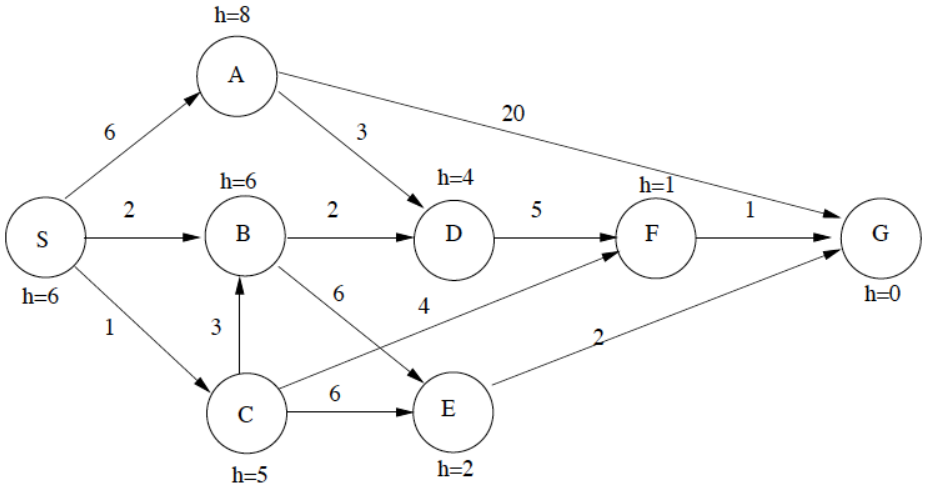
University of Waterloo
Department of Electrical and Computer Engineering
ECE 457A Cooperative and Adaptive Algorithms
Final Examination
August 14, 2013

Attempt all questions.

Question 1. [25 points]

(a) [10 points]

Consider the search problem below with start state S and goal state G. The transition costs are next to the edges, and the heuristic values are next to the states.



i. If we use Uniform-Cost Search: What is the final path for this search.

ii. If we use Depth First Search, and it terminates as soon as it reaches the goal state: What is the final path for this DFS search? If a node has multiple successors, then we always expand the successors in increasing alphabetical order.

iii. If we use **A*** search: What is the final path for this A* search?

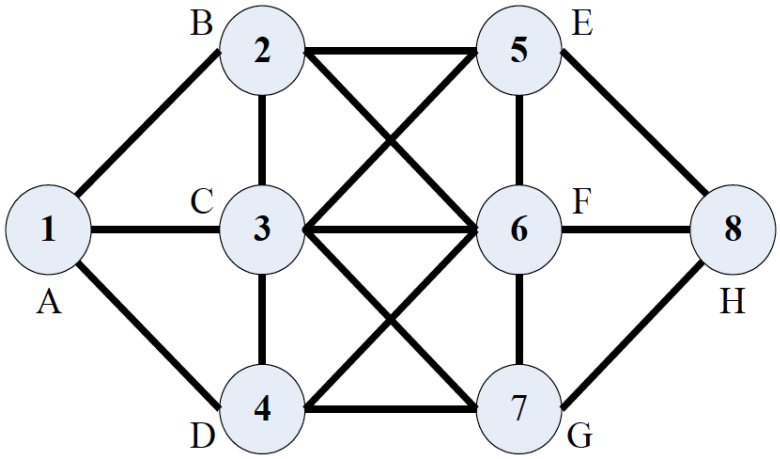
iv. Is the heuristic function in this example admissible? Explain your answer.

(b) [15 points]

i. What is meant by completeness and optimality of a search strategy?

ii. Explain approaches that have been proposed to make Tabu Search adaptive.

iii. Consider using TS to solve the problem of assigning numbers from 1 to 8 to the nodes of the following graph such that each number appears exactly once and no connected nodes have consecutive numbers.



Starting from a random initial assignment such as (1 to A, 2 to B, 3 to C, 4 to D, 5 to E, 6 to F, 7 to G, 8 to H)

a) Define a cost function to specify the quality of an assignment,
b) Define a suitable neighborhood operator,
c) Define Tabu moves and a suitable matrix-structured Tabu memory showing how this memory is updated after a certain move is selected,
d) Perform TWO iterations of TS and show how the Tabu memory structure is updated after each selected move. Restrict the neighborhood to 2 applications of your operator.

Question 2. [25 points]

(a) [15 points] Genetic Algorithm

1. Discuss drawbacks of the roulette wheel selection mechanism, and describe two methods to avoid (or minimise) these drawbacks.
2. One-Point Crossover is not suitable for The Travelling Salesman Problem (TSP). Why is this?
3. Define a fitness function and a crossover operator to solve the N-Queens problem with a GA.
4. What are the steps involved in a cycle of Simple Genetic Algorithm (SGA)? Briefly explain each of them.
5. The following table shows sizes and playing times of 10 different video files. It is required to store a subset of these files onto a DVD such that: 1-the files have combined size at most 4500 MB (i.e. the size of the DVD) and 2-the total playing time of the stored files is as large as possible.

File No.	1	2	3	4	5	6	7	9	9	10
Size (in MB)	800	700	650	750	600	900	975	875	1050	1500
Playing time (in mins)	121	95	85	100	78	125	130	128	135	120

i. Compute the size of the search space of this problem.
ii. Represent the problem domain as a chromosome.

iii. Define a fitness function to evaluate the performance of each chromosome.

iv. Run the GA (with population size N = 6, crossover probability pc = 0.7 and mutation probability pm = 0.1) for one generation. Note that, you must write each step in your answer.

(b) Simulated Annealing [10 points]

1. Describe the idea behind the simulated annealing algorithm making reference to its origins as an optimization methodology.
2. Describe a simulated annealing algorithm and why it can escape local minimum.
3. How could you change the algorithm so that it implements Hill Climbing search.
4. When does Simulated Annealing perform better than Hill Climbing?
5. What are the advantages and disadvantages of Simulated Annealing?
6. Assume that simulated annealing starts from a state s at the center of a large plateau. That is, the values of all states on the plateau are exactly the same.
   (i) Say in the first step the random neighbor we picked is t, which of course has the same value as s. What will simulated annealing do? Justify your answer.
   (ii) To encourage the search to escape this plateau as quickly as possible, what should we do with the temperature T? Justify your answer.

Question 3. [25 points]

(a) Ant Colonies [15 points]

i. Describe how ants are able to find the shortest path to a food source.

ii. Using the travelling salesman problem as an example, describe the following terms in relation to ant algorithms

- *Visibility*
- *Evaporation*
- *Transition Probability*

iii. Assume 4 cities {A, B, C, D}, which are represented by a fully connected graph. The following tables represent the pheromone levels on each edge of the graph and the distances between each city (assume the pheromone levels and distances are symmetric).

	Pheromone Levels			
	A	B	C	D
A				
B	0.25			
C	0.11	0.98		
D	0.34	0.54	0.67	

	Distances			
	A	B	C	D
A				
B	12			
C	10	6		
D	8	15	3	

Assume an ant started its journey at city A and has travelled to city C. Using the formulae described in the lectures

i) What is the probability that the ant will travel to city A?
ii) What is the probability that the ant will travel to city B?
iii) What is the probability that the ant will travel to city D?

Assume alpha and beta are set to 1.

iv) Assume the ant completes its tour using the route ACBD. What will be the pheromone levels on each edge once they have been updated? Assume Q = 100 and the evaporation parameter is set to 0.5.

(b) PSO [10 points]

i. Discuss difference between physical neighbors and social neighbors in neighborhood selection and their impact on the performance of PSO algorithm.

ii. Describe the binary version of PSO and how the particle velocity and position are defined and updated.

iii. Robot motion planning involves finding the path a robot needs to traverse from a given start point to a given end point while avoiding obstacles along the way. This problem can be solved using PSO. Using the following figure to illustrate your answer:

iii-a

With the objective of minimizing the path length show how the problem is formulated explaining what the particles will represent giving the equations of motion and update.

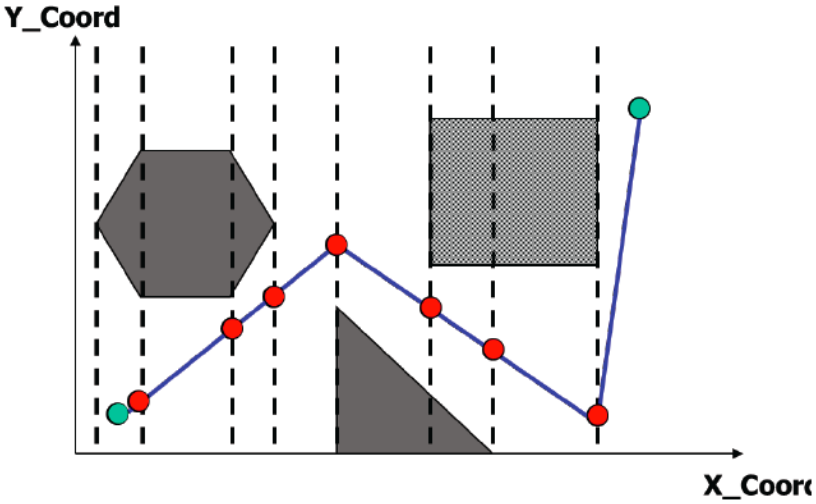
iii-b

If the objective is to maximize the distance to obstacles, discuss how this can be achieved and its implication on the PSO algorithm

iii-c

What will need to change if the number of obstacles and their geometries change?

The idea is to optimize the y-coordinates at which the path intersects with the vertical lines



Vertical lines are drawn at the obstacles vertices

Question 4. [25 points]

a. Describe the concept of Evolutionary computation. What are the components of this solution paradigm? How does it work? Please use an example to explain your understanding.
b. Describe the concept of Genetic Programming. What are the components of this solution paradigm? How does it work? Please use an example to explain your understanding.
c. Describe the concept of Evolutionary strategies. What are the components of this solution paradigm? How does it work? Please use an example to explain your understanding.
d. With reference to evolutionary strategies explain the difference between the comma and plus notation.
e. With regards to evolutionary strategies, describe the Rechenberg "1/5 success rule", discuss why it is used and possible parameters.
f. With regard to evolutionary strategies what do you understand by the term self-adaptation? How is it achieved? What are the parameters considered in self-adaptation? Explain their influence on the evolution of the solution process.
g. What is the difference between evolutionary strategies, Genetic Programming, and Genetic Algorithms?
h. Where did we meet
    a. State machines,
    b. Overall learning rate,
    c. Diversification,
    d. Intensification,
    e. Recency memory,
    f. Tribes,
    g. Aspiration?