COMP-424: Artificial intelligence

Homework 1

Due on *myCourses* Friday Jan 29, 11:59pm.
Contact TA: Emmanuel Bengio

General instructions.

- This is an <u>individual</u> assignment. You can discuss solutions with your classmates, but should only exchange information orally, or else if in writing through the discussion board on *myCourses*. All other forms of written exchange are prohibited.
- Unless otherwise mentioned, the only sources you should need to answer these questions are your course notes, the textbook, and the links provided. Any other source used should be acknowledged with proper referencing style in your submitted solution.
- For each problem, you can solve manually, or write a program to help you. You can use a programming language of your choice. You can modify code from other sources if you provide adequate citation; this cannot be code from other students in the class.
- Submit a <u>single</u> pdf document containing all your pages of your written solution on your McGill's *myCourses* account. You can scan-in hand-written pages. If necessary, learn how to combine many pdf files into one.
- Submit any code developed to answer questions as a separate file to McGill's *myCourses*.

Question 1: Search

* You can solve this problem manually, or write a program to help you.

Consider the map of the Brussels metro (*http://metroscheme.com/Belgium/Brussels.html*). Each node represents a station (*state*) and each edge (including dotted edges) represents a transition operator. Assume you start from the *Gare du Nord* station (end of line #3) and would like to get to the *Roi Baudoin* station (end of line #6). Assume that there is a single node where all four lines meet at Gare de l'Ouest and Porte de Hal (similar to Beekkant or Porte du Midi) and that the two nearby Simonis stops are also treated as one node.

To facilitate your work, we provide an encoding of the state graph listing neighbouring stations in the desired search order (i.e. clockwise from 12 o'clock) in a file: *www.cs.mcgill.ca/~jpineau/comp424/Homework/brussels_metro.json*

a) What is the solution path found by each of the following algorithms? Assume each transition has unit cost.
   i. Breadth first search
   ii. Uniform cost search
   iii. Depth first search
   iv. Iterative deepening

b) Repeat finding the path for each algorithm, now assuming that the cost of a transition operator along lines #1, #2 and #3 (the older lines) is twice the cost of a transition operator along lines #4, #5, #6 (the new lines).

c) One possible heuristic for this problem is to use the birds-flight distance. This can be calculated with a tool: http://www.distancefromto.net E.g. From: "Gare du Nord station, Brussels", To: "Roi Beaudoin station, Brussels", Air distance. Considering the cost function in part (a), is this heuristic admissible? Explain.

d) Consider now the driving distance as the heuristic. This can be calculated using the same tool (select "Driving distance"). Considering the cost function in part (a), is this heuristic admissible? Explain.

Question 2: Properties of search algorithms

* You will probably find it easier to solve this problem by hand.

(From Russell & Norvig) Prove each of the following statements, or give a counterexample:

a) Breadth-first search is a special case of uniform-cost search.
b) Depth-first search is a special case of best-first tree search.
c) Uniform-cost search is a special case of A* search.

Question 3: Optimization

* You will probably find it easier to write a program to solve this problem.

Consider the following function: $Y=\sin(X^2/2)/\text{sqrt}(X)$, in the range $X=[0, 10]$.

a) Apply hill-climbing, starting from each of the following starting points: $X_0=\{0, 1, 2, \ldots, 10\}$ and step sizes $\Delta X = \{0.01, 0.02, \ldots, 0.1\}$.
b) Repeat using simulated annealing with a range of different temperatures (of your choosing). Consider each of the different starting points in (a). Consider only those step sizes from part (a) that produced good result (use your own judgment in defining this; briefly explain your reasoning and method.)

For each part report the number of steps to convergence and final result (X*,Y*) for each case. Use plots and tables to report your results in an organized manner. Don't forget to include labels & captions.

Question 4: Constraint satisfaction

* You will probably find it easier to solve this problem by hand.

Consider the following scheduling problem: Dr. Bug owns a factory that produces robot widgets. Dr. Bug would like to make these widgets in 20 minutes or less. The building of the widgets requires four steps. Here is the list of steps, and time required to complete each one.

- Install the onboard computer on the chassis: 10 minutes.
- Install the on-board sensors: 5 minutes.
- Download the code: 5 minutes.
- Do the wiring: 10 minutes.

If Dr. Bug was able to perform all steps simultaneously, he would be able to produce a widget in 10 minutes. However some tasks need to be completed before others. In particular, the onboard computer must be installed before the code is downloaded. Also, the on-board sensors must be installed before the wiring is done. Finally, only one employee, Mr. Cricket, is qualified to install the computer and do the wiring. Therefore these two steps cannot be done simultaneously.

a) Formulate this problem as a Constraint Satisfaction problem. Describe the set of variables, and their domain. List the set of constraints. Show the constraint graph.

b) Show the search tree generated with applying backtracking search, without forward checking. Show clearly the domain for each variable at every point in the search.

c) Show the search tree generated with applying backtracking search, this time using forward checking.