Multi-Robot Motion Planning

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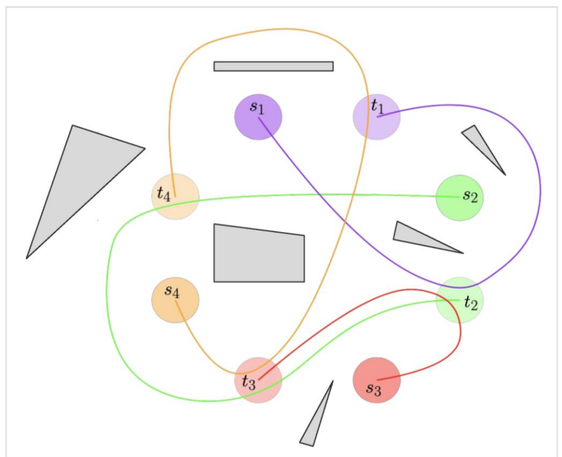
Objective

P: Polygonal environment

$R_1, R_2, \ldots, R_m$: *m* robots represented as unit discs

Properties of each robot:

- s_i: starting position of R_i
- f_i: final position of R_i
- Revolving area of radius 2

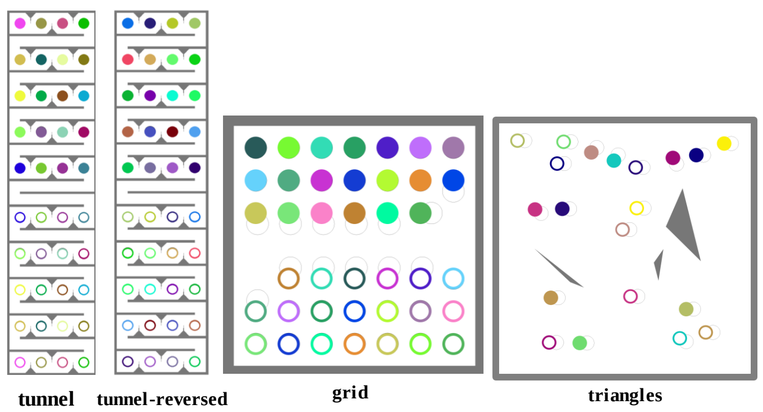


Goal: Find a collision-free path for each robot that minimizes the total distance traveled.

Overall Approach

1. Find the **shortest path** between start and target positions ignoring other robots. Code is provided by the Halperin et al. codebase.
2. Choose the **order** that robots R_i are moved.
3. **Retract** the position of R_j if it conflicts with R_i's path

Testing Environments



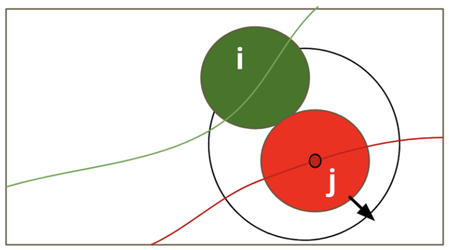
Algorithms

Quicksort order heuristic:

- **Randomly select** a robot. Then **compare** all other robots to the selected to determine which should move first.
- **Repeat** process for every random robot pair to get the final order.

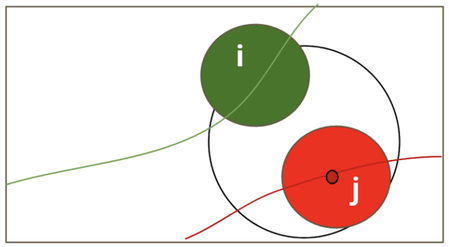
Retraction method:

- Robots take advantage of their revolving area to move out of the way of other robots.



*Retraction needed (**i** will collide with **j**)*

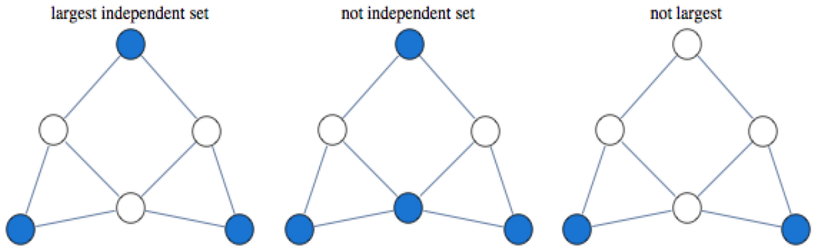
move j out of way



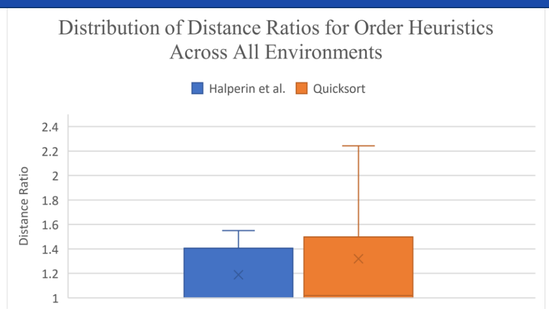
i** can now move safely without collision with **j

Heuristic for computing parallel robot groups:

- **Construct a graph** on $R_1, R_2, \ldots, R_m$, where (R_i, R_j) is an edge if their paths collide.
- Find large **independent set** (IS) in *G*, then remove IS to form new *G*.
- Find the IS of the new *G*. **Repeat** until *G* is empty.
- Each IS represents a parallel group.



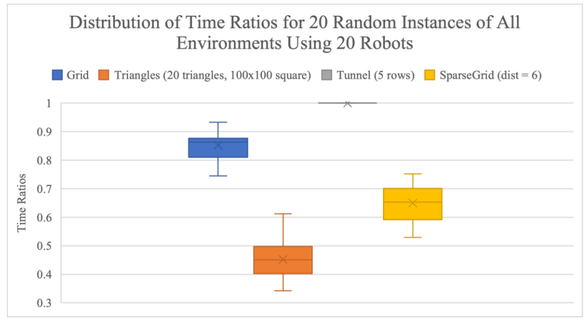
Results



- Quicksort heuristic has a **higher distance ratio** on average and range up to ~2.4, while Halperin et al. is concentrated around 1-1.5.

Halperin et al.'s retraction method has a **larger range** and **larger distance ratios** in more environments.

- 100% of the data from Agarwal et al. falls within the bottom 75% of Halperin et al.'s data.



- In all settings except for Tunnel, the **time ratio < 1.**
- Grid's median is 0.86 while Triangle's median is 0.45.

Conclusion

- Implemented a heuristic for computing order, an improved retraction method, and a **new approach** for **parallel motion**.
- There is lots of room for research in parallel motion that will **improve** the current **heuristic**.

References

[1] Israela Solomon and Dan Halperin. Motion planning for multiple unit-ball robots in $\mathbb{R}^d$. In *WAFR*, pages 799–816, 2018.

[2] Erin Taylor and Pankaj Agarwal. Multi-Robot Motion Planning for Unit Discs with Revolving Areas. *(Unpublished)*