CRH*: A Deadlock Free Framework for Scalable Prioritised Path Planning in Multi-Robot Systems

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Motivation

A critical blocking factor in Multi-robot system deployments in physical interference while sharing workspace (Erdman, 1987).
Among the existing multi-robot path planning approaches, decentralised and decoupled approaches scale well (Velagapudi, 2010).

Aim

Project aim was to develop a framework offering a scalable, and deadlock free implementation of prioritised planning with novel customisation options designed to improve performance.

Objectives

1. Implement scalable framework for dynamic priority assignment.
2. Implement novel customisation options.
3. Evaluate efficacy of novel customisation options.
4. Evaluate the scalability of solution with optimal set of customisation options.

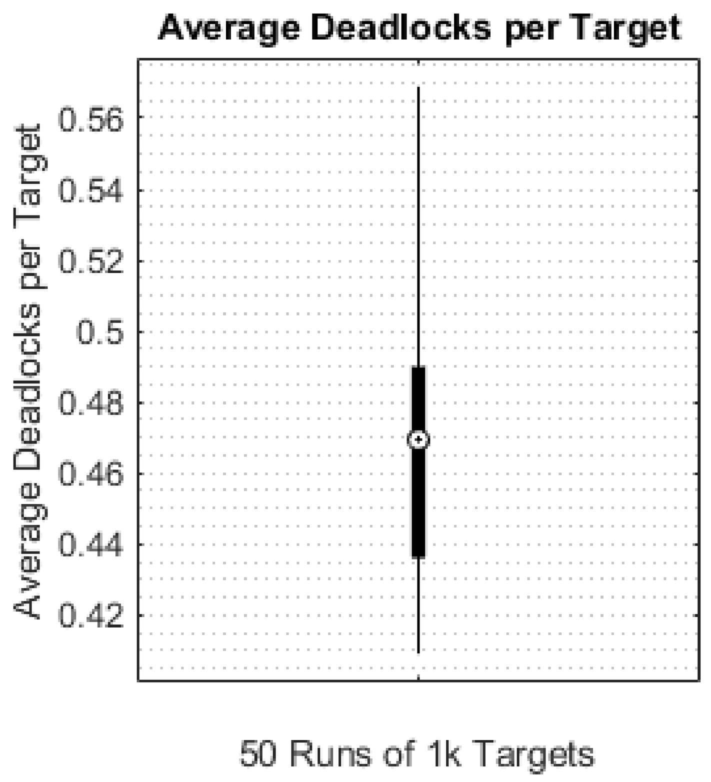
Conflict Resolution Heuristic (CRH*)

- Path Planning adapted from Extended version of A*
- Makes use of time-based reservations of edges in topological map overlay.
- Reservations made by calculating CRH scores generated from prioritisation schema.
- Reservations taken over if CRH score is beaten.
- Beaten reservations cause agent replanning.
- Best of 3 replan methods used: replan from start, replan from conflict, and replan with delay.

Heuristics

Implementation included 6 heuristics:
- Euclidian Distance (VanDenBerg, 2005)
- Optimal Route Length: length of optimal path
- Planning Time (Velagapudi, 2010): processing time to identify optimal route
- Agent ID (Erdmann, 1987): order added to network
- Random
- No Replanning: every CRH score returns 0

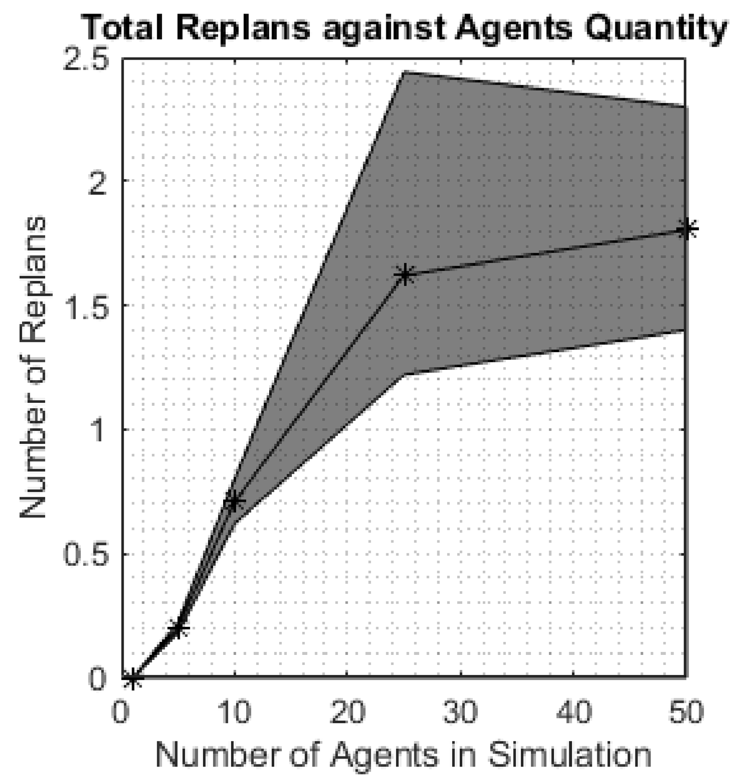
Deadlocks



- Implementation uses FAILED flag for unattainable edges.
- When deadlocked, a delay is added to the most promising FAILED edge.
- Edges which make it to the final route having gone through this are totalled.

The distribution shows deadlocks are occurring and being successfully managed.

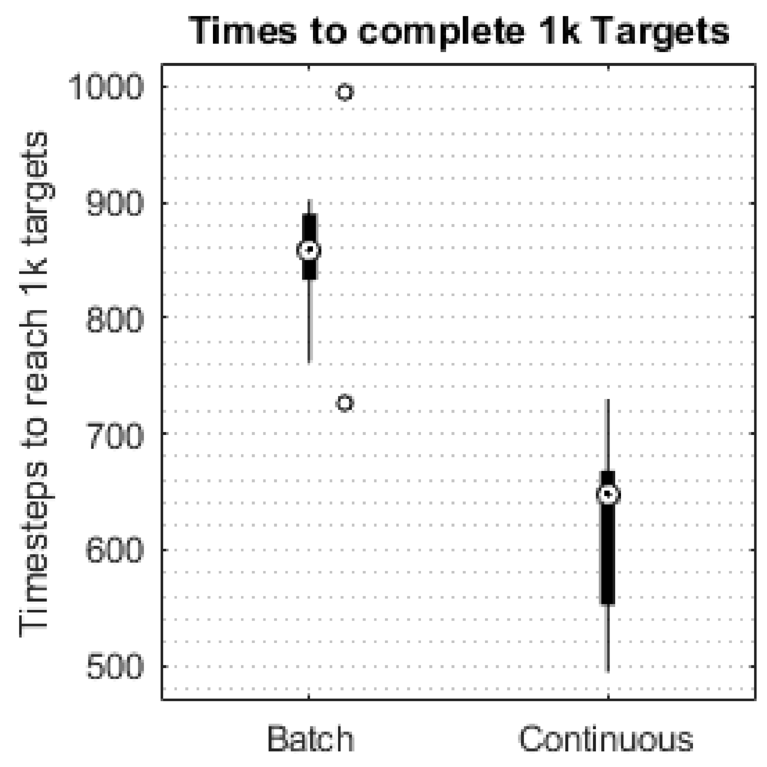
Scalability



- Deployed in distributed manner
- Measured by monitoring communications
- Replans trigger the only permissive communications
- Thus they are an accurate measure of the scalability.

Results show good trend, replan count flattens as agents increase.

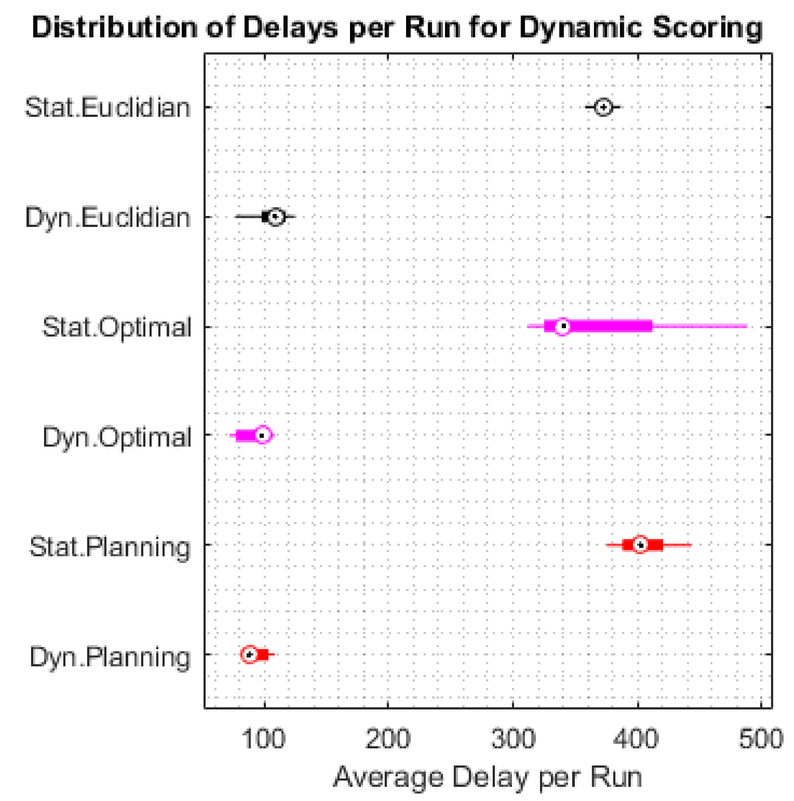
Continuous Assignment



- Continuous assignment removes idle space between agents reaching their target and a new target being assigned.
- Targets can be completed more frequently.

Results show continuous assignments taking less time then batch assignment to complete 1k total routes.

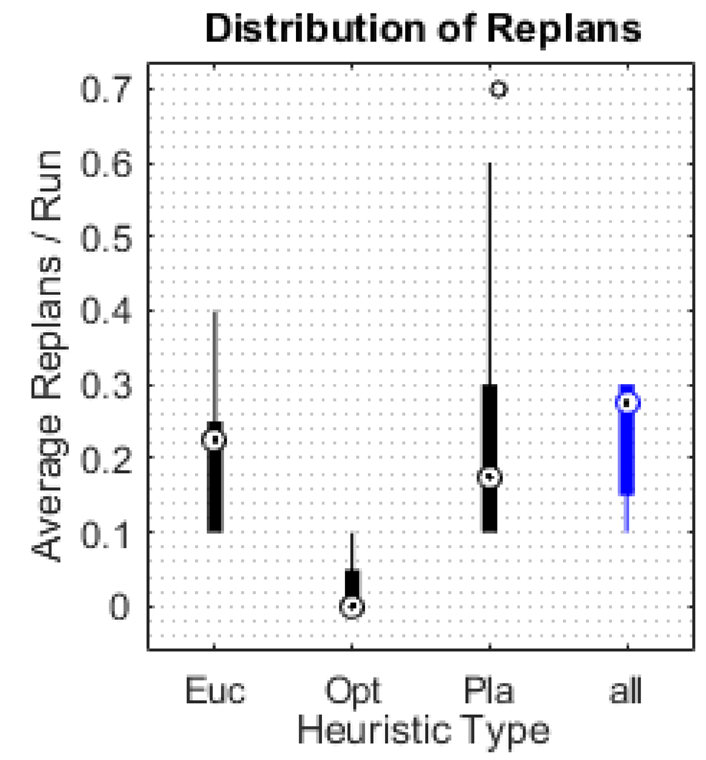
Dynamic Scoring



- Static scoring, all edges would be reserved by the same initial score.
- Dynamic scoring, calculates a new score for each edge.
- Each reservation uses score generated with no historical reference of the agents location.

Results show dynamic planning schemas are efective, evident by smaller delay per run.

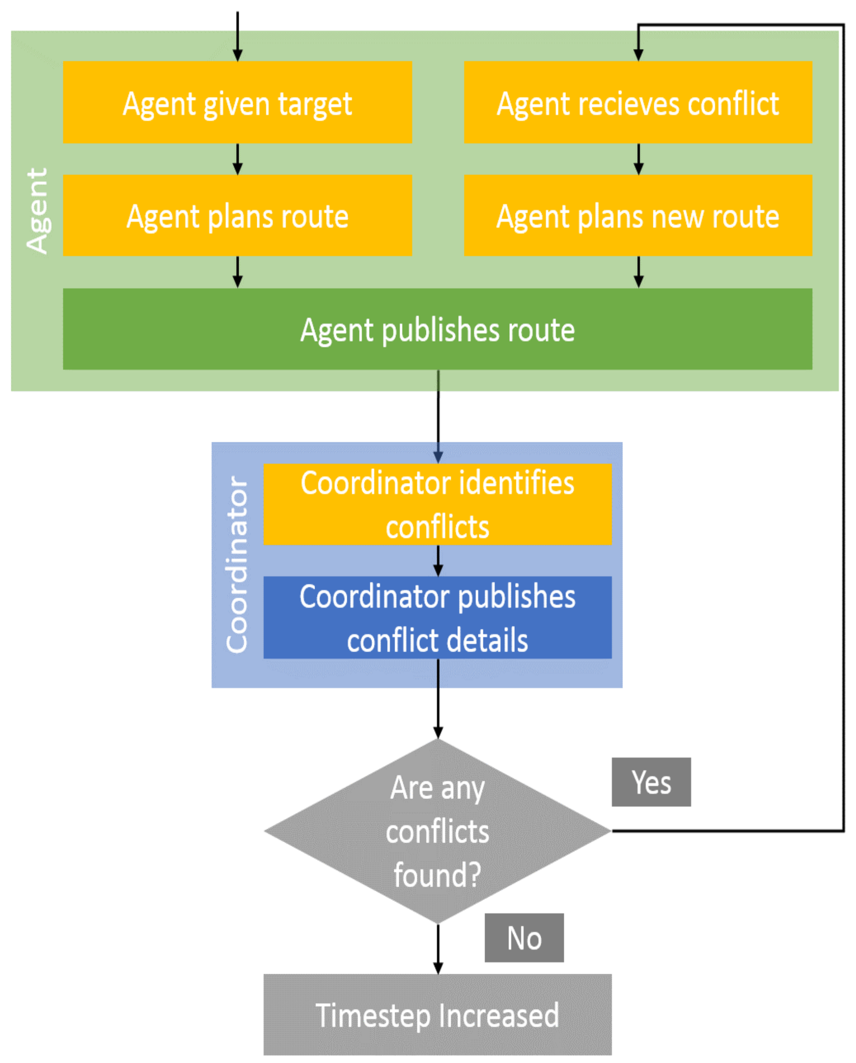
Combinatorial Heuristics



- Work to restrict outliers by using the collective opinion from multiple heuristics.
- Schema in which agents are awarded a priority respective to the consistency of the importance.

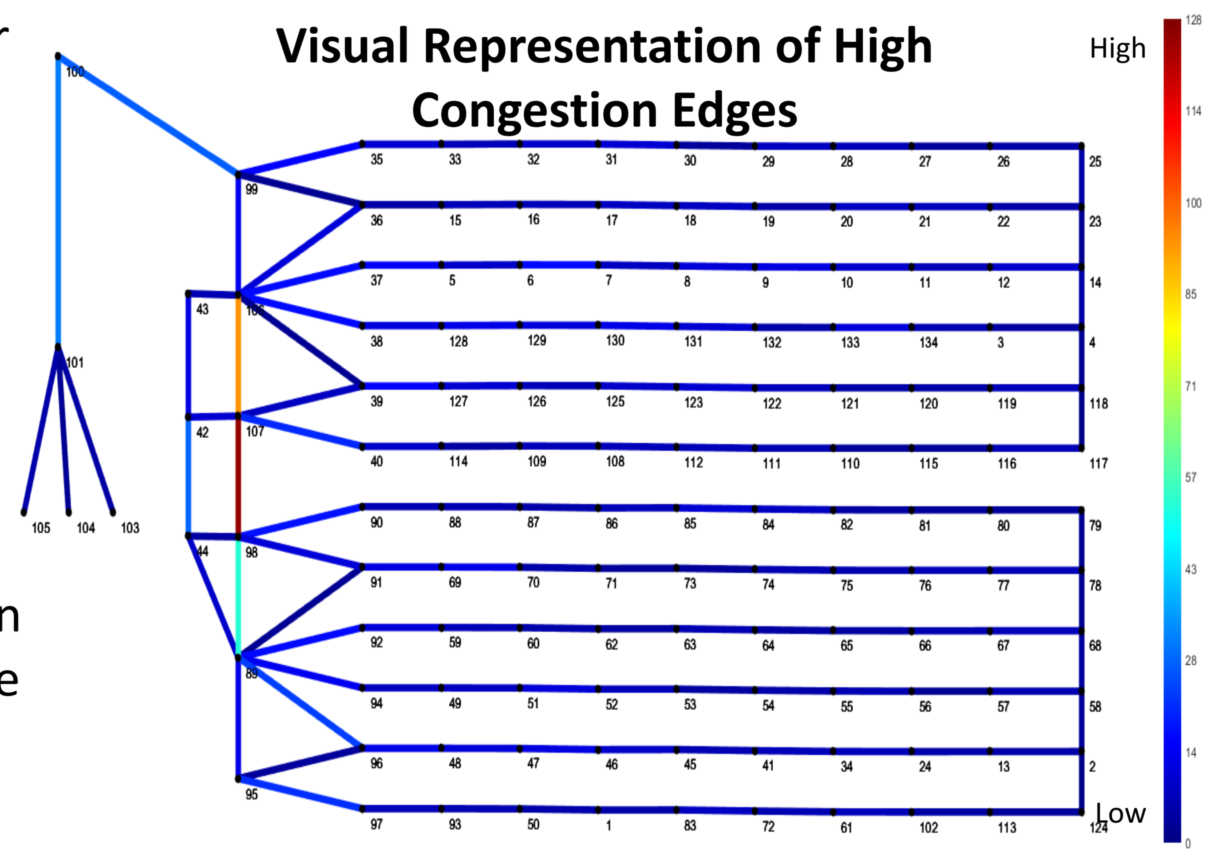
Results show combined heuristic has smaller maximum value than independent heuristics thus it is effective in restricting assignments.

Implementation Structure



Region Analysis

- Coordinator increments edge counter when conflicts identified.
- Counters displayed on scale of blue (low) to red (high).



Results show a collection of three edges on the left, are the only significant source of conflict. Having 128, 90 and 50 conflicts.

Conclusions

- Implementation succeeded in being scalable and deadlock free.
- There is still room for further developments within prioritised planning.

Further Work

- Test solution with more complex simulations.
- Implement node capacity limits.
- Evaluate further, context-dependent heuristics.

References

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