Homework 4 (Generic Version)

Assigned on: Friday, September 29, 2017
Due: Friday, October 13, 2017

Programming assignment should be submitted with handin. Do not hesitate to seek help during recitation and office hours.

This homework has two parts:

1. A regular ‘exercise’ on AI games.
2. A programming assignment. The goal of the programming assignment is to implement both uninformed and heuristic search.

   (a) Romanian Holidays is mandatory for all students. The implementation is explained in great details.

   (b) Eight-sliding puzzle is a bonus assignment for curious students. Rough explanations about the implementation are provided.

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1 Adverserial Search (Total 5 points)

Consider the following game tree:

```
  MAX
    /  \
   /    \ 
MIN  B  C  D
    / \
   /  \
MIN  E  F  G
    / \
   /  \
MIN  L  M  N
     \  \  \\
     |  |  |
     M  O  P
        |  |
        Q  R
```

1. Compute the minimax decision. Show your answer by writing the values at the appropriate nodes in the above tree. 4 points

2. What move should Max choose? 1 point
2  Alpha-beta Pruning (Total 5 points)

Using the alpha-beta pruning method, with standard left-to-right evaluation of nodes, show what nodes are not examined by alpha-beta.

3  AIMA, Exercise 5.8, Page 197 (Total 10 points)

4  Romanian Holidays (Total 100 points)

This exercise will guide you, step by step, to implement the data structures representing Romania’s map and the search algorithms for conducting search. It is mandatory to all students.

Note that in the following sections, we refer to variable and function names that may not be accepted by the programming language you choose (e.g., C, C++, and Java variables cannot contain hyphens). In these cases, just use names that are similar but acceptable by the language by, for example, using camel case instead of hyphens. Additionally, an association list is merely a list of key-value pairs.

It is not necessary to implement these structures exactly, but your implementation should be similar enough that the graders can clearly see the analogous variables and structures.
4.1 Data structures (50 points)
Create the data structures required to represent the map of Romania. Include the information about the distances between two cities linked by a road as well as the distance from any given city to Bucharest as indicated in Figure 1.

Indications (follow illustration in Figure 2):

- Create a data structure for a city.
- Include an attribute `name` to store the name of the city.
- Include an attribute `neighbors` to store the neighboring cities.
- Include an attribute `h` that provides the value of the straight-line distance to Bucharest.
- Create two ways to access the cities:
  1. a list called `allCitiesList` and
2. a hash-table allCitiesHash

• After creating structures for all the cities, loop through them again in order to include, in the relevant attribute of a city, a reference its neighboring cities. Store these neighbors as an association list of the structure of a neighbor and the distance between the two.

4.1.1 Tasks

1. (10 points) Design, implement and test your map.

2. (5 points) Write a function allCitiesFromList that takes a global variable, allCitiesList, and returns a list of all names of cities on the map.

3. (5 points) Write a function allCitiesFromHtable that takes a variable, allCitiesHtable and returns a list of all the structures of cities on the map.

4. (5 point) Write two functions getCityFromList and getCityFromHtable that take the name of a city as input and return the corresponding structure (by accessing a variable, allCitiesList and allCitiesHtable, respectively).

5. (5 points) Write two functions neighborsUsingList and neighborsUsingHtable that take the name of a city as input and return the list of structures of its direct neighbors. neighborsUsingList and neighborsUsingHtable should use getCityFromList and getCityFromHtable, respectively.

6. (10 points) Using allCitiesHtable, write a function neighborsWithinD that takes the name of a city myCity and a number distance, then returns, for all direct neighbors within distance from myCity (≤), an association list of the structures of the neighbors of myCity and their distance to myCity.

7. (10 points) Using allCitiesHtable, write a function neighborsP that takes the name of two cities cityOne and cityTwo, and returns the distance between them if they are directly connected or nil if they are not.

4.2 Implementing Search (50 points)

You are asked to implement search the following search strategies, first as a Tree-Search then as a Graph-Search:

• Any uninformed search strategy of your choice, 10 points
• A Greedy search strategy, and 10 points
• An A* search strategy. 10 points

for the ‘Romanian Holiday’ problem. Needless to say, you should first get Section 1 to work. Write Search that take as input the name of any city on the map, the name of a search strategy, and outputs:

1. The path to Bucharest,
2. The number of nodes generated/visited by the search process,
3. The cost of the path found (even when the function g(n) is not used to choose the node to expand),
4. The running time spent on the search.

Hints:

• You may choose to write one search function and give it the strategy as an argument.
4.2.1 Results to report

In addition to your code, report the results of your two functions applied to each city in Romania as indicated in the table below. Report two tables:

1. One result table for Tree-Search. 10 points
2. One result table for Graph-Search. 10 points

Uninformed search of your choice

<table>
<thead>
<tr>
<th>City name</th>
<th>#nodes visited</th>
<th>Path to Bucharest</th>
<th>Total cost of path</th>
<th>CPU time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arad</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bucharest</td>
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</tr>
<tr>
<td>Vaslui</td>
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<td></td>
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<tr>
<td>Zerind</td>
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</tr>
</tbody>
</table>

Greedy Search

<table>
<thead>
<tr>
<th>City name</th>
<th>#nodes visited</th>
<th>Path to Bucharest</th>
<th>Total cost of path</th>
<th>CPU time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arad</td>
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<tr>
<td>Bucharest</td>
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<td>Zerind</td>
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</tbody>
</table>

A* Search

<table>
<thead>
<tr>
<th>City name</th>
<th>#nodes visited</th>
<th>Path to Bucharest</th>
<th>Total cost of path</th>
<th>CPU time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arad</td>
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<td>Bucharest</td>
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<td>Zerind</td>
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</tbody>
</table>

4.2.2 Some indications

Follow the requirements below:

1. For Graph-Search, modify the data structure of a city that you implemented in Section 4.1 to add one more field visited, initialized to Nil. Use this attribute for loop control during search: when a city is visited, set this field to T.

2. Create a new data structure to represent a node in the search tree. The structure should have attributes that point to the structures of its parent (when applicable), its children (list), the city it represents. Other attributes may be necessary, such as path value at the node.

3. Implement a function expand-node that takes a node in the search tree and generates its children, which, for Graph-Search, should correspond to cities not yet visited. It needs to generate one node data-structure per child.

4. Implement a function evaluate-node that takes a node and a search strategy and returns the value of the node (e.g., g(n), h(n) or f(n)).

5. Implement a function that takes a fringe (i.e., a list of nodes to be expanded) and returns the node to expand. As a refinement, you can provide the name of the search strategy as an optional second argument (check :key in the list of arguments of a function).

6. If you separate the implementation search strategy from the evaluation functions cleverly enough, you may be able to use the same search function for all search strategies you implement.
7. Implement the search strategies iteratively, not recursively.

8. Declare a global variable \texttt{*nnv*} for storing the \textit{number of nodes visited}. The search function should set up its value and the function \texttt{expand-node} should increment this value at every expansion (technically, every instantiation of a search-node structure).

9. Load the information about the cities from the file \texttt{all-cities.lisp} which is on the course website (it is also acceptable to hard-code this information if you don’t want to parse a lisp file).

5 \textbf{Eight-Piece Sliding Puzzle (Bonus 80 points)}

The goal is to implement A* search for solving the Eight-Piece Sliding Puzzle Problem with the two admissible heuristics: the displaced tile and the Manhattan distance heuristics.

5.1 Requirements

Below is the list of basic requirements:

1. Implement a generator of random states, to be used to generate an initial and a goal state.

2. Implement A* that

   - takes as arguments an initial state, a goal state, and the name of a heuristic function and
   - returns the list of moves of the empty tile from the initial state to the goal state, the cost of the path found, and the CPU time.

3. Count the movement of each tile as unity cost.

4. Generate 100 combinations of random initial and goal states (more if possible).

5. Run A* with each heuristic on each combination initial and goal states, reporting the following:

\begin{tabular}{|c|c|c|c|c|c|}
\hline
Instance & \texttt{#NV} & Path Cost & CPU time & \texttt{#NV} & Path Cost & CPU time \\
\hline
Combination 1 & & & & & & \\
Combination 2 & & & & & & \\
\vdots & & & & & & \\
Combination 99 & & & & & & \\
Combination 100 & & & & & & \\
\hline
\end{tabular}

5.2 Indications

In contrast to the previous problem, you do not need to generate a state space. Use to the extent possible the explanations provided above for the Romanian Holidays and the mechanisms

1. Implement a state as a 2 dimensional array (Chapter 17 in CITI).

2. Implement a generator of random states, to be used to generate an initial and a goal state.

3. Implement a function that takes as input a state and computes the value of the heuristic function (there are two of them).

4. Implement functions that correspond to the actions of moving the \textit{empty tile} north, south, east and west (similar to the Farmer’s dilemma).

5. Implement functions that determine whether a move is legal or not (similar to the Farmer’s dilemma). A move north is not legal when the empty tile is in the first row.