University of Waterloo
Department of Electrical and Computer Engineering
ECE457A: Cooperative and Adaptive Algorithm

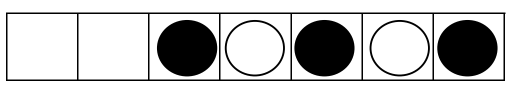
Assignment 1 – Optimization Techniques, Graph Search and Game Playing

Due date: June 2, 2014 - Midnight

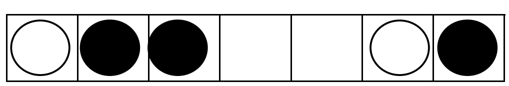
What to hand in: a report that contains:

- The solutions for the first two written exercises, typed or neatly handwritten
- Matlab/Octave code for the programming exercise (Exercise #3).
- Zip the assignment report and the source code (including a README file) and name it "**Assignment#-Your Project Number#.zip**" such as "**A1-Team3.zip**"
- Upload this file to Assignment-1 drop box available on UW LEARN.
- Anything handed in after the due date will be penalized by 50% for each 24 hours of lateness.

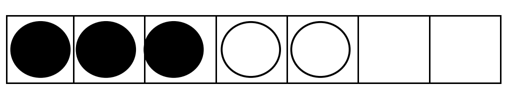
1. **[Written Exercise - 6 Marks]** Consider the following puzzle: Three black and two white coins are laid out on a grid containing seven squares, as shown in figure 1(a). A move consists of sliding any of two adjacent coins to free squares (the coins may not be separated or rotated). For example, figure 1(b) shows the arrangement of coins which would result from one possible choice for first move. The aim is to arrive at the goal state shown in figure 1(c).



(a) Initial Configuration



(b) One possible move



(c) Goal configuration

Figure 1. Puzzle Configurations

a) Specify a set of possible valid moves to transform from one state to another.

b) By numbering the nodes in order of their expansion and not to generate the same node from more than one parent, construct the search tree to obtain the goal configuration using the following search methods:

i) Breadth First Search.

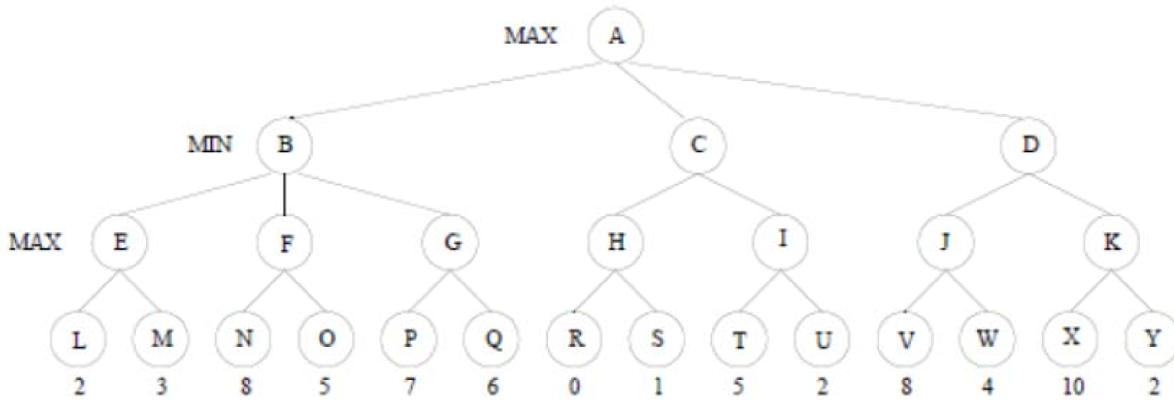
ii) Depth First Search with depth limit of 3.

iii) Hill Climbing Search using a heuristic (explain your development of the heuristic) as a measure of the distance to the goal.

iv) Best First Search using your heuristic developed in (iii)

v) Compare the performance of the above search strategies in terms of the number of nodes generated.

2. **[Written Exercise - 4 Marks]** 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.



a) What is the minimax value computed at the root node for this tree?
b) What move should MAX choose?
c) Which nodes are not examined when α-β pruning is performed? Assume children are visited left to right.
d) Is there a different ordering for the children of the root for which more pruning would result by α-β? If so, state the order. If not, say why not.

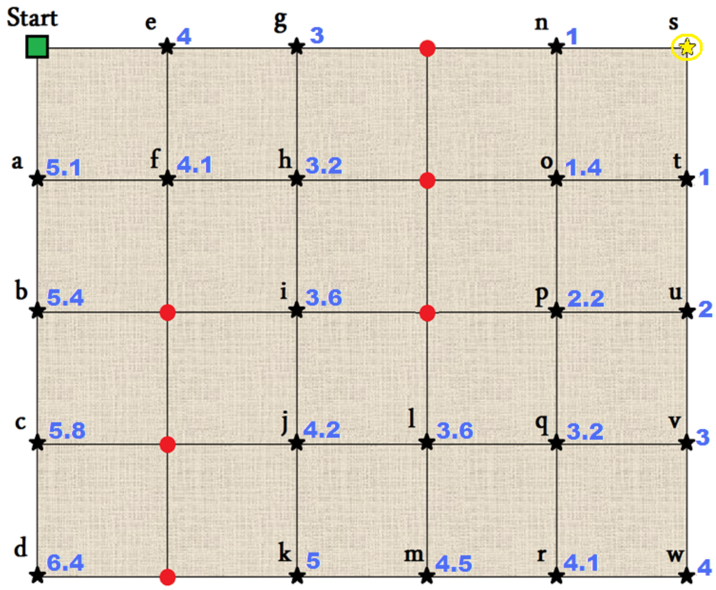
3. **[Programming Exercise – 10 Marks]** Tic-tac-toe (or Noughts and crosses, Xs and Os) is a zero-sum game where players' preferences are opposed, i.e. the winner's reward or payoff is exactly equal to the defeated player's loss In this game, a single evaluation function is used to describe the goodness of a board with respect to both players. The given code **tictactoe.rar** contains a Matlab implementation for a 3×3 grid. In this implementation, the player who succeeds in placing three respective marks in a horizontal, vertical, or diagonal row wins the game. This playing strategy in this code is a rule-based strategy considering all the possible actions of the opponent and selecting the appropriate player's action accordingly.

a) Modify the given code by replacing the rule-based strategy by minimax strategy

b) Modify the implemented minimax strategy by allowing α-β pruning.

4. **Non-Graded Extra Exercises**

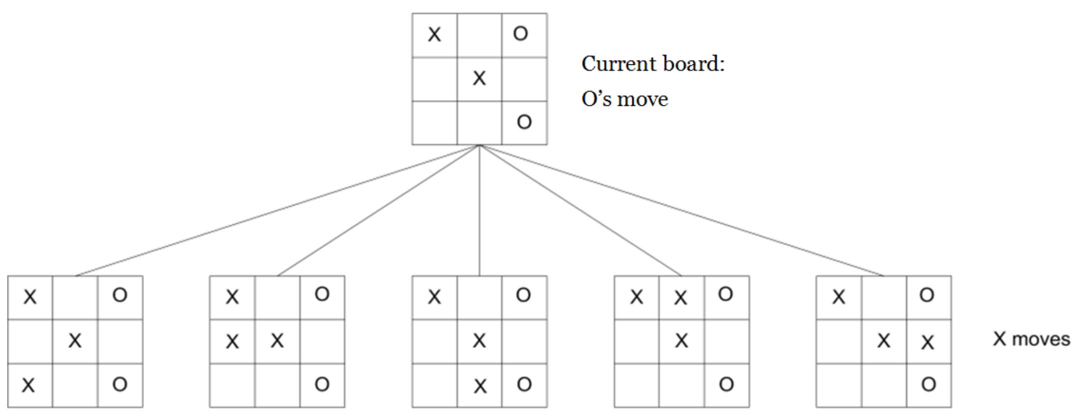
a. Path Planning is considered as one of the core problems of autonomous mobile robots. This problem is an interesting problem that has been studied extensively over the last two decades. Different approaches have been proposed with different levels of complexity, accuracy and applicability. This problem addresses how to find a collision-free path for a mobile robot from a start position to a given goal position, amidst a collection of obstacles. Path planning can be seen as an optimization problem which aims at improving some system objectives with several constraints. System objectives may be the travelling distance, travelling time, and consuming energy. However, the travelling distance is the most common objective. Consider planning an optimal path for a mobile robot to move from Start position to Goal position S in the following 4x5 grid environment. In this environment, the red circles represent obstructive positions.



Show how to use A* to find the shortest path between the start position and the goal. Assume that the heuristic value is calculated using the Euclidian distance, which represents the distance from a point to the goal.

b. What is the difference between hard and soft constraints?

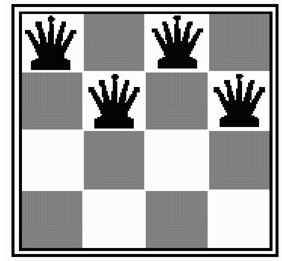
c. Given the following board configuration in tic-tac-toe game:



Assume that *f*(n) is evaluation function or static evaluator used to describe the goodness of a board with respect to MAX player. *f*(n) = [# of 3-lengths open for the MAX player] - [# of

3-lengths open for MIN player or opponent]. Calculate the f(n) for each of the X moves shown in the above board.

d. N-queen problem is an example for constraint-satisfaction problem that does not define an explicit objective function. Instead, the objective is to find a solution which satisfies all of a set of constraints. In N-queen problem, the goal is to put *n* queens on an *n*x*n* board with no two queens on the same row, column, or diagonal. Starting from the given configuration, move the queens to reduce number of conflicts until you reach the final configuration where no queen is attacking another queen.

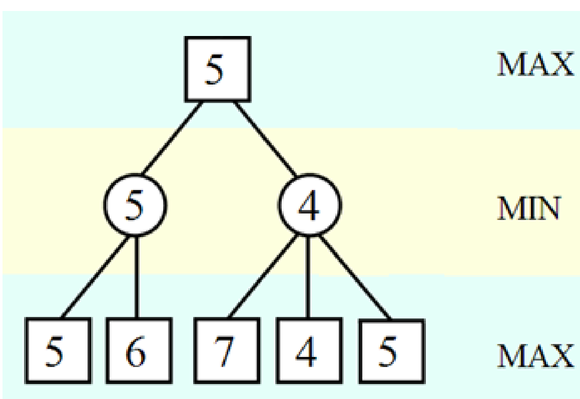


e. MCQs & T/F.

a) What is the type of this optimization problem: max x+y subject to 0 < x < 5, 0 < y < 2 and 2x + y = 8.
   - o Unconstrained multiobjective optimization
   - o Multiobjective optimization with multiple constraints.
   - o Constrained nonlinear optimization with a single objective (uni-objective).
   - o None of the above

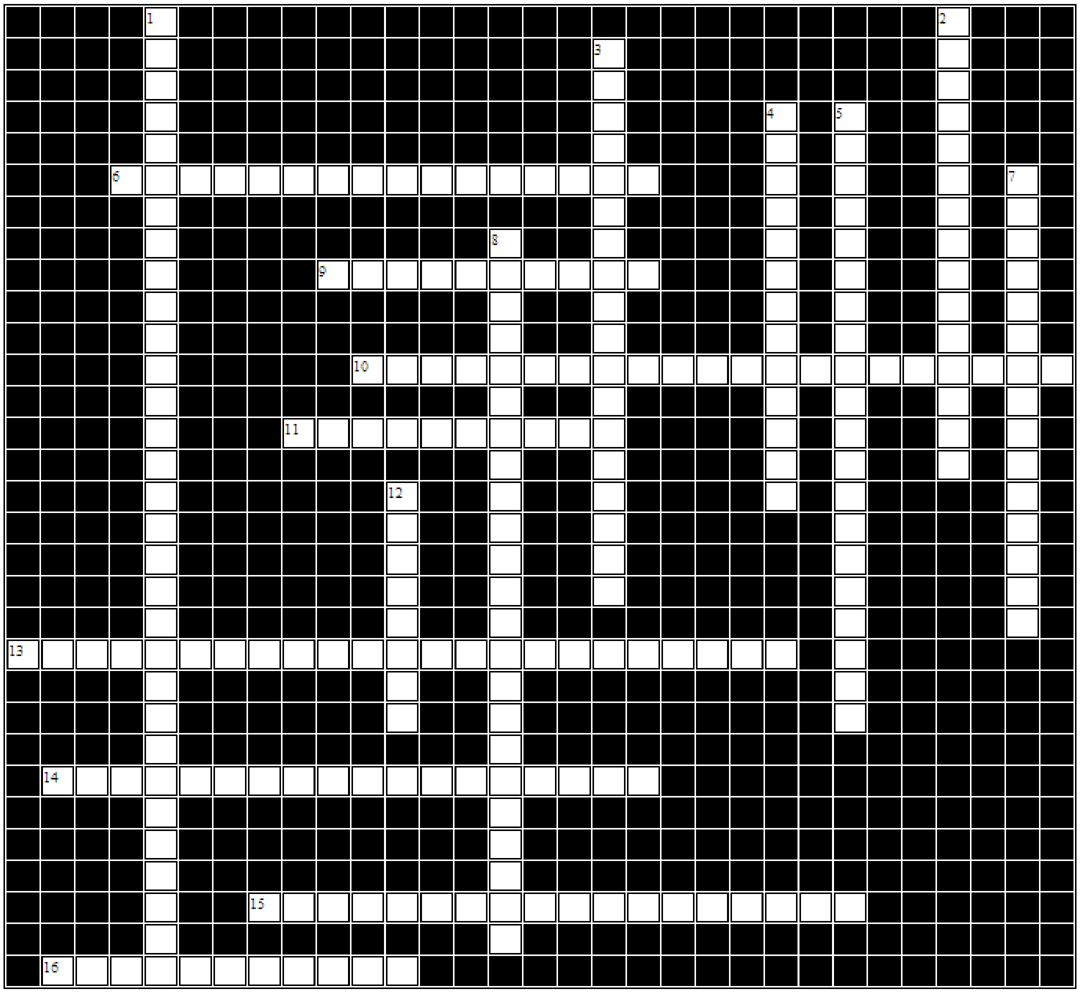
b) For very large workspace where the goal is deep within the workspace, the number of nodes could expand exponentially and depth-first search will demand a very large memory requirement.
   - o True
   - o False

c) For the following game tree, which nodes will be pruned? Assume children are visited left to right.



   - o Node 6 (child of 5) in the MAX layer
   - o Node 7 (child of 4) in the MAX layer
   - o Node 4 (child of 4) in the MAX layer
   - o Node 5 (child of 4) in the MAX layer
   - o All of the above
   - o None of the above

f. Solve the following crossword puzzle



Across

6. any algorithm that follows the problem solving heuristic of making the locally optimal choice at each stage with the hope of finding the global optimum.

9. a guessing game for two players where not all state information is available to all players and outcome of actions is deterministic.

10. a feasible solution that provides a superior objective function value, but not necessarily the best.

11. a solution strategy or rules by trial-and-error to produce acceptable (optimal or near-optimal) solutions to a complex problem in a reasonably

Down

1. a problem that does not define an explicit objective function. Instead, the objective is to find a solution which satisfies all of a set of constraints.

2. a form of exploration to cause the search to consider new areas. Examines unvisited regions, generates different solutions.

3. a graph search algorithm for traversing or searching tree or graph data structures. One starts at the root (selecting some arbitrary node as the root in the case of a graph) and explores as far as possible along each branch before backtracking.

4. is a game where the players' preferences are opposed: The winner's reward or payoff is exactly equal to the defeated player's loss.

practical time.

13. a problem that specifies more than one sub-objective which need to be simultaneously optimized.
14. any algorithm is able to adjust to new or different situations or to improve behaviour or evolves and learns from instructor, example or by discovery.
15. a procedure which can prune large parts of the search tree and allow search to go deeper
16. an informed breadth-first algorithm

5. an optimization technique in which time is not so important and a user is willing to wait maybe even days if he/she can get an optimal or close-to-optimal result.
7. a problem constraint that is desirable to satisfy
8. a problem that can be stated in terms of numerical variables. Its goals can be specified in terms of a well defined objective function and there exists an algorithmic solution for it.
12. a graph search algorithm that solves the single-source shortest path problem for a fully connected graph with nonnegative edge path costs, producing a shortest path tree.

Hint: Spaces and dashes MUST be used if the answer consists of two or more words.