From Air to Ground: Coordinating UAVs and UGVs in SAR missions

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Context

- Search and Rescue (SAR)
  - The goal is to find individuals in danger, usually in difficult environments
  - There is limited time to locate survivors
- Unmanned Aerial Vehicles (UAVs) can search the area, looking for these individual, as they have an aerial vision
- Unmanned Ground Vehicles (UGVs) can navigate difficult terrains, provide ground assistance and carry individuals
- Combining UAVs and UGVs can help decreasing the time it takes to find survivors

Related Work

TABLE I: Related Work Comparison

Paper	Algorithm	Num of UAVs - UGVs	Coverage Path Planning	UAV Constraints	UGV Constraints	Communication	Evaluated Metrics
Cladera *et al.* [6]	Heuristic	1 - N	Predefined waypoints	Energy consumption	No GPS	P2P opportunistic	Number of visited targets Average time to visit targets
Miller *et al.* [7]	Heuristic	1 - 2	Global semantic planner	-	No GPS	P2P opportunistic	Time to visit all targets
de Castro *et al.* [8]	Neural Networks	2 - 1	Wave front algorithm	Battery scarcity	Limited visibility	P2P opportunistic	Obstacle avoidance success rate Path efficiency
A2G-Coord	Heuristic	N - N	Wave front algorithm	Fixed coverage path planning	No GPS Limited visibility	P2P opportunistic	Time to visit all targets

Problem Formulation

- Agents
  - UAVs
    - Wave front algorithm for Coverage Path Planning
    - Battery limited to a section of the map
    - Has GPS
  - UGVs
    - No GPS
  - POIs
    - No GPS
- Opportunistic communication
- Goal: minimize the time for all PoI to be visited once by an UGV

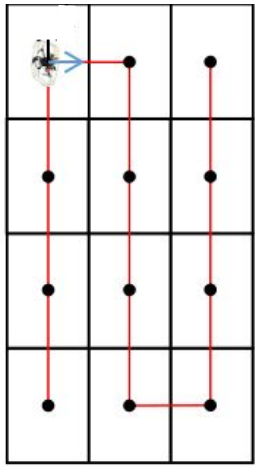
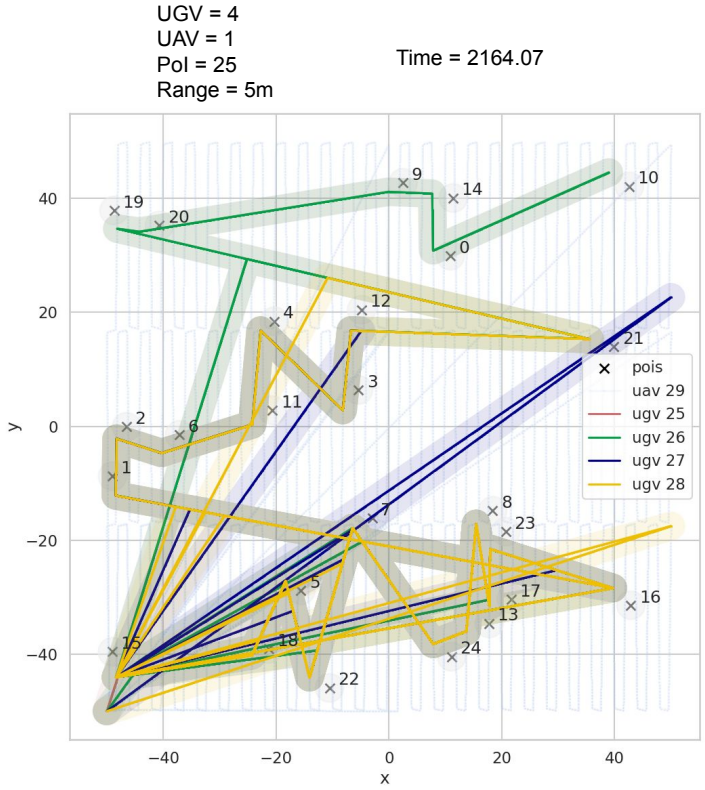


Figure: L. H. Nam, L. Huang, X. J. Li, and J. F. Xu, “An approach for coverage path planning for uavs,” in 2016 IEEE 14th International Workshop on Advanced Motion Control (AMC), 2016, pp. 411–416.

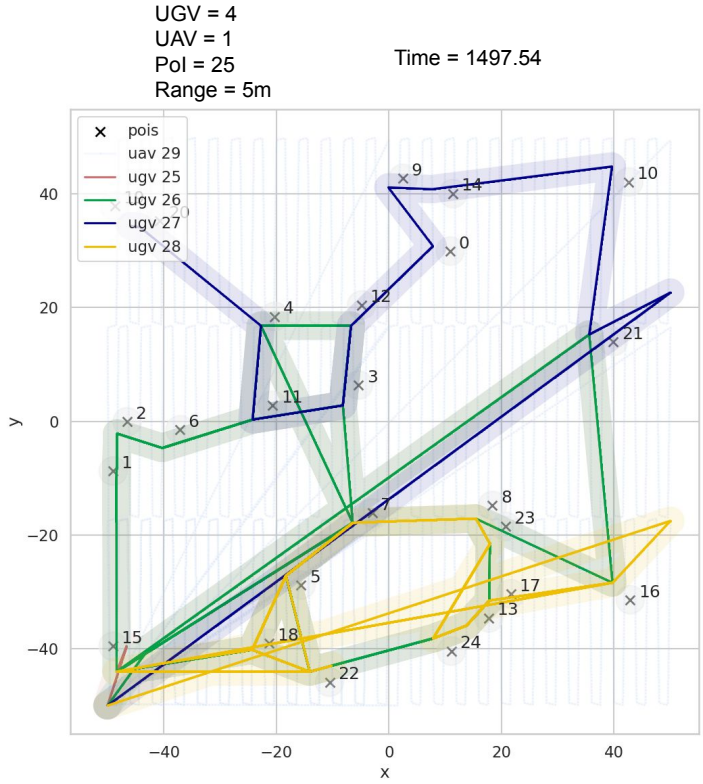
Base Algorithm (BA)

- POI
  - Acts as a beacon
- UAV
  - Broadcasts messages every few seconds to find PoIs and UGVs
  - Communication:
    - UAV-POI: the UAV's own position is stored on *PoI Buffer*
    - UAV-UGV: the UAV calculates directions to the positions stored on a copy of *PoI Buffer* and sends them to the UGV
- UGV
  - Receives the directions from the UAV
  - Communicates with POI



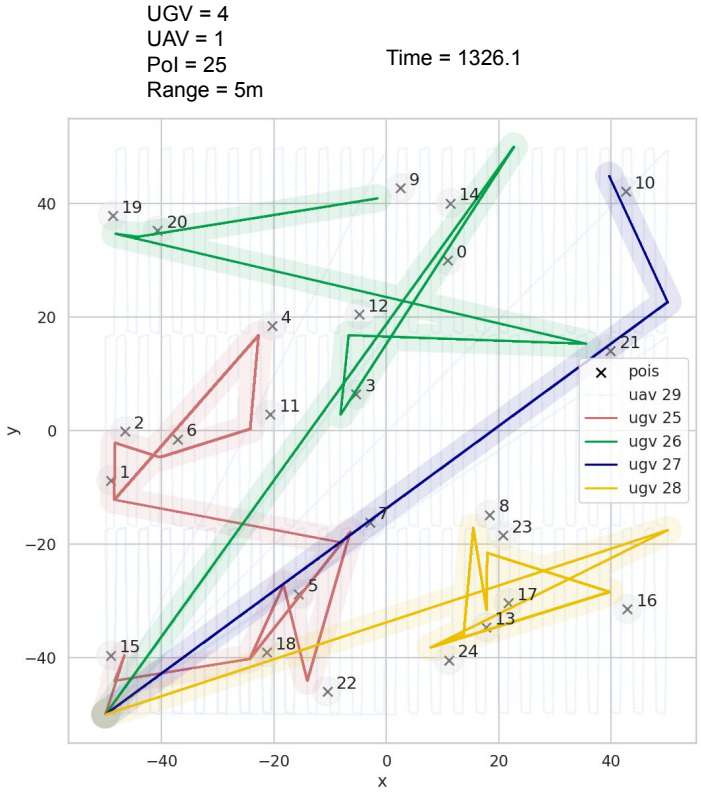
Greedy Algorithm (GA)

- POI
  - Acts as a beacon
- UAV
  - Uses a greedy algorithm to order the copy of *PoI Buffer* by proximity, based on the UAV's current position
- UGV
  - Receives the directions from the UAV
  - Communicates with POI



Load Balancing Algorithm (LBA)

- POI
  - Acts as a beacon
- UAV
  - UAV records which UGVs it has already sent to UGVs
  - The UAV will only send a direction from new POIs
- UGV
  - Receives the directions from the UAV
  - Communicates with POI

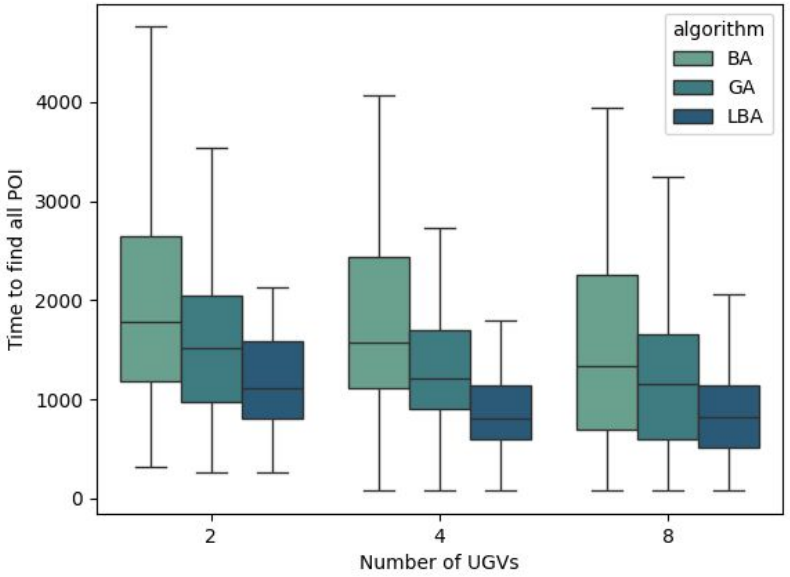


Simulation

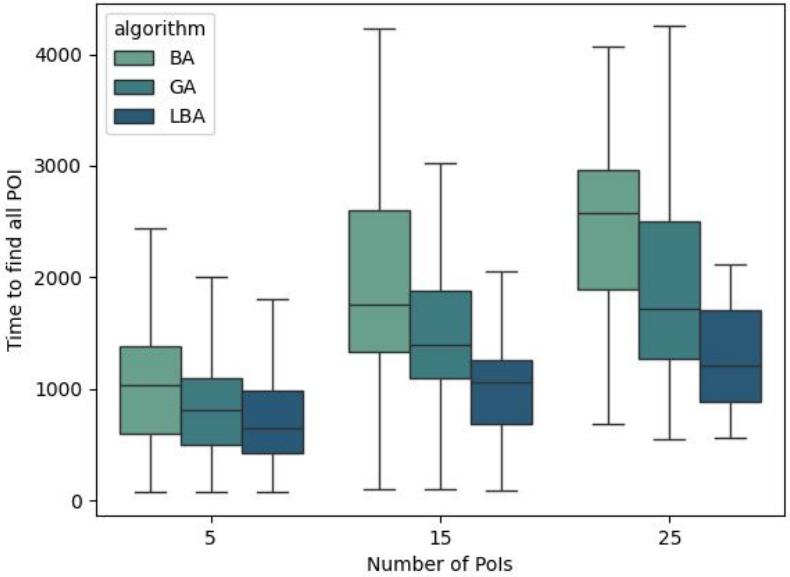
- Simulation Environment
  - GrADyS-SIM NextGen
- Simulations Parameters
  - Number of UGVs: 2, 4 and 8
  - Number of UAVs: 1 and 2
  - Communication Range: 5, 10 and 20 m
  - POI Density: 0.05, 0.15 and 0.25 points/m²
- 10 simulations for each combination of parameters
- Total simulations: 540
- Metric: time to find all PoI

Results

Number of UGVs vs Time to find all POI

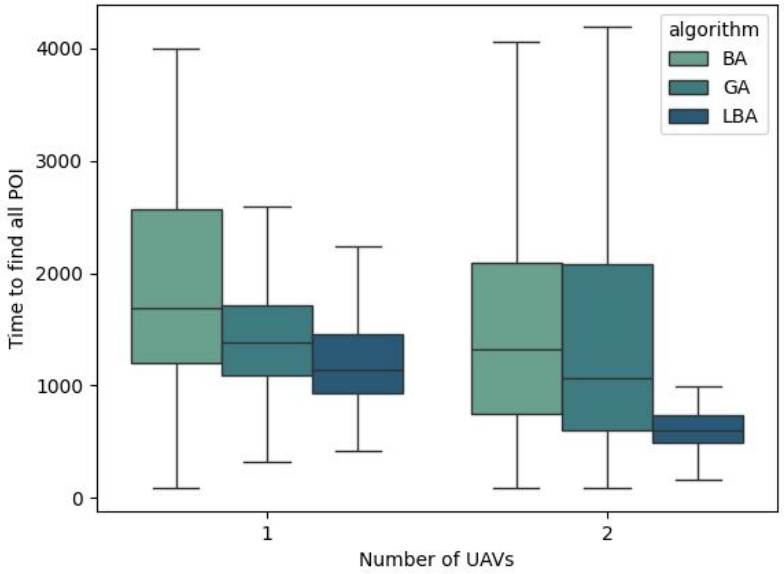


Number of POIs vs Time to find all POI

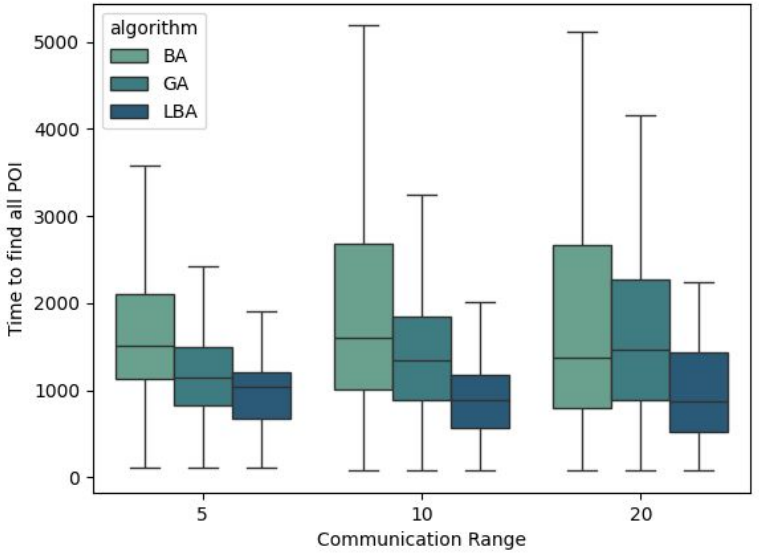


Results

Number of UAVs vs Time to find all POI



Communication Range vs Time to find all POI



Conclusions and Future Work

- The presented work focuses on an UAV-UGV coordination algorithm to find points of interest in an unknown area
- This approach can be used on SAR missions, where POIs are individuals in danger and UAVs search the area to locate them
- Future work
  - Effective collaboration between UAVs
  - Include new metrics (e.g. Energy Consumption)