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

AATISSH.V
VU22CSEN0101347

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')
```

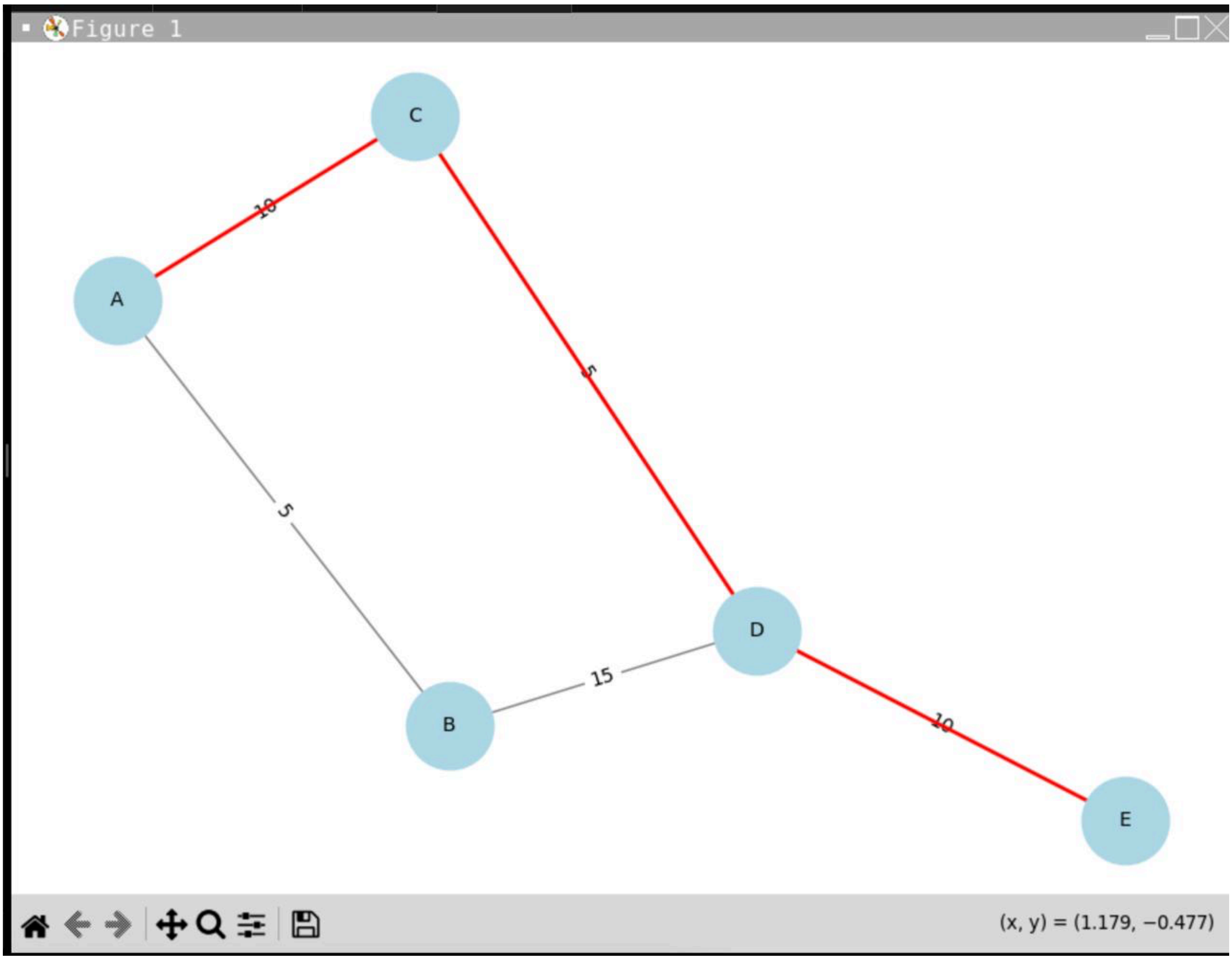
```
        plt.figure(figsize=(6, 6))
        nx.draw(self.graph, pos, with_labels=True, node_color='lightblue',
edge_color='gray', node_size=2000, font_size=10)
        nx.draw_networkx_edge_labels(self.graph, pos, edge_labels=labels)

        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:-

```python
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))
```

```
~/workspace$ python ai.py
Minimum fuel cost path from A to E: ['A', 'C', 'D', 'E'], Cost:
25
```

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).

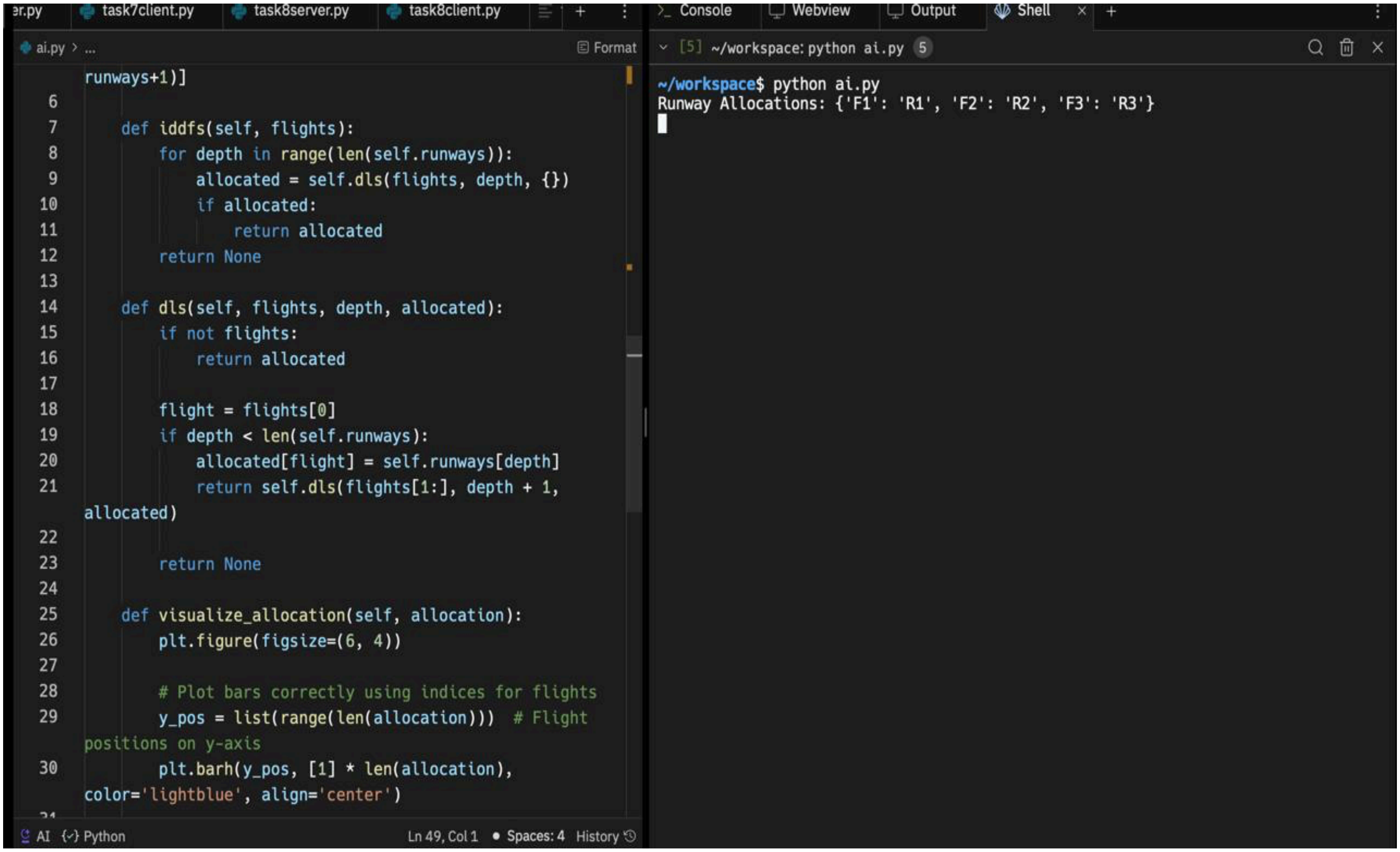
Challenges & Extensions:

- **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:-



er.py
task7client.py
task8server.py
task8client.py
Console
Webview
Output
Shell
ai.py > ...
Format
[5] ~/workspace: python ai.py 5
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', align='center')
~/workspace$ python ai.py
Runway Allocations: {'F1': 'R1', 'F2': 'R2', 'F3': 'R3'}
AI
Python
Ln 49, Col 1
Spaces: 4
History

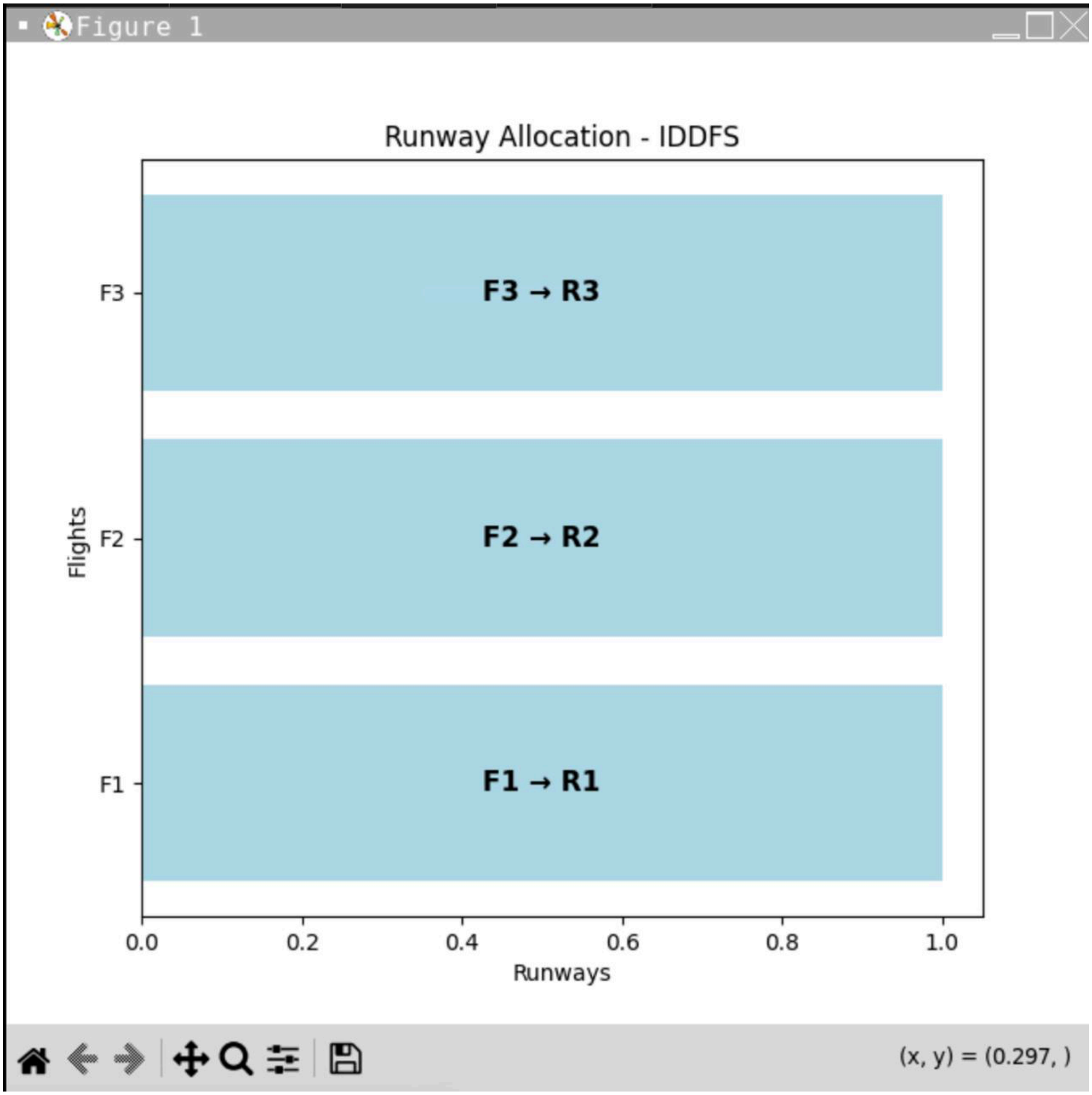


Figure 1
Runway Allocation - IDDFS
F3 → R3
F2 → R2
F1 → R1
F3
F2
F1
Flights
0.0
0.2
0.4
0.6
0.8
1.0
Runways
(x, y) = (0.297,)

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:

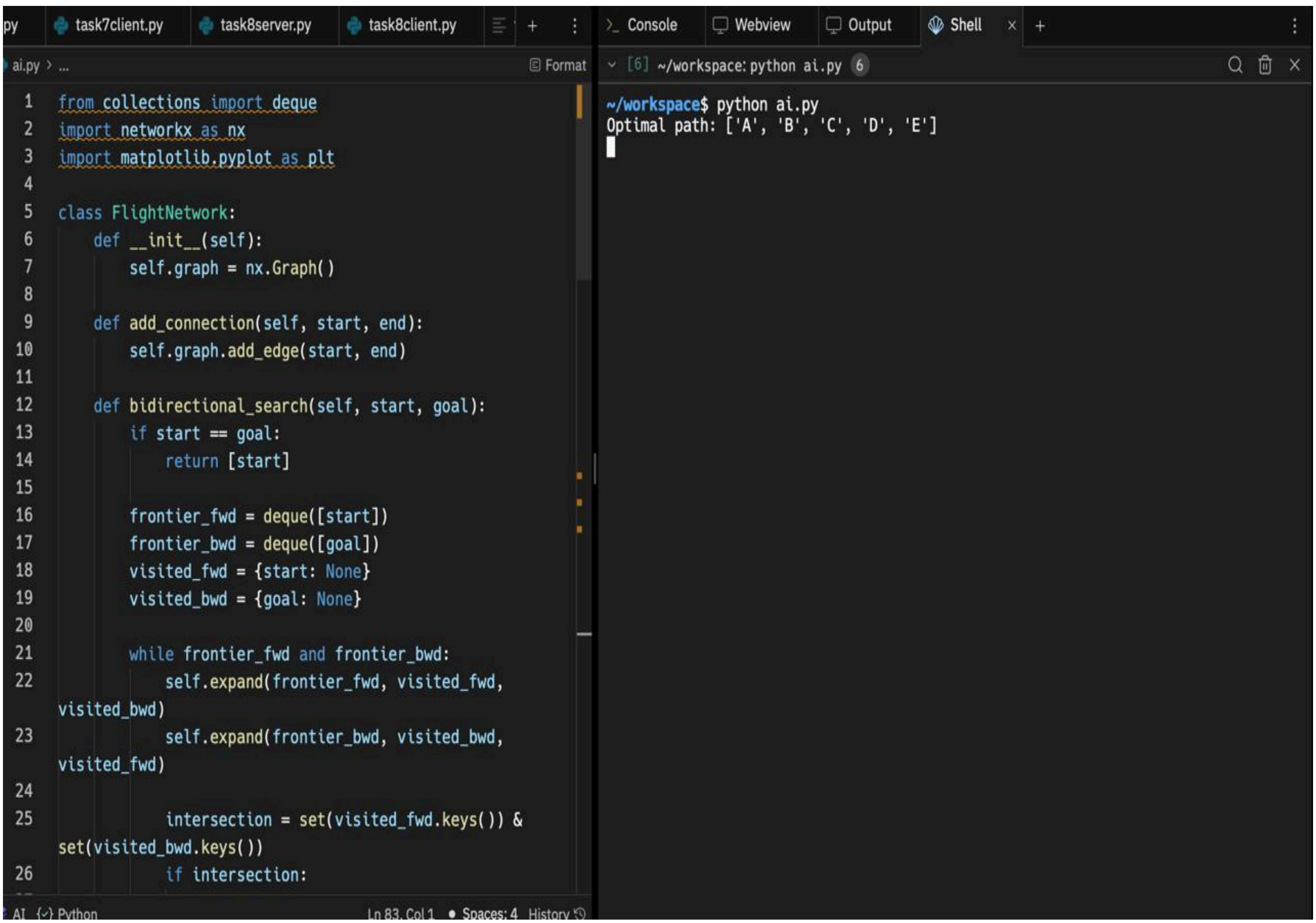
- **Challenges:**
    - **Managing timing conflicts between landing and takeoff slots.**
    - **Handling simultaneous requests from multiple flights.**
- **Extensions:**
    - **Introducing emergencies requiring prioritized landing or takeoff.**

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)
```



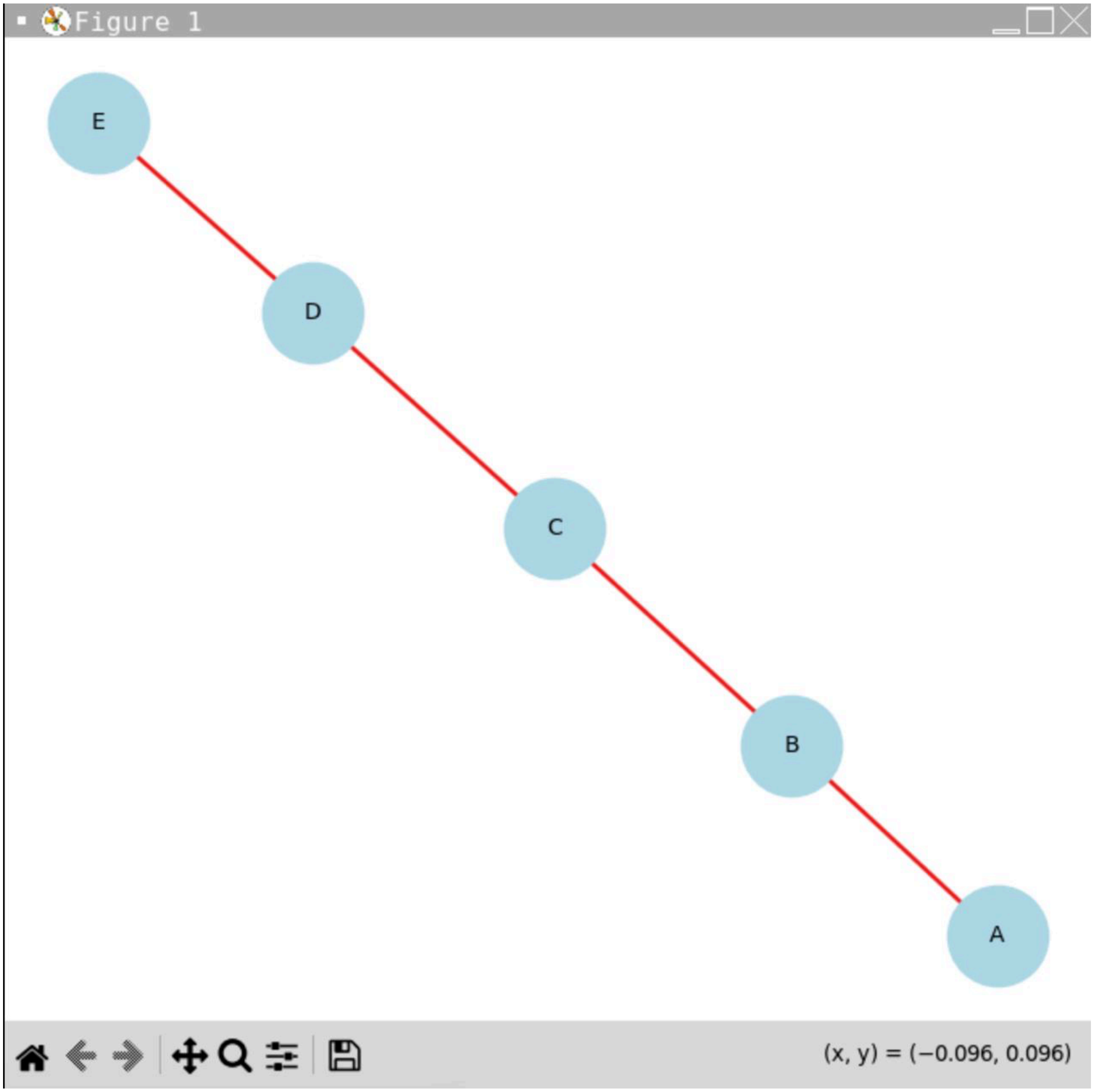


Figure 1
E
D
C
B
A
(x, y) = (−0.096, 0.096)