AI ASSIGNMENT — Search Algorithms
Deadline : 11:59 PM, 17/9/2024

Total Marks : 100 Marks Weightage: 10%

Instructions:
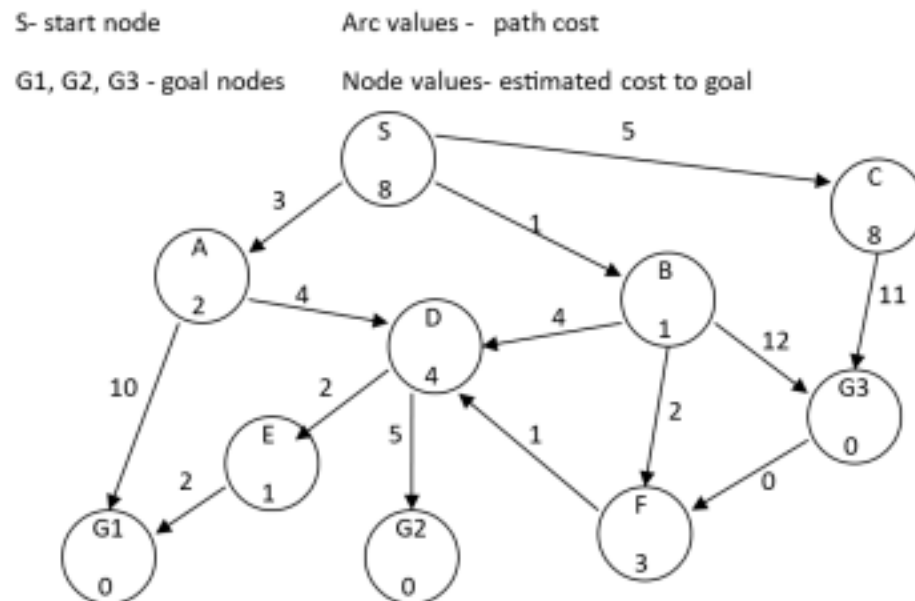
1. Assignments are to be attempted individually.

2. Submit the assignment as a single zipped folder (Search ⟨RollNumber⟩.zip) contain ing a pdf file for all the theory questions and a python file (code ⟨RollNumber⟩.py) for programming questions.

3. Please read the instructions given in the questions carefully. In case of any ambiguity, post your queries on Google Classroom at least a week before the deadline. No TA will be responsible for responding to the queries after this.

4. A part of the assignment evaluation involves automatic testing of your submitted code on private test cases. Please make sure that you do not change the structure of the methods provided in the boilerplate code.

5. All the TAs will strictly follow the rubric provided below. No requests will be enter tained related to scoring strategy.

6. The use of generative tools (such as ChatGPT, Gemini, etc.) is strictly pro hibited. Failure to comply may result in severe consequences related to plagiarism.

7. Extension and Penalty clause:

   • Even a 1 minute late submission on google classroom will be considered as late. Please turn-in your submissions atleast 5 minutes before the deadline.

   • Not explaining the answers properly will lead to zero marks.

1. Consider the search space below where an edge from node x to node y means that y can be generated from x by an operator. The edges are labeled with the actual path cost and the estimated costs to a goal (h-values) are provided inside the nodes. You are required to find the shortest path from S to goal G1 using the following algo rithms:
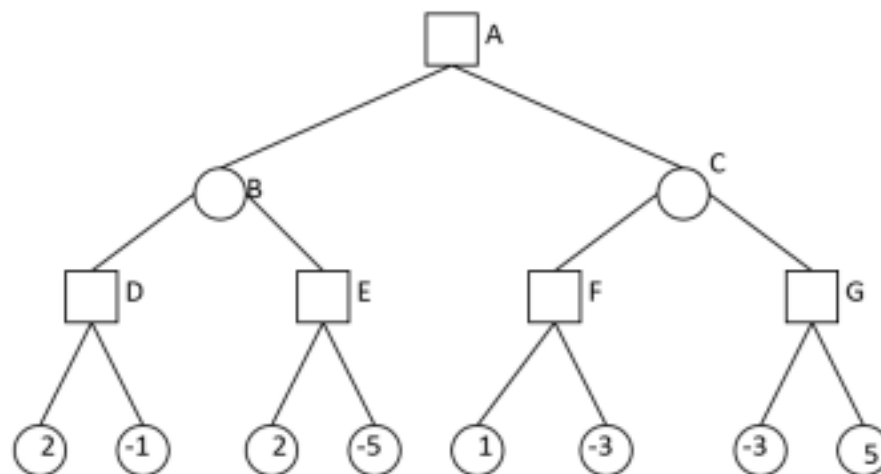
   (a) A* (5) (b) Uniform cost search (5) (c) Iterative deepening A* (5)

   List the order of nodes expanded (not generated) by these algorithms together with the f-values and total path costs. Show detailed steps of each algorithm in a table with node
   expansions, frontier nodes, explored nodes (where applicable) for each algorithm.

Note: Explore nodes in counter clock-wise direction (left to right) when no other criterion is specified. Also, if two nodes are at the same cost, pick nodes alphabetically for tie breaking.

S- start node   Arc values - path cost

G1, G2, G3 - goal nodes   Node values- estimated cost to goal

2. Consider the following game tree. Note that each square signifies a Max node and each circle is a Min node.

(a) Part A

- Use min-max algorithm to determine best play for both players, i.e. best moves at all levels of the tree for both players. Use arrows to represent the best moves. Show all legitimate moves. (2)
- Alpha-beta pruning is a directional search algorithm, i.e. it explores children from left to right. Apply alpha-beta pruning to the given game tree. Cross-out the branches where pruning can be done and mark them with

alpha or beta depending on its type. (3)

(b) Part B

- Best case: Rearrange the leaf nodes (and internal nodes if necessary) of the given tree so that the maximum pruning is achieved by alpha-beta pruning that explores branches from left to right. Justify your answer. (4)
- Worst case: Rearrange the leaf nodes again to make the worst case for alpha beta pruning. Justify your answer. (4)

(c) Part C

Based on your best case, briefly explain why the best-case complexity is $O(b^{d/2})$, where b and d are the branching factor and look-ahead depth, respectively. (2)

3. Consider a graph $G = (V, E)$ representing our institute (Fig 1), where V is the set of nodes and E is the set of edges. Each node $u \in V$ represents a unique geographical location and each edge $e_{uv} \in E$ represents a road connecting the locations u and v. The graph G is given in the form of an $n \times n$ adjacency matrix A, where $A_{uv} > 0$ indicates the travel cost between locations u and v along edge e_{uv}, whereas $A_{uv} = 0$ means that locations u and v are not directly connected, implying an infinite cost for direct travel between them. The locations are named as $\{0, \cdots, n-1\}$ and all the nodes in the graph are attributed with (x, y) denoting the latitude and longitude of the corresponding lo cation. The dataset and the boilerplate code can be downloaded from this link.

The primary objective of this programming question is to find a path (sequence of nodes traversed including u and v) from a source node u to destination v for a given graph $G = (V, E)$ using various algorithms and compare them. The output of a few 'public' test cases is provided in the shared code. The final scoring will be done automatically using 'multiple private' test cases. For this purpose, you must not change the method defini tions provided in the boilerplate code; otherwise, your submission will not be graded.

(a) Implement the following uninformed search algorithms: (10 + 10 = 20) • Iterative Deepening Search

- Bidirectional Breadth-First Search

(b) For each public test case, analyze whether the path obtained to travel from source u to destination v using both algorithms is the same. If you find that the path obtained is identical (or different), comment whether it will always be identical (or different) for any pair of nodes in the given graph G. (2.5 + 2.5 = 5)

(c) Obtain the path between all pairs of nodes using both algorithms. Compare the memory usage and time of execution for both algorithms. (2.5 + 2.5 = 5)

(d) Let $dist(u, v)$ be a function that calculates the Euclidean distance between two

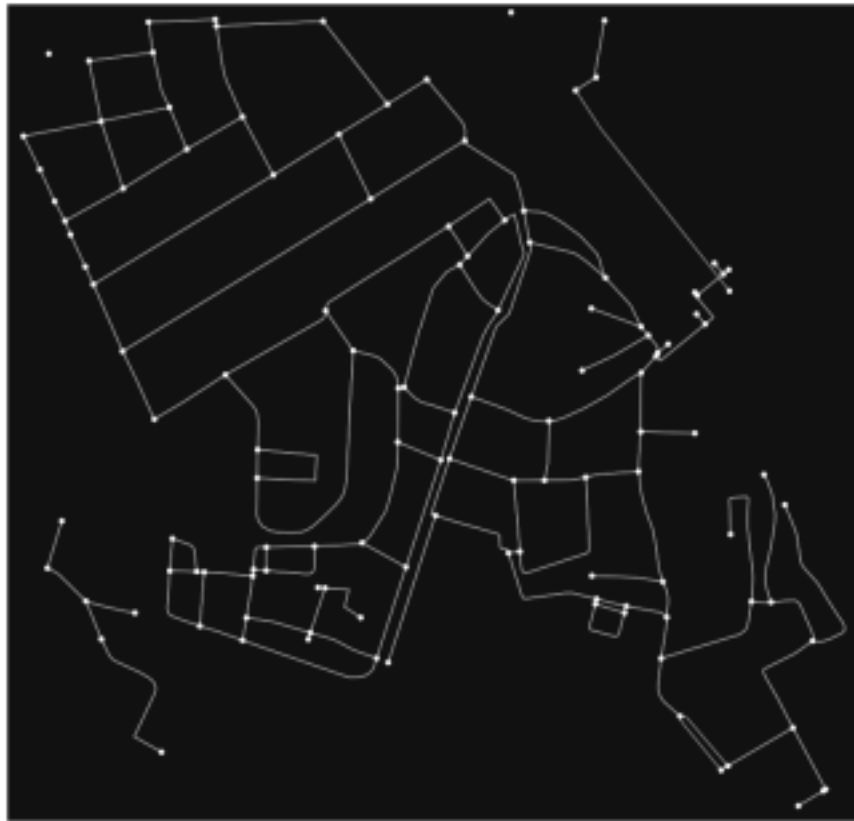nodes *u* and *v* using the node attributes (*x, y*). Use the heuristic function given

Figure 1: A graph representing IIIT Delhi

below to implement the following informed search algorithms. (10 + 10 = 20)

$$h(w) = dist(u, w) + dist(w, v)$$

- A* Search
- Bidirectional A* Search

(e) Repeat the exercises (*b*) and (*c*) using both these informed search algorithms. (2.5+ 2.5 + 2.5 + 2.5 = 10)

(f) Analyze the results obtained using all the uninformed and informed search algo rithms. Using scatter plots, compare and contrast the efficiency (in terms of space and time) and optimality (in terms of cost of traveling) of all the algorithms. Ex plain how the metric to generate the scatter plots was obtained. Also, comment on the benefits and drawbacks of using informed search algorithms over uninformed ones, supported via the empirical analysis. (5 + 5 = 10)

(g) (BONUS) There might be geographical locations that are only connected via one road. Removal of such a road will disconnect the geographical locations.

For example, India and Sri Lanka were only connected via The Ram Sethu bridge but due to its submersion the cities in India are no more connected to that of Sri Lanka via roads. In order to reduce the vulnerability of such road networks, the minister of road transport and highways wants to construct new roads within our country. For this purpose, the ministry has asked you to develop an algorithm that can be used to identify all vulnerable roads. Specifically, for the given graph G, identify all the edges whose removal would increase the number of disconnected components. (10)