LAB 2

LAB 2

```
from google.colab import drive
drive.mount('/content/drive')

dataset_path = "/content/drive/My Drive/Colab Notebooks/lab1"
```

```
Mounted at /content/drive
```

```
import sys
from collections import deque
sys.path.append("/content/drive/My Drive/Colab Notebooks/lab1")

from utils import *  # Import utils.py


class Problem:
    """The abstract class for a formal problem. You should subclass
    this and implement the methods actions and result, and possibly
    __init__, goal_test, and path_cost. Then you will create instances
    of your subclass and solve them with the various search functions."""

    def __init__(self, initial, goal=None):
        """The constructor specifies the initial state, and possibly a goal
        state, if there is a unique goal. Your subclass's constructor can add
        other arguments."""
        self.initial = initial
        self.goal = goal

    def actions(self, state):
        """Return the actions that can be executed in the given
        state. The result would typically be a list, but if there are
        many actions, consider yielding them one at a time in an
        iterator, rather than building them all at once."""
        raise NotImplementedError

    def result(self, state, action):
        """Return the state that results from executing the given
        action in the given state. The action must be one of
        self.actions(state)."""
        raise NotImplementedError

    def goal_test(self, state):
        """Return True if the state is a goal. The default method compares the
        state to self.goal or checks for state in self.goal if it is a
        list, as specified in the constructor. Override this method if
        checking against a single self.goal is not enough."""
        if isinstance(self.goal, list):
            return is_in(state, self.goal)
        else:
            return state == self.goal

    def path_cost(self, c, state1, action, state2):
        """Return the cost of a solution path that arrives at state2 from
        state1 via action, assuming cost c to get up to state1. If the problem
        is such that the path doesn't matter, this function will only look at
        state2. If the path does matter, it will consider c and maybe state1
        and action. The default method costs 1 for every step in the path."""
        return c + 1

    def value(self, state):
        """For optimization problems, each state has a value. Hill Climbing
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        and related algorithms try to maximize this value."""
        raise NotImplementedError


# ______________________________________________________________________________

class Node:
    """A node in a search tree. Contains a pointer to the parent (the node
    that this is a successor of) and to the actual state for this node. Note
    that if a state is arrived at by two paths, then there are two nodes with
    the same state. Also includes the action that got us to this state, and
    the total path_cost (also known as g) to reach the node. Other functions
    may add an f and h value; see best_first_graph_search and astar_search for
    an explanation of how the f and h values are handled. You will not need to
    subclass this class."""

    def __init__(self, state, parent=None, action=None, path_cost=0):
        """Create a search tree Node, derived from a parent by an action."""
        self.state = state
        self.parent = parent
        self.action = action
        self.path_cost = path_cost
        self.depth = 0
        if parent:
            self.depth = parent.depth + 1

    def __repr__(self):
        return "<Node {}>".format(self.state)

    def __lt__(self, node):
        return self.state < node.state

    def expand(self, problem):
        """List the nodes reachable in one step from this node."""
        return [self.child_node(problem, action)
                for action in problem.actions(self.state)]

    def child_node(self, problem, action):
        """[Figure 3.10]"""
        next_state = problem.result(self.state, action)
        next_node = Node(next_state, self, action, problem.path_cost(self.path_cost, self.state, action, next_state)
        return next_node

    def solution(self):
        """Return the sequence of actions to go from the root to this node."""
        return [node.action for node in self.path()[1:]]

    def path(self):
        """Return a list of nodes forming the path from the root to this node."""
        node, path_back = self, []
        while node:
            path_back.append(node)
            node = node.parent
        return list(reversed(path_back))

    # We want for a queue of nodes in breadth_first_graph_search or
    # astar_search to have no duplicated states, so we treat nodes
    # with the same state as equal. [Problem: this may not be what you
    # want in other contexts.]

    def __eq__(self, other):
        return isinstance(other, Node) and self.state == other.state

    def __hash__(self):
        # We use the hash value of the state
        # stored in the node instead of the node
        # object itself to quickly search a node
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        # with the same state in a Hash Table
        return hash(self.state)

# ______________________________________________________________________________
# Uninformed Search algorithms


def breadth_first_tree_search(problem):
    """
    [Figure 3.7]
    Search the shallowest nodes in the search tree first.
    Search through the successors of a problem to find a goal.
    The argument frontier should be an empty queue.
    Repeats infinitely in case of loops.
    """

    frontier = deque([Node(problem.initial)])  # FIFO queue

    while frontier:
        node = frontier.popleft()
        print(node.state)
        if problem.goal_test(node.state):
            return node
        frontier.extend(node.expand(problem))
    return None


def depth_first_tree_search(problem):
    """
    [Figure 3.7]
    Search the deepest nodes in the search tree first.
    Search through the successors of a problem to find a goal.
    The argument frontier should be an empty queue.
    Repeats infinitely in case of loops.
    """

    frontier = [Node(problem.initial)]  # Stack

    while frontier:
        node = frontier.pop()
        print(node.state)
        if problem.goal_test(node.state):
            return node
        frontier.extend(node.expand(problem))
    return None


def depth_first_graph_search(problem):
    """
    [Figure 3.7]
    Search the deepest nodes in the search tree first.
    Search through the successors of a problem to find a goal.
    The argument frontier should be an empty queue.
    Does not get trapped by loops.
    If two paths reach a state, only use the first one.
    """
    frontier = [(Node(problem.initial))]  # Stack

    explored = set()
    while frontier:
        node = frontier.pop()
        print(node.state)
        if problem.goal_test(node.state):
            return node
        explored.add(node.state)
        frontier.extend(child for child in node.expand(problem)
                        if child.state not in explored and child not in frontier)
```

```
    return None


def breadth_first_graph_search(problem):
    """[Figure 3.11]
    Note that this function can be implemented in a
    single line as below:
    return graph_search(problem, FIFOQueue())
    """
    node = Node(problem.initial)
    if problem.goal_test(node.state):
        return node
    frontier = deque([node])
    explored = set()
    while frontier:
        node = frontier.popleft()
        print(node.state)
        explored.add(node.state)
        for child in node.expand(problem):
            if child.state not in explored and child not in frontier:
                if problem.goal_test(child.state):
                    return child
                frontier.append(child)
    return None


def best_first_graph_search(problem, f, display=False):
    """Search the nodes with the lowest f scores first.
    You specify the function f(node) that you want to minimize; for example,
    if f is a heuristic estimate to the goal, then we have greedy best
    first search; if f is node.depth then we have breadth-first search.
    There is a subtlety: the line "f = memoize(f, 'f')" means that the f
    values will be cached on the nodes as they are computed. So after doing
    a best first search you can examine the f values of the path returned."""
    f = memoize(f, 'f')
    node = Node(problem.initial)
    frontier = PriorityQueue('min', f)
    frontier.append(node)
    explored = set()
    while frontier:
        node = frontier.pop()
        print(node.state)
        if problem.goal_test(node.state):
            if display:
                print(len(explored), "paths have been expanded and", len(frontier), "paths remain in the frontier")
            return node
        explored.add(node.state)
        for child in node.expand(problem):
            if child.state not in explored and child not in frontier:
                frontier.append(child)
            elif child in frontier:
                if f(child) < frontier[child]:
                    del frontier[child]
                    frontier.append(child)
    return None


def uniform_cost_search(problem, display=False):
    """[Figure 3.14]"""
    return best_first_graph_search(problem, lambda node: node.path_cost, display)


# ______________________________________________________________________________
# Informed (Heuristic) Search


# greedy_best_first_graph_search = best_first_graph_search
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# Greedy best-first search is accomplished by specifying f(n) = h(n).


def astar_search(problem, h=None, display=False):
    """A* search is best-first graph search with f(n) = g(n)+h(n).
    You need to specify the h function when you call astar_search, or
    else in your Problem subclass."""
    h = memoize(h or problem.h, 'h')
    return best_first_graph_search(problem, lambda n: n.path_cost + h(n), display)


# ______________________________________________________________________________
# A* heuristics


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# The remainder of this file implements examples for the search algorithms.

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# Graphs and Graph Problems


class Graph:
    """A graph connects nodes (vertices) by edges (links). Each edge can also
    have a length associated with it. The constructor call is something like:
        g = Graph({'A': {'B': 1, 'C': 2})
    this makes a graph with 3 nodes, A, B, and C, with an edge of length 1 from
    A to B,  and an edge of length 2 from A to C. You can also do:
        g = Graph({'A': {'B': 1, 'C': 2}, directed=False)
    This makes an undirected graph, so inverse links are also added. The graph
    stays undirected; if you add more links with g.connect('B', 'C', 3), then
    inverse link is also added. You can use g.nodes() to get a list of nodes,
    g.get('A') to get a dict of links out of A, and g.get('A', 'B') to get the
    length of the link from A to B. 'Lengths' can actually be any object at
    all, and nodes can be any hashable object."""

    def __init__(self, graph_dict=None, directed=True):
        self.graph_dict = graph_dict or {}
        self.directed = directed
        if not directed:
            self.make_undirected()

    def make_undirected(self):
        """Make a digraph into an undirected graph by adding symmetric edges."""
        for a in list(self.graph_dict.keys()):
            for (b, dist) in self.graph_dict[a].items():
                self.connect1(b, a, dist)

    def connect(self, A, B, distance=1):
        """Add a link from A and B of given distance, and also add the inverse
        link if the graph is undirected."""
        self.connect1(A, B, distance)
        if not self.directed:
            self.connect1(B, A, distance)

    def connect1(self, A, B, distance):
        """Add a link from A to B of given distance, in one direction only."""
        self.graph_dict.setdefault(A, {})[B] = distance

    def get(self, a, b=None):
        """Return a link distance or a dict of {node: distance} entries.
        .get(a,b) returns the distance or None;
        .get(a) returns a dict of {node: distance} entries, possibly {}."""
        links = self.graph_dict.setdefault(a, {})
        if b is None:
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```
            return links
        else:
            return links.get(b)

    def nodes(self):
        """Return a list of nodes in the graph."""
        s1 = set([k for k in self.graph_dict.keys()])
        s2 = set([k2 for v in self.graph_dict.values() for k2, v2 in v.items()])
        nodes = s1.union(s2)
        return list(nodes)


def UndirectedGraph(graph_dict=None):
    """Build a Graph where every edge (including future ones) goes both ways."""
    return Graph(graph_dict=graph_dict, directed=False)


class GraphProblem(Problem):
    """The problem of searching a graph from one node to another."""

    def __init__(self, initial, goal, graph):
        super().__init__(initial, goal)
        self.graph = graph

    def actions(self, A):
        """The actions at a graph node are just its neighbors."""
        return list(self.graph.get(A).keys())

    def result(self, state, action):
        """The result of going to a neighbor is just that neighbor."""
        return action

    def path_cost(self, cost_so_far, A, action, B):
        return cost_so_far + (self.graph.get(A, B) or np.inf)

    def find_min_edge(self):
        """Find minimum value of edges."""
        m = np.inf
        for d in self.graph.graph_dict.values():
            local_min = min(d.values())
            m = min(m, local_min)

        return m

    def h(self, node):
        """h function is straight-line distance from a node's state to goal."""
        locs = getattr(self.graph, 'locations', None)
        if locs:
            if type(node) is str:
                print(int(distance(locs[node], locs[self.goal])))
                return int(distance(locs[node], locs[self.goal]))

            print(int(distance(locs[node.state], locs[self.goal])))
            return int(distance(locs[node.state], locs[self.goal]))
        else:
            return np.inf



# ______________________________________________________________________________

""" [Figure 3.2]
Simplified road map of Romania
"""
romania_map = UndirectedGraph(dict(
    Arad=dict(Zerind=75, Sibiu=140, Timisoara=118),
    Bucharest=dict(Urziceni=85, Pitesti=101, Giurgiu=90, Fagaras=211),
```

```
    Bucharest=dict(Urziceni=85, Pitesti=101, Giurgiu=90, Fagaras=211),
    Craiova=dict(Drobeta=120, Rimnicu=146, Pitesti=138),
    Drobeta=dict(Mehadia=75),
    Eforie=dict(Hirsova=86),
    Fagaras=dict(Sibiu=99),
    Hirsova=dict(Urziceni=98),
    Iasi=dict(Vaslui=92, Neamt=87),
    Lugoj=dict(Timisoara=111, Mehadia=70),
    Oradea=dict(Zerind=71, Sibiu=151),
    Pitesti=dict(Rimnicu=97),
    Rimnicu=dict(Sibiu=80),
    Urziceni=dict(Vaslui=142)))
romania_map.locations = dict(
    Arad=(91, 492), Bucharest=(400, 327), Craiova=(253, 288),
    Drobeta=(165, 299), Eforie=(562, 293), Fagaras=(305, 449),
    Giurgiu=(375, 270), Hirsova=(534, 350), Iasi=(473, 506),
    Lugoj=(165, 379), Mehadia=(168, 339), Neamt=(406, 537),
    Oradea=(131, 571), Pitesti=(320, 368), Rimnicu=(233, 410),
    Sibiu=(207, 457), Timisoara=(94, 410), Urziceni=(456, 350),
    Vaslui=(509, 444), Zerind=(108, 531))


import time

def main():
    print("Executing search algorithms on Romania Map...\n")

    # Define the problem
    romania_problem = GraphProblem('Fagaras', 'Zerind', romania_map)

    # Choose five search algorithms (using GRAPH search to avoid infinite loops)
    algorithms = [
        ("Breadth-First Graph Search", breadth_first_graph_search),
        ("Depth-First Graph Search", depth_first_graph_search),
        ("Uniform Cost Search", uniform_cost_search),
        ("A* Search", lambda p: astar_search(p, h=p.h)),  # A* search needs heuristic function
        ("Best-First Search", lambda p: best_first_graph_search(p, lambda node: node.path_cost))  # FIXED HERE
    ]

    results = []

    for name, algorithm in algorithms:
        print("=" * 50)  # Add a separator line
        print(f"\n🔍 Running {name}...\n")  # Add spacing before
        print("=" * 50)

        start_time = time.time()
        result_node = algorithm(romania_problem)
        elapsed_time = time.time() - start_time

        if result_node:
            solution_path = result_node.solution()
            path_cost = result_node.path_cost
            explored_states = len(result_node.path())
        else:
            solution_path = None
            path_cost = float('inf')
            explored_states = 0

        # Append results
        results.append([name, explored_states, solution_path, path_cost, round(elapsed_time, 4)])

        print("\n✅ Completed:", name)  # Add spacing after

    # Print results in a table
    print("\nFinal Results:\n" + "=" * 50)
    import pandas as pd
    from IPython.display import display
```

```
    from IPython.display import display
    df = pd.DataFrame(results, columns=["Algorithm", "Explored States", "Solution Path", "Path Cost", "Time (s)"])
    display(df)

if __name__ == "__main__":
    main()
```

```
Executing search algorithms on Romania Map...

==================================================

🔍 Running Breadth-First Graph Search...

==================================================
Fagaras
Sibiu
Bucharest
Arad

✅ Completed: Breadth-First Graph Search
==================================================

🔍 Running Depth-First Graph Search...

==================================================
Fagaras
Bucharest
Giurgiu
Pitesti
Craiova
Drobeta
Mehadia
Lugoj
Timisoara
Arad
Zerind

✅ Completed: Depth-First Graph Search
==================================================

🔍 Running Uniform Cost Search...

==================================================
Fagaras
Sibiu
Rimnicu
Bucharest
Arad
Oradea
Pitesti
Urziceni
Giurgiu
Zerind

✅ Completed: Uniform Cost Search
==================================================

🔍 Running A* Search...

==================================================
213
Fagaras
123
356
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