high fitness value, given your fitness function? Explain your answer.