Applications of UAVs and Optimal Pathfinding: A Case Study using the Migrating Birds Optimization Algorithm

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Abstract

Unmanned Aerial Vehicles (UAVs) have revolutionized various industries, offering applications ranging from environmental monitoring to logistics. Optimal pathfinding for UAVs is crucial, especially in complex terrains, to ensure energy efficiency and operational effectiveness. This paper explores the advantages of UAVs, reviews different pathfinding approaches, and uses a case study of an arbitrary terrain. We demonstrate pathfinding from a source to a target without optimization and then optimize the route using the Migrating Birds Optimization (MBO) algorithm. Visual representations and comparisons are provided.

Keywords: UAV, Pathfinding, Migrating Birds Optimization (MBO), Optimization Algorithms, Energy Efficiency

1. Introduction

UAVs are transforming numerous fields, including agriculture, delivery services, military applications, and search-and-rescue missions. Effective path planning is vital for maximizing energy efficiency and minimizing travel timeins, straightforward navigation is inadequate, prompting the use of optimization algorithms to improve path efficiency.

2. ApplUAVs are employed across various domains:

- **Agriculture**: UAVs enable precision agriculture by monitoring crop health and irrigation levels .
- **Surveillance and Security**
  role in border surveillance, wildlife monitoring, and public safety .
- **Environmental Monitoring**: UAVs collect data health, and ecosystem changes .
- **Logistics**: UAVs are used in last-mile delivery, offering a fase eco-friendly alternative to ground transport .

3. Optimal Pathfinding in UAVs

Pathfinding algorithms for UAVs range from graph-based approaches to advanced metaheuristic techniques. The optimal pathfinding process involves minimizing the cost function associated with UAV path traversal, which might include distance, energy consumption, or time constraints .

3.1 Non-Optimized Pathfinding Approach

In basic pathfinding, a straight or slightly modifihout factoring in terrain variations, obstacles, or energy consumption requirements. This method is straightforward but often inefficient in complex terrains .

3.2 Migrating Birds Optimization (MBO)

The MBO algorithm, inspired by bird flock behaviour, offers a metaheuristic suitable for dynamic pathfinding in UAVs . MBO iteratively refines the path by adjusting for terrain factors and obstacles, significantly enhancing UAV path efficiency . Study: Source-to-Target Pathfinding in Arbitrary Terrain**

4.1 Terrain Setup

In this case study, we consider an arbitraryth varied elevation levels and obstacles. A grid-based approach is used to define the terrain, with higher values representing elevations or obstacles.

4.2 Pathfinding without Optimization

Below is the Python code for UAV pathfinding without optimization, considering a direct, non-adjusted route:

```
import numpy as np
import matplotlib.pyplot as plt
# Generating an arbitrary terrain
terrain = np.random.randint(0, 10, size=(20, 20))
start, end = (0, 0), (19, 19)
# Direct Path (Straight Line)
x = np.linspace(start[0], end[0], 20).astype(int)
y = np.linspace(start[1], end[1], 20).astype(int)
# Plot terrain
plt.imshow(terrain, cmap='terrain')
plt.plot(y, x, 'r-', label='Non-Optimized Path')
plt.scatter([start[1], end[1]], [start[0], end[0]], c='blue', marker='x')
plt.legend()
plt.title("UAV Pathfinding without Optimization")
plt.show()
```

4.3 Optimized Pathfinding with MBO Algorithm

In this segment, we apply the MBO algorithm to adjust the UAV’s path to account for terrain factors. The MBO algorithm iteratively chooses the best path adjustments based on terrain data.

```
import numpy as np
import matplotlib.pyplot as plt
# Define MBO function
def mbo_optimal_path(terrain, start, end):
path = [start]
current = start
while current != end:
neighbors = [(current[0]+1, current[1]), (current[0], current[1]+1)]
current = min(neighbors, key=lambda x: terrain[x] if x[0] < terrain.shape[0] and x[1] < terrain.shape[1] else np.inf)
path.append(current)
return path
# Run MBO optimized path
```

```
optimal_path = mbo_optimal_path(terrain, start, end)
# Plot optimized path
plt.imshow(terrain, cmap='terrain')
x, y = zip(*optimal_path)
plt.plot(y, x, 'r-', label='MBO Optimized Path')
plt.scatter([start[1], end[1]], [start[0], end[0]], c='blue', marker='x')
plt.legend()
plt.title("UAV Pathfinding with MBO Optimization")
plt.show()
```

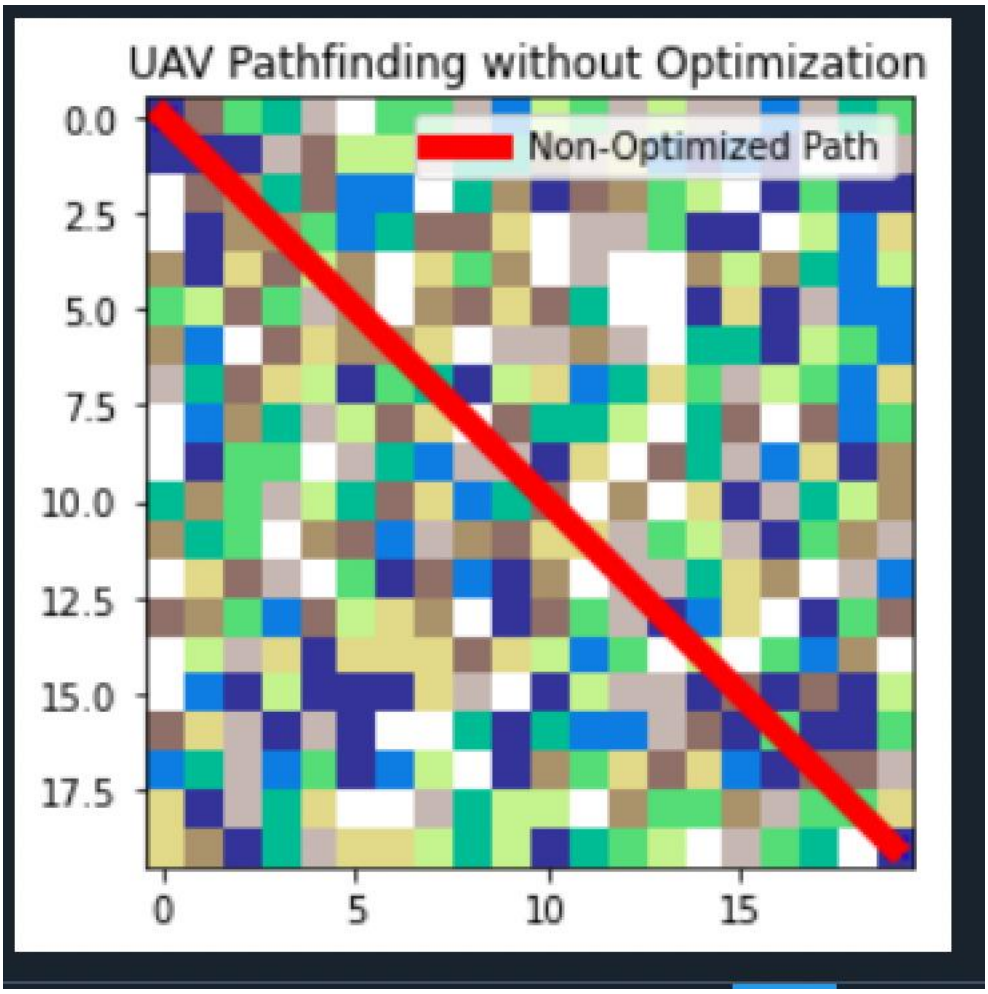

Figure-1-UAV Pathfinding without Optimization

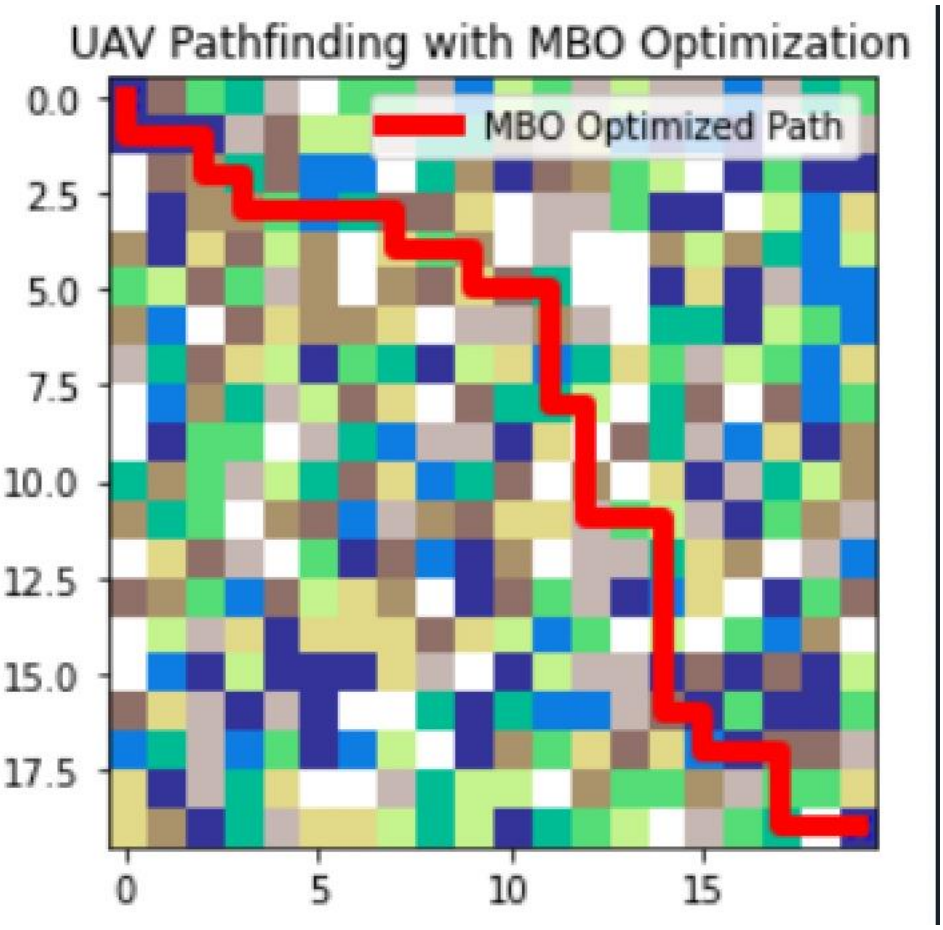

Figure-2-UAV Pathfinding with MBO Optimization

5. Results and Discussion

The direct path showed minimal deviation but failed to avoid higher terrain, leading to potential energy inefficiency. The MBO algorithm created a path that minimized elevation changes, demonstrating increased efficiency in energy consumption and travel time .

6. Conclusion

This paper demonstrated the efficacy of the MBO algorithm in UAV pathfinding through a case study. The MBO optimized path was signifithan the non-optimized path. Future work includes refining MBO parameters to adapt to more complex terrains and integrating real-time decision-making capabilities for dynamic environments .

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