Heterogeneity informatics of Multi-Agent Systems

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Many species in nature demonstrate symbiotic relationships leading to emergent behaviors through cooperation, which are sometimes beyond the scope of the partnerships within the same species. These symbiotic relationships are classified as **mutualism, commensalism and parasitism** based on the benefit levels involved. While these partnerships are ubiquitous in nature, it is imperative to understand their benefits in designing heterogeneous multi-agent systems. In this work, we validate our hypothesis on the benefits of heterogeneity through a search and rescue problem for different rescuer strategies and heterogeneous group compositions. The heterogeneity informatics obtained from our simulations showed a positive correlation between the heterogeneity measure and the collection speeds demonstrating benefits in most of the scenarios. However, we also found this effect reversing in some cases implying heterogeneity sometimes hampers the group's abilities.

Approach

Searchers

- Searchers, move around the configuration space looking for treasure.
- Searcher have long range and short-range treasure sensors.
- If multiple treasure points are located by the long-range treasure sensor, the searcher moves towards the one at the shortest distance.
- Once a treasure is detected by the long-range treasure sensor, searchers current location and an alert message are transmitted to neighbors.
- Once a treasure falls within the short-range treasure sensor , the robot stops.

Rescuers

- Rescuers behave like searchers.
- For our study we tried 3 different strategies.
- Strategy 1
  All sensors enabled
- Strategy 2
  Rescuers **cannot communicate** with other rescuers.
- Strategy 3
  Rescuers **cannot communicate** with other rescuers.
  And, **long-range** treasure detection sensors are **disabled**
- Once a treasure falls within the short-range treasure sensor , the rescuer stops and picks the treasure and moves it to the drop point

Experiments

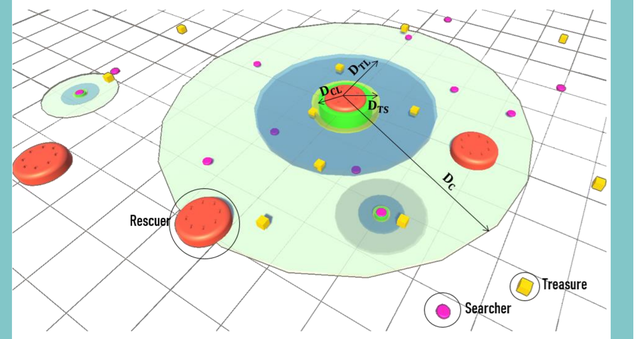

Fig 1: Configuration Space developed for the current simulations

Table 1: Simulation Hyperparameters

Scenario	Agent Combination
1	$n_r = 5:5:50$
2	$n_r = 25, n_s = 0:5:50$
3	$n_r + n_s = n_h = 50, n_s = 0:5:45$
Treasure Blocks	250
Collection Points	4
Rescuer Strategies	1,2,3
Trials	10
Trial Duration	300 s @ 0.02s/ Iteration (Frame)

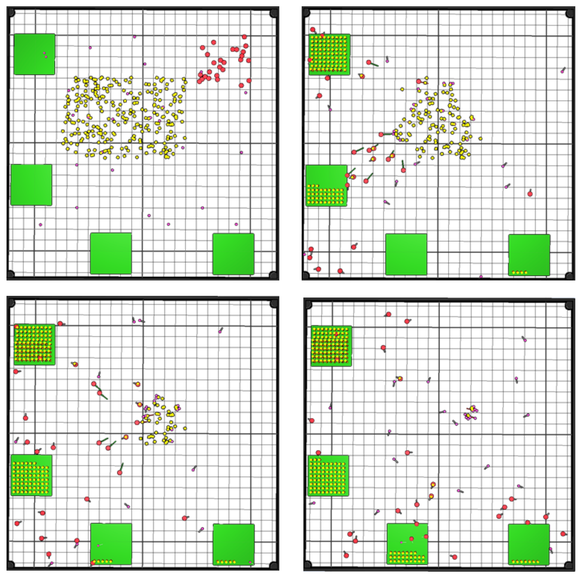

Fig 2: Snapshot of the simulations at different intervals (Strategy – 1, Scenario – 3)

Results

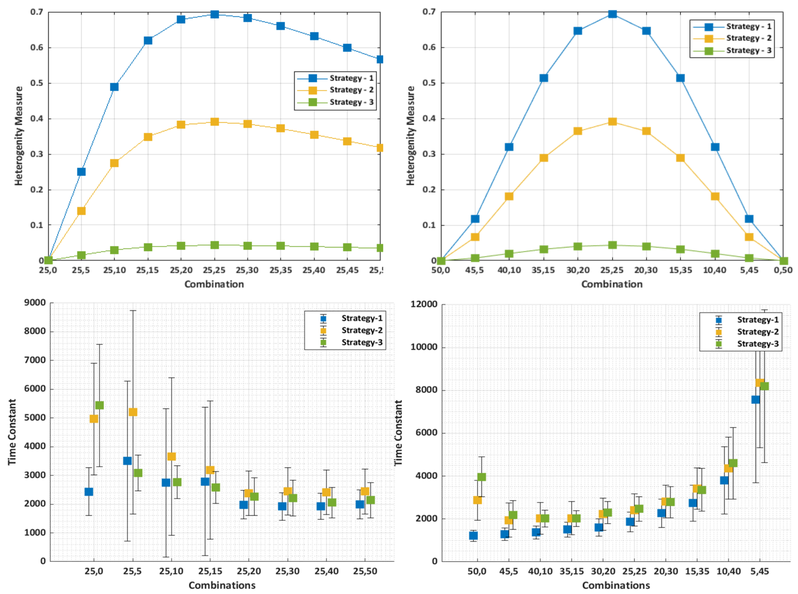

Fig 3: Heterogeneity Measure and Time constant graphs of the system for various agent combinations and strategies.

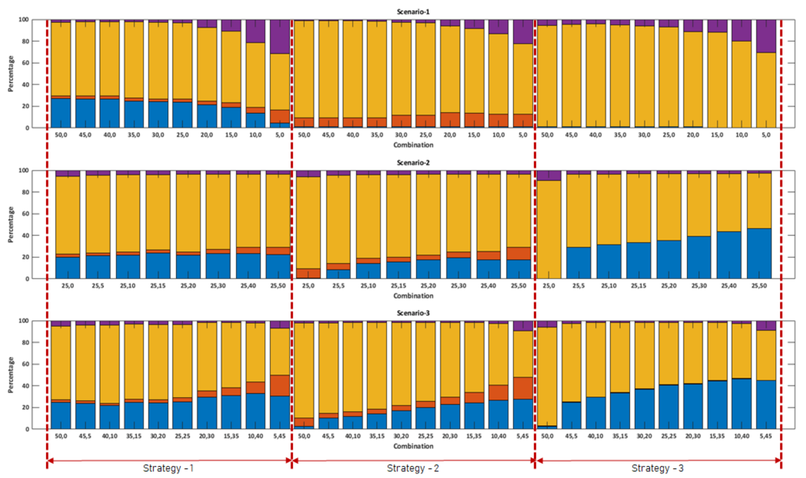

Fig 4: Dominant state percentage bars for different combinations across various strategies

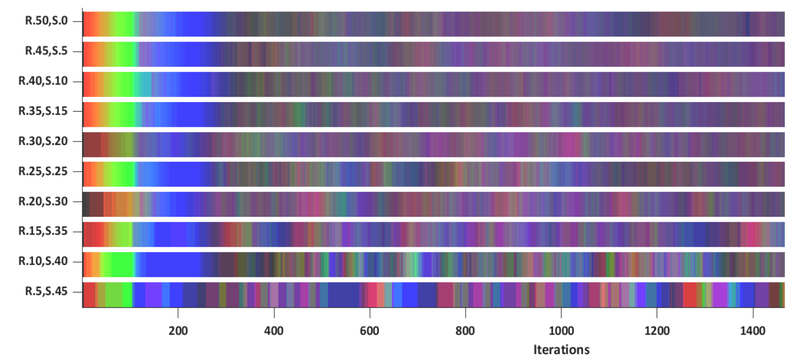

Fig 3: Aurora Graph showing the states of agents (**Signal Reception**, **Long Range Detection** , **Treasure Carry** and **Idle**) across iterations in strategy 1 and scenario 3.

[1] Brambilla, M.; Ferrante, E.; Birattari, M.; Dorigo, M. Swarm robotics: a review from the swarm engineering417perspective.Swarm Intelligence2013,7, 1–41.

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