

AI CASE STUDY:-

Airplane Traffic Simulation Management-themed case study

Using :-

- 4. Uniform Cost Search (UCS): Fuel-Efficient Routing**
- 5. Iterative Deepening Depth-First Search (IDDFS): Runway Allocation**
- 6. Bidirectional Search: Inbound and Outbound Traffic Synchronization**

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4. Uniform Cost Search (UCS): Fuel-Efficient Routing

Narrative: Minimize fuel consumption for a long-haul flight by finding the most cost-effective route.

Solution Approach:

- **Algorithm:** Uniform Cost Search (UCS) is used because it finds the least-cost path in a weighted graph.
- **State Space:** Nodes represent airports, and edges represent possible flight paths with a cost function based on fuel consumption.
- **Cost Function:**
 1. Distance traveled
 2. Wind patterns (tailwinds reduce fuel use, headwinds increase it)
 3. Altitude effects on fuel burn
- **Implementation Steps:**
 1. Start from the departure airport.
 2. Expand the least-cost node first (i.e., the airport with the lowest total fuel cost so far).
 3. Continue until reaching the destination airport.
 4. Backtrack to reconstruct the optimal path.

Challenges & Extensions:

- **Challenges:**
 - Defining a realistic cost function balancing speed, fuel use, and wind patterns.
 - Handling real-time changes in air traffic or fuel prices.
 - **Extensions:**
 - Introducing penalties for exceeding time limits or entering restricted zones.
-

**PYTHON CODE:-
(UNIFORM COST SEARCH)**

```
import heapq
import networkx as nx
import matplotlib.pyplot as plt

class Graph:
    def __init__(self):
        self.graph = nx.Graph()

    def add_edge(self, start, end, cost):
        self.graph.add_edge(start, end, weight=cost)

    def uniform_cost_search(self, start, goal):
        pq = [(0, start, [])] # (cost, node, path)
        visited = {}

        while pq:
            cost, node, path = heapq.heappop(pq)

            if node in visited and visited[node] <= cost:
                continue
            visited[node] = cost
            path = path + [node]

            if node == goal:
                return path, cost # Optimal path and its cost

            for neighbor in self.graph.neighbors(node):
                edge_cost = self.graph[node][neighbor]['weight']
                heapq.heappush(pq, (cost + edge_cost, neighbor, path))

        return [], float('inf') # No valid route found

    def draw_graph(self, path=[]):
        pos = nx.spring_layout(self.graph)
        labels = nx.get_edge_attributes(self.graph, 'weight')
```

```
plt.figure(figsize=(6, 6))
nx.draw(self.graph, pos, with_labels=True, node_color='lightblue',
edge_color='gray', node_size=2000, font_size=10)
nx.draw_networkx_edge_labels(self.graph, pos, edge_labels=labels)

if path:
    edges = list(zip(path, path[1:]))
    nx.draw_networkx_edges(self.graph, pos, edgelist=edges,
edge_color='red', width=2)

plt.title("Uniform Cost Search - Fuel Efficient Route")
plt.show()
```

Example usage

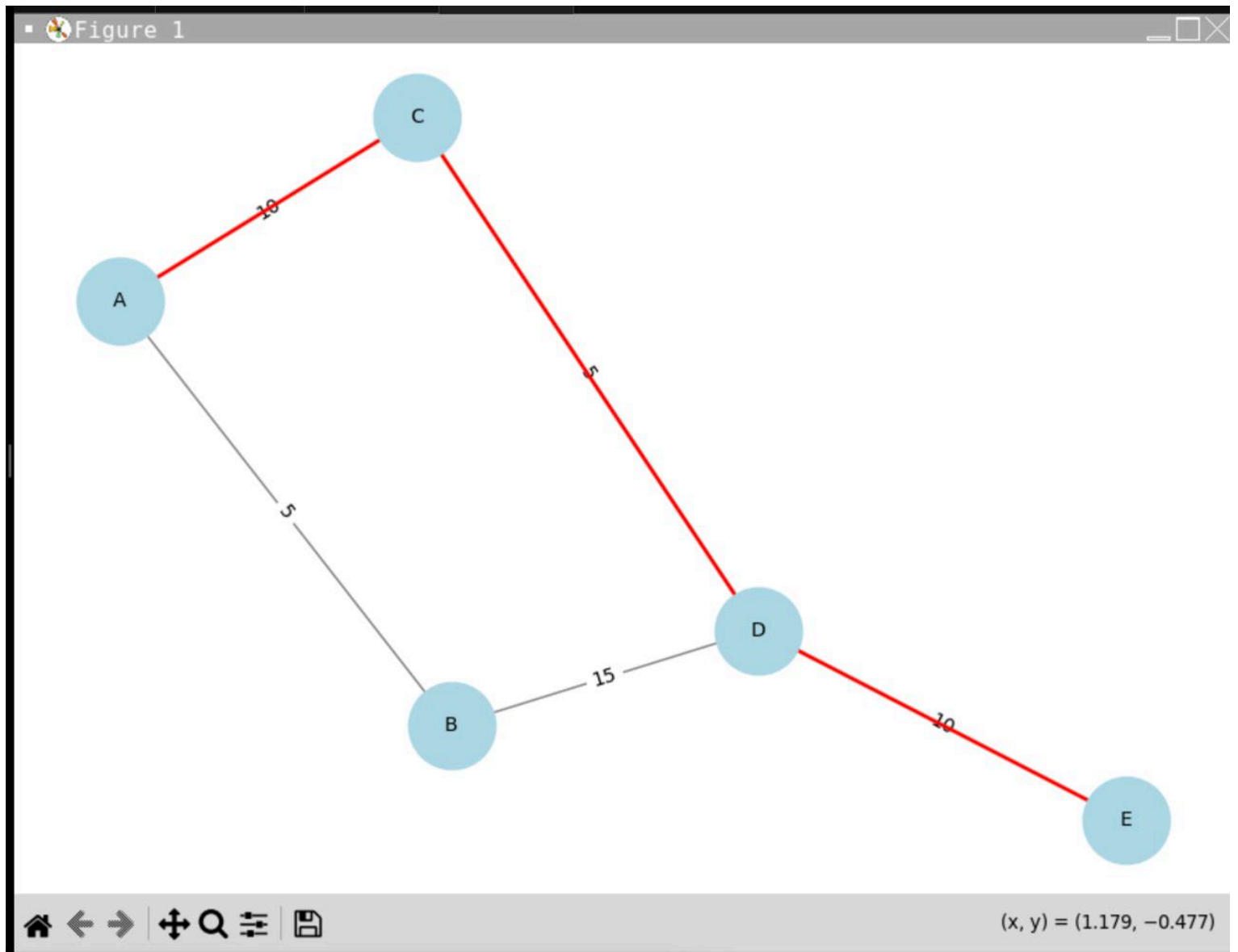
```
graph = Graph()
graph.add_edge("A", "B", 5)
graph.add_edge("A", "C", 10)
graph.add_edge("B", "D", 15)
graph.add_edge("C", "D", 5)
graph.add_edge("D", "E", 10)
```

```
start, goal = "A", "E"
path, cost = graph.uniform_cost_search(start, goal)
print(f"Minimum fuel cost path from {start} to {goal}: {path}, Cost: {cost}")
graph.draw_graph(path)
```

OUTPUT:-

```
ai.py > ...  
1 import heapq  
2 import networkx as nx  
3 import matplotlib.pyplot as plt  
4  
5 class Graph:  
6     def __init__(self):  
7         self.graph = nx.Graph()  
8  
9     def add_edge(self, start, end, cost):  
10        self.graph.add_edge(start, end, weight=cost)  
11  
12    def uniform_cost_search(self, start, goal):  
13        pq = [(0, start, [])] # (cost, node, path)  
14        visited = {}  
15  
16        while pq:  
17            cost, node, path = heapq.heappop(pq)  
18  
19            if node in visited and visited[node] <= cost:  
20                continue  
21            visited[node] = cost  
22            path = path + [node]  
23  
24            if node == goal:  
25                return path, cost # Optimal path and its cost  
26  
27            for neighbor in self.graph.neighbors(node):  
28                edge_cost = self.graph[node][neighbor]['weight']  
29                heapq.heappush(pq, (cost + edge_cost, neighbor, path))  
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```

GRAPH:-



5. Iterative Deepening Depth-First Search (IDDFS): Runway Allocation

Narrative: Planes landing at an airport are assigned runways incrementally based on availability and priority.

Solution Approach:

- **Algorithm:** IDDFS is useful here because it systematically searches for available runways while controlling depth.
- **State Space:** Nodes represent runway states (available or occupied), and transitions represent landing assignments.
- **Implementation Steps:**
 1. Start with a depth limit of 1 and perform Depth-First Search (DFS).
 2. If a solution is not found, increase the depth limit and restart the search.
 3. Continue until a valid runway allocation is determined.
 4. Prioritize high-priority flights (e.g., emergency landings).

Challenges & Extensions:

- **Challenges:**
 - Avoiding assigning the same runway to multiple flights.
 - Balancing runway utilization and minimizing delays.
 - **Extensions:**
 - Introducing dynamic runway closures, forcing recalculations.
-

**PYTHON CODE:-
(ITERATIVE DEEPENING SEARCH)**

```
import matplotlib.pyplot as plt

class Airport:
    def __init__(self, runways):
        self.runways = ["R" + str(i) for i in range(1, runways+1)]

    def iddfs(self, flights):
        for depth in range(len(self.runways)):
            allocated = self.dls(flights, depth, {})
            if allocated:
                return allocated
        return None

    def dls(self, flights, depth, allocated):
        if not flights:
            return allocated

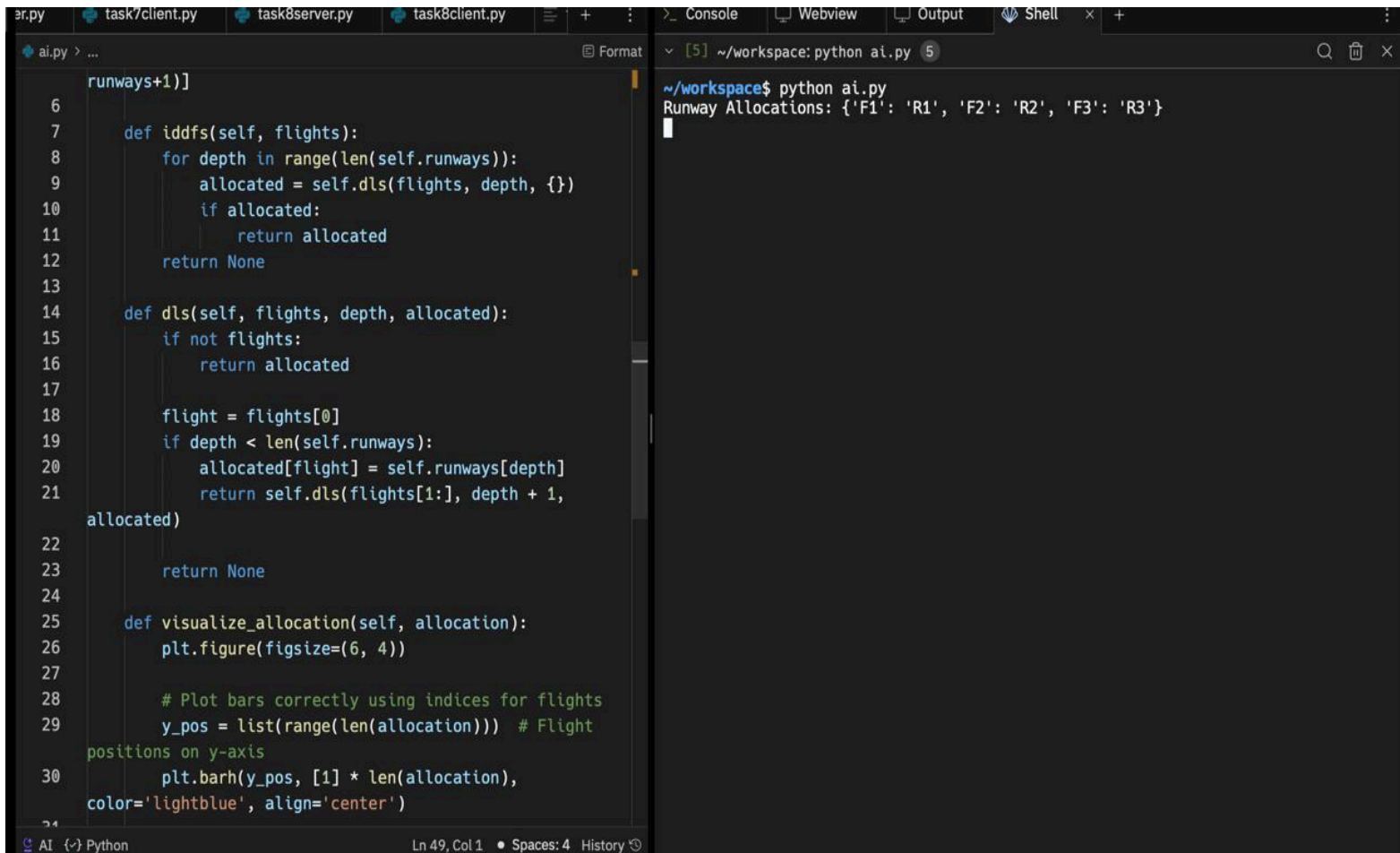
        flight = flights[0]
        if depth < len(self.runways):
            allocated[flight] = self.runways[depth]
            return self.dls(flights[1:], depth + 1, allocated)

        return None

    def visualize_allocation(self, allocation):
        plt.figure(figsize=(6, 4))

        # Plot bars correctly using indices for flights
        y_pos = list(range(len(allocation))) # Flight positions on y-axis
        plt.barh(y_pos, [1] * len(allocation), color='lightblue')
```


OUTPUT:-



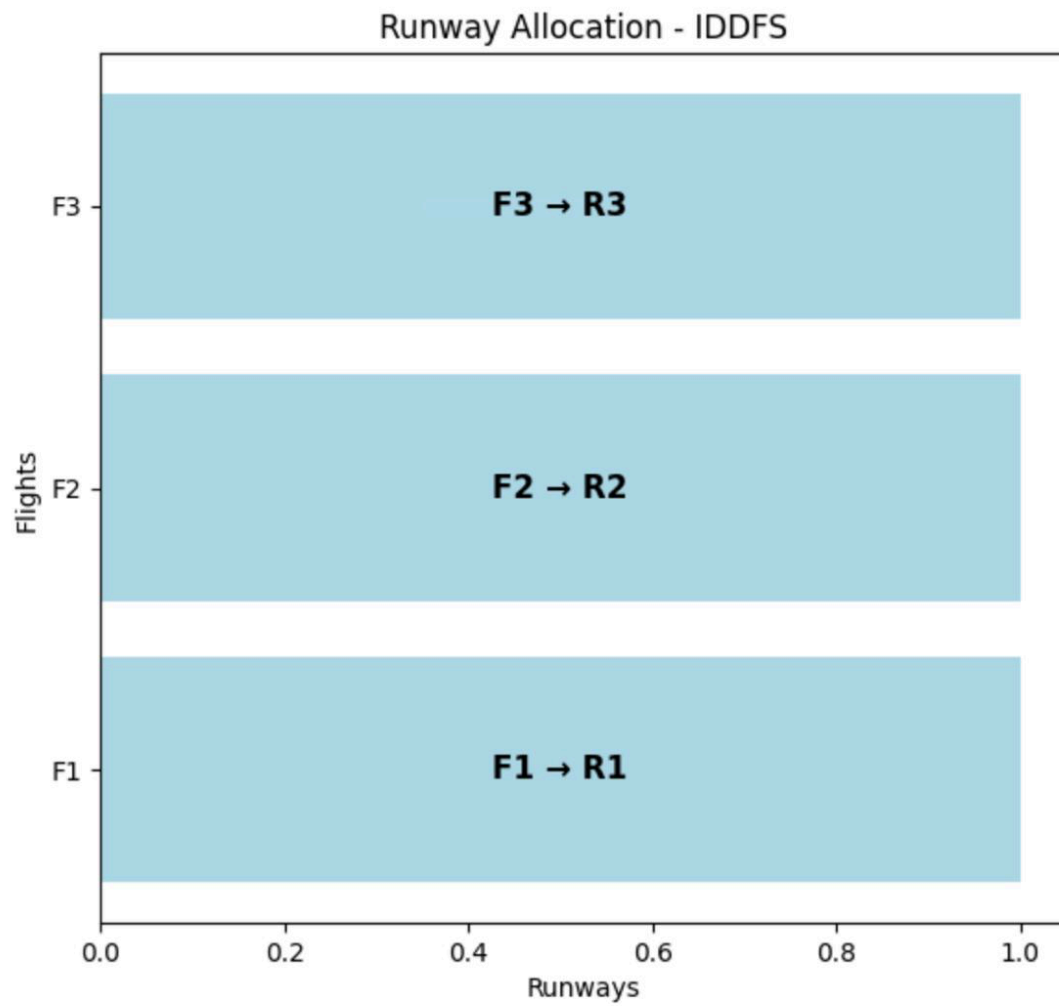
The image shows a VS Code editor window with a Python file named `ai.py` open. The file contains a class `ai` with several methods. The `iddfs` method iterates over runways and calls `dls` to find a flight allocation. The `dls` method recursively assigns flights to runways. The `visualize_allocation` method uses `matplotlib` to create a bar chart showing the allocation. The console on the right shows the command `python ai.py` being executed, resulting in the output: `Runway Allocations: {'F1': 'R1', 'F2': 'R2', 'F3': 'R3'}`.

```
ai.py task7/client.py task8server.py task8client.py
ai.py > ...
runways+1]]
6
7 def iddfs(self, flights):
8     for depth in range(len(self.runways)):
9         allocated = self.dls(flights, depth, {})
10        if allocated:
11            return allocated
12    return None
13
14 def dls(self, flights, depth, allocated):
15     if not flights:
16         return allocated
17
18     flight = flights[0]
19     if depth < len(self.runways):
20         allocated[flight] = self.runways[depth]
21         return self.dls(flights[1:], depth + 1,
22         allocated)
23     return None
24
25 def visualize_allocation(self, allocation):
26     plt.figure(figsize=(6, 4))
27
28     # Plot bars correctly using indices for flights
29     y_pos = list(range(len(allocation))) # Flight
30     positions on y-axis
31     plt.barh(y_pos, [1] * len(allocation),
32     color='lightblue', align='center')
```

~/workspace\$ python ai.py
Runway Allocations: {'F1': 'R1', 'F2': 'R2', 'F3': 'R3'}
█

AI {>} Python Ln 49, Col 1 • Spaces: 4 History

Figure 1



(x, y) = (0.297,)

6. Bidirectional Search: Inbound and Outbound Traffic Synchronization

Narrative: Coordinate inbound and outbound flights to minimize delays at a busy airport.

Solution Approach:

- **Algorithm: Bidirectional Search** is used to search from both the inbound and outbound directions to meet in the middle.
- **State Space:** Nodes represent flight statuses (approaching or departing), and edges represent possible transitions.
- **Implementation Steps:**
 1. Start one search from inbound flights and another from outbound flights.
 2. Expand both searches simultaneously.
 3. Stop when the two searches meet, indicating an optimal synchronization.
 4. Resolve timing conflicts dynamically.

Challenges & Extensions:

- **Challenges:**
 - Managing timing conflicts between landing and takeoff slots.
 - Handling simultaneous requests from multiple flights.
- **Extensions:**
 - Introducing emergencies requiring prioritized landing or takeoff.

**PYTHON CODE:-
(BI-DIRECTIONAL SEARCH)**

```
from collections import deque
import networkx as nx
import matplotlib.pyplot as plt

class FlightNetwork:
    def __init__(self):
        self.graph = nx.Graph()

    def add_connection(self, start, end):
        self.graph.add_edge(start, end)

    def bidirectional_search(self, start, goal):
        if start == goal:
            return [start]

        frontier_fwd = deque([start])
        frontier_bwd = deque([goal])
        visited_fwd = {start: None}
        visited_bwd = {goal: None}

        while frontier_fwd and frontier_bwd:
            self.expand(frontier_fwd, visited_fwd, visited_bwd)
            self.expand(frontier_bwd, visited_bwd, visited_fwd)

            intersection = set(visited_fwd.keys()) & set(visited_bwd.keys())
            if intersection:
                meeting_point = intersection.pop()
                return self.reconstruct_path(meeting_point, visited_fwd, visited_bwd)

        return None

    def expand(self, frontier, visited, other_visited):
        if frontier:
            node = frontier.popleft()
```

```

for neighbor in self.graph.neighbors(node):
    if neighbor not in visited:
        visited[neighbor] = node
        frontier.append(neighbor)
    if neighbor in other_visited:
        return

```

```

def reconstruct_path(self, meeting_point, visited_fwd, visited_bwd):
    path_fwd, path_bwd = [], []

```

```

    # Construct forward path
    node = meeting_point
    while node is not None:
        path_fwd.append(node)
        node = visited_fwd[node]

```

```

    # Construct backward path
    node = visited_bwd[meeting_point]
    while node is not None:
        path_bwd.append(node)
        node = visited_bwd[node]

```

```

    return path_fwd[::-1] + path_bwd # Reverse fwd path and append backward
path

```

```

def draw_graph(self, path=[]):
    pos = nx.spring_layout(self.graph)

    plt.figure(figsize=(6, 6))
    nx.draw(self.graph, pos, with_labels=True, node_color='lightblue',
edge_color='gray', node_size=2000, font_size=10)

```

```

    if path:
        edges = list(zip(path, path[1:]))
        nx.draw_networkx_edges(self.graph, pos, edgelist=edges,
edge_color='red', width=2, alpha=0.8)

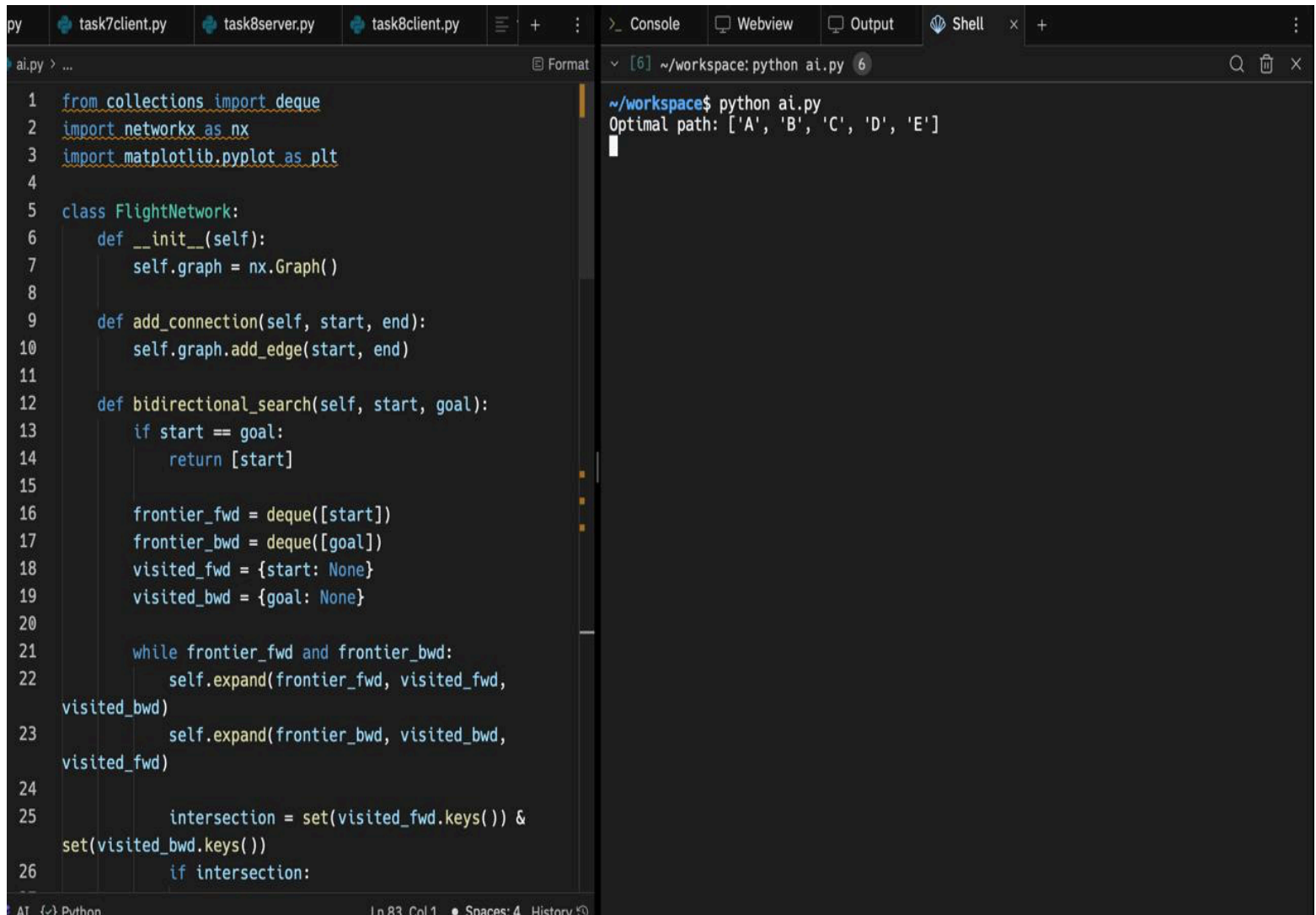
```

```
plt.title("Bidirectional Search - Optimal Path")
plt.show()
```

Example usage

```
network = FlightNetwork()
network.add_connection("A", "B")
network.add_connection("B", "C")
network.add_connection("C", "D")
network.add_connection("D", "E")
```

```
start, goal = "A", "E"
path = network.bidirectional_search(start, goal)
print("Optimal path:", path)
network.draw_graph(path)
```



The screenshot shows a VS Code editor with a Python file named `ai.py` and a terminal window. The Python code defines a `FlightNetwork` class with methods for adding connections and performing a bidirectional search. The terminal output shows the execution of `python ai.py` resulting in the optimal path `['A', 'B', 'C', 'D', 'E']`.

```
py task7client.py task8server.py task8client.py + : >_ Console Webview Output Shell x +
ai.py > ... Format [6] ~/workspace: python ai.py 6
1 from collections import deque
2 import networkx as nx
3 import matplotlib.pyplot as plt
4
5 class FlightNetwork:
6     def __init__(self):
7         self.graph = nx.Graph()
8
9     def add_connection(self, start, end):
10        self.graph.add_edge(start, end)
11
12    def bidirectional_search(self, start, goal):
13        if start == goal:
14            return [start]
15
16        frontier_fwd = deque([start])
17        frontier_bwd = deque([goal])
18        visited_fwd = {start: None}
19        visited_bwd = {goal: None}
20
21        while frontier_fwd and frontier_bwd:
22            self.expand(frontier_fwd, visited_fwd,
23            visited_bwd)
24            self.expand(frontier_bwd, visited_bwd,
25            visited_fwd)
26
27            intersection = set(visited_fwd.keys()) &
28            set(visited_bwd.keys())
29            if intersection:
```

```
~/workspace$ python ai.py
Optimal path: ['A', 'B', 'C', 'D', 'E']
```

AI Python Ln 83, Col 1 • Spaces: 4 History

