A Meta-heuristic Approach Algorithm for an Unmanned Aerial-Ground Vehicles Path Planning Problem

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Abstract

- This study concerns the challenges of path planning and scheduling for multi-agent unmanned aerial vehicles (UAVs) operating under battery constraints while considering the presence of unmanned ground vehicles (UGVs) capable of recharging them. The objective is to efficiently coordinate UAVs and a UGV to maximize collected rewards by visiting nodes continuously in a 20 km x 20 km coverage area.

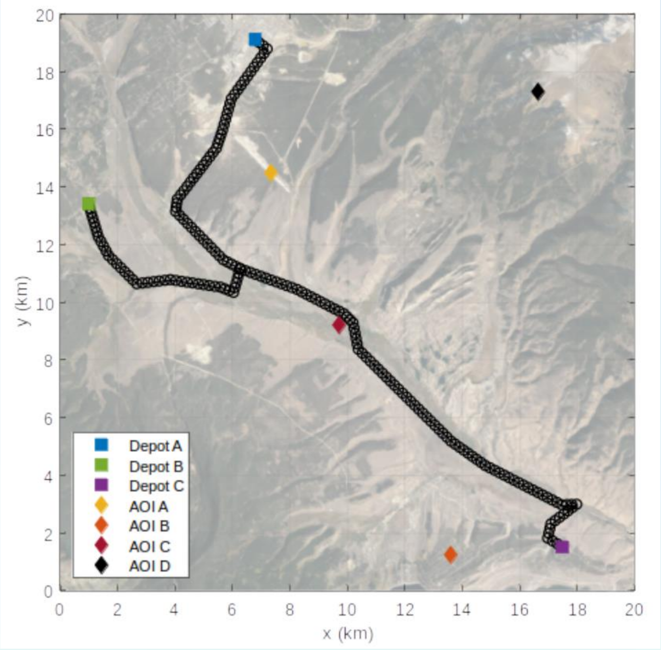
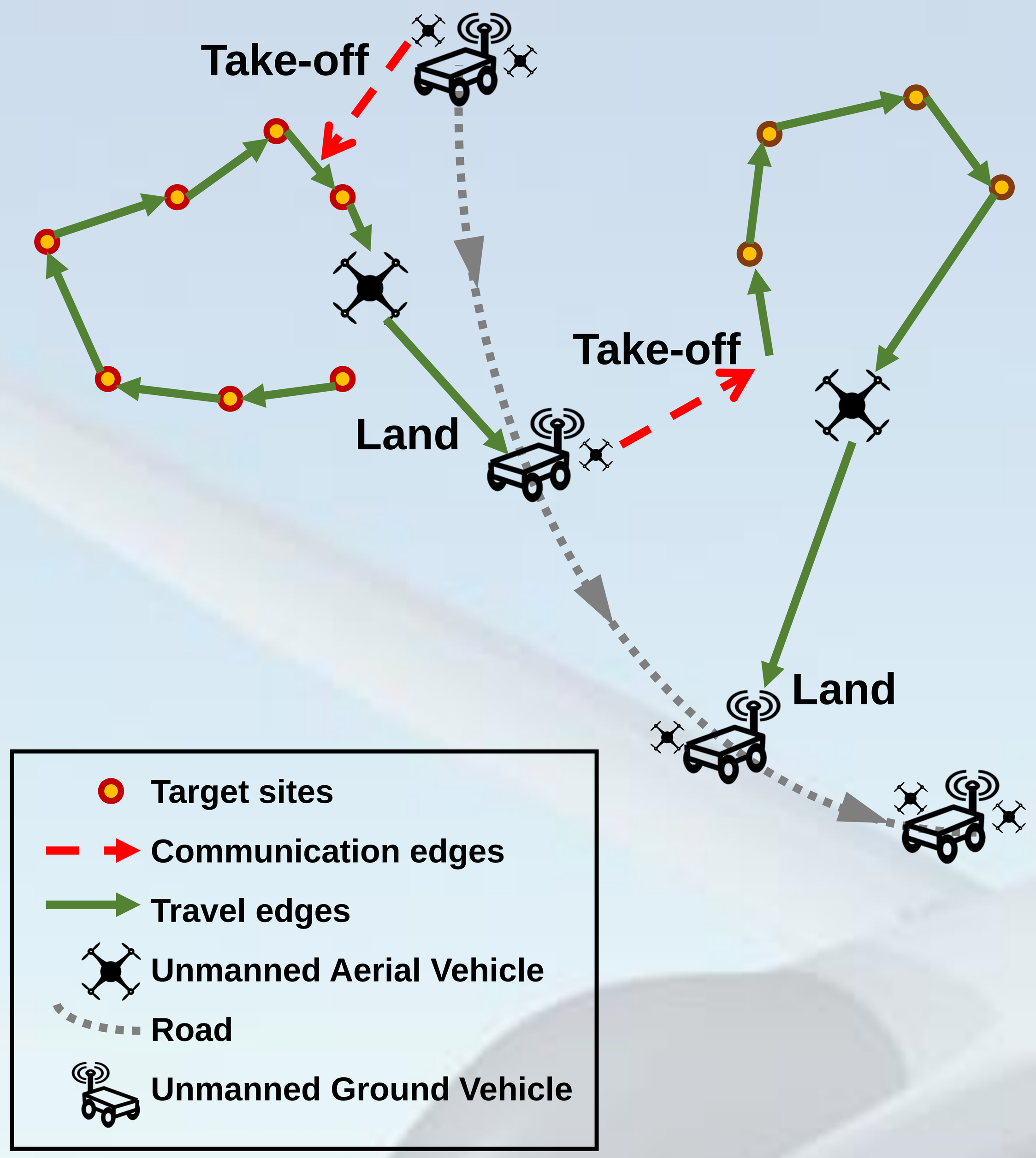


Fig. Area coverage scenario within a 20 x 20 km^2 map; 3 depots and 4 areas of interest are shown among a road network (black)

Research Objective



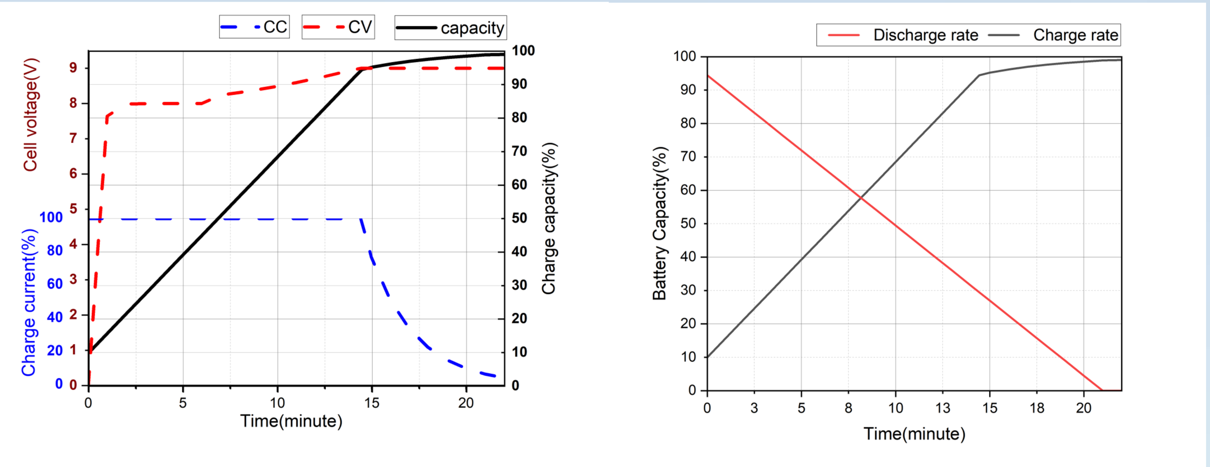


Fig. UAV battery charing(left) and discharging(right) graph

- Objective: To find the shortest and most feasible path in time and fuel constraints. The problem involves conducting 3 mission types over a duration of 72 hours: Persistent ISR over the road network, visiting a predetermined Convoy point at a specific time and visiting the AOIs.
- Question: Due to the lack of communication between the UAVs and UGV while UAVs are flying, how do we schedule to find a feasible solution to maximize rewards?

New Meta-heuristic Algorithm

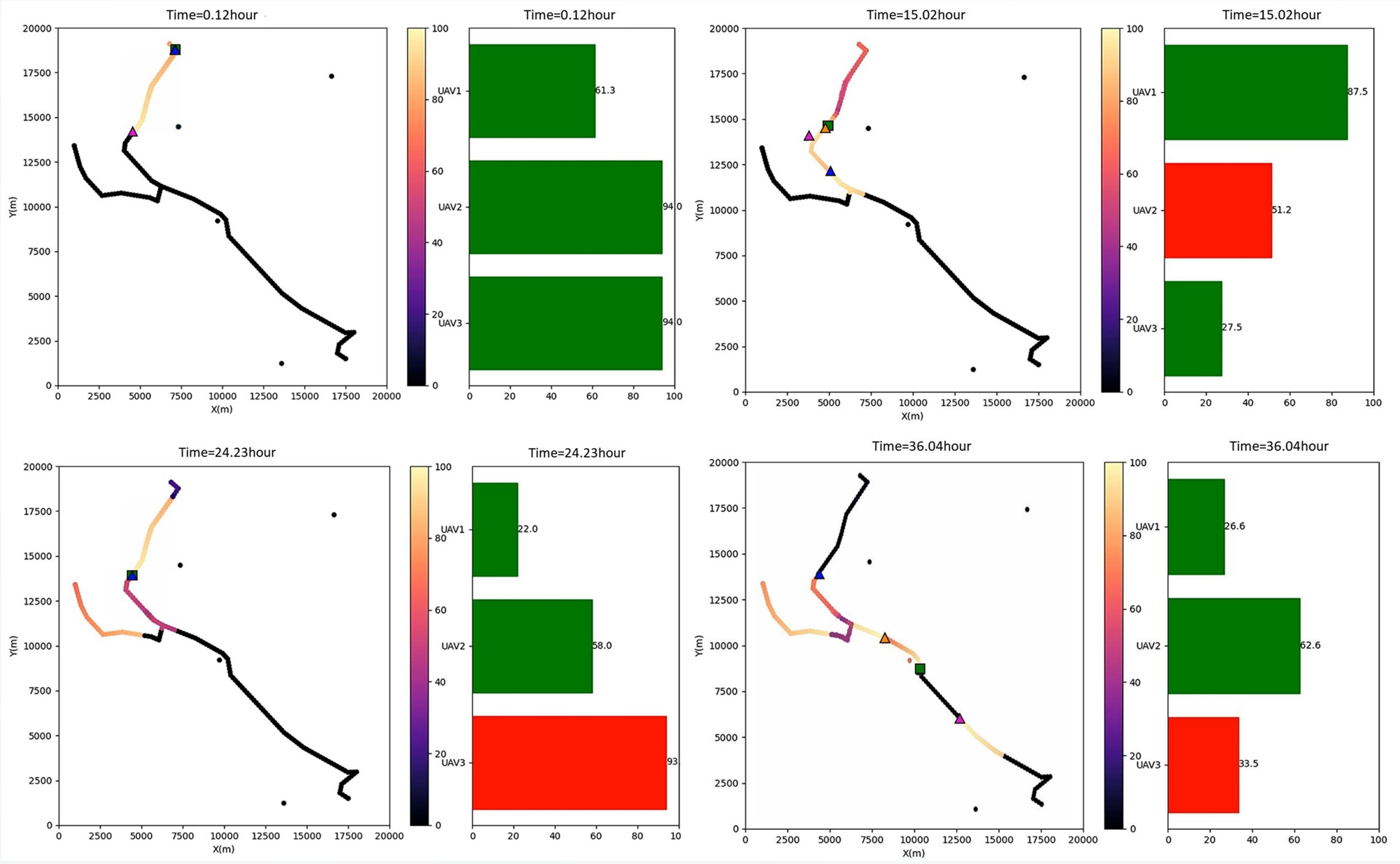
	Orienteering Problem(OP)	Team Orienteering Problem(TOP)	Meta-heuristic TOP
Number of vehicles	One vehicle	Multi vehicles	Multi vehicles
Number of trips	One-time trip	One-time trip	Multiple trips
Destination	Fixed	Fixed	Moving
Starting point	One point	The same point to all vehicles	Various points
Ending point	Another point	Another same point to all vehicles	Various points

Algorithm 1 A Meta-heuristic for TOP

Step 1. Initialization
  Perform initialization
  Set *team score* = team score of the initial solution
Step 2. Improvement
  For $k = 1, 2, \dots, K$
    For $i = 1, 2, \dots, I$
      Perform two-point exchange
      Perform one-point movement
      Perform route optimization(two-opt)
      Perform rearrange
      If no movement has been made above, end I loop
      If a better solution has been obtained, reset the *team score*
    End I **loop**
    If no new *team score* is obtained in 5 iterations, then go to **Step 3**
    Perform Tabu search (reinitialize for k points)
  End K **loop**
Step 3. Tabu search reinitialize and redo Step 2 once more.
Step 4. Reattachment

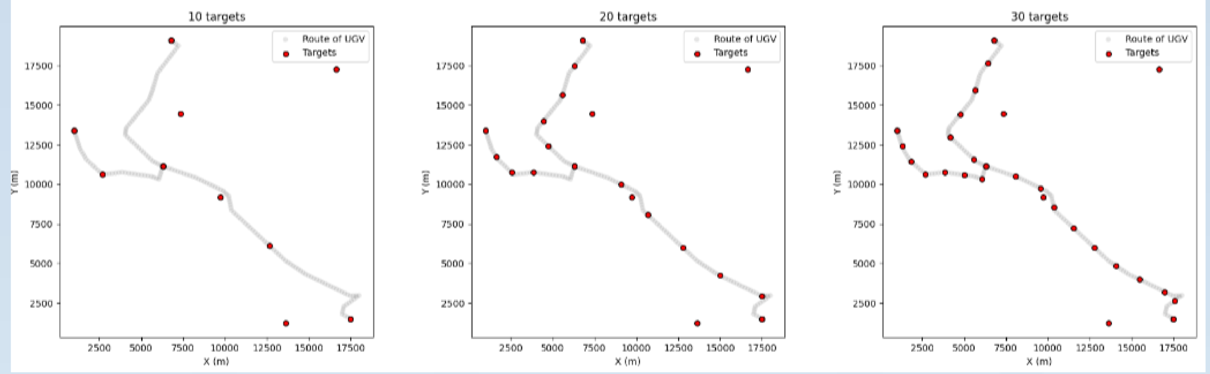
Simulation result

Over a 72-hour period, we applied our algorithms to this problem instance and obtained promising results.



This study makes a valuable contribution to the field of UAV operations by offering a comprehensive solution to the path planning and scheduling problem. Our approach considers battery constraints and employs a multi-phase strategy, thereby enhancing the overall effectiveness of reconnaissance surveillance systems without human intervention.

Numerical Results



Increase the range for specific number of targets							
		10 targets		20 targets		30 targets	
		Time	Visited targets	Time	Visited targets	Time	Visited targets
Meta	1uav+1ugv	0.105ms	8	0.191ms	19	0.213ms	24
-Heuristic	2uavs+1ugv	0.398ms	15	0.433ms	38	0.491ms	45
algorithm	3uavs+1ugv	0.516ms	22	0.578ms	58	0.613ms	67
Greedy	1uav+1ugv	0.002ms	6	0.003ms	15	0.003ms	23
Dijkstra	2uavs+1ugv	0.005ms	12	0.006ms	29	0.006ms	43
algorithm	3uavs+1ugv	0.004ms	17	0.006ms	32	0.007ms	59

Fig. Alogirhtm comparison result by subsets of 10, 20, and 30 targets

Conclusions

- Our study contributes to the field of UAV operations by providing a comprehensive solution to the path planning and scheduling problem. By considering battery constraints and utilizing a multi-phase approach, we have demonstrated the efficacy of our solution. This research opens avenues for further advancements in optimizing UAV operations and paves the way for practical implementation in real-world scenarios.

Acknowledgements

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References

1.Chour, Kenny, et al. "An agent-based modeling framework for the multi-UAV rendezvous recharging problem." *Robotics and Autonomous Systems* (2023): 104442.

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