FY24 Strategic University Research Partnership (SURP)

Communication-Adaptive Navigation for Autonomous Multi-Robot Systems

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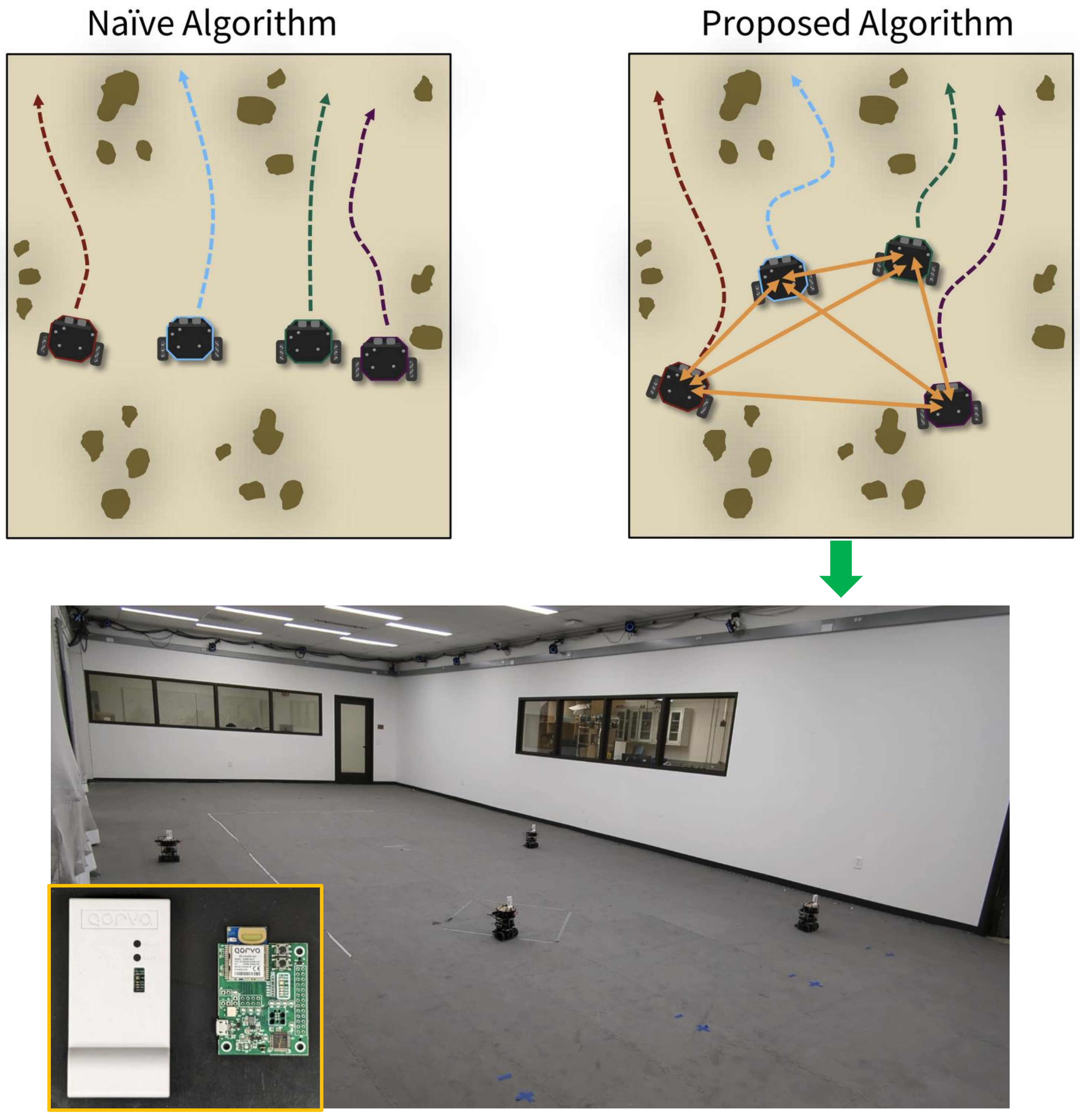
Objective

- *Create a multi-robot collaborative navigation algorithm that allows agents to navigate towards exploration goals while maintaining low position uncertainty and remaining collision free. Highlights:*
  - Reduction of uncertainty by planning with dilution of precision cost
  - Implementation of the capabilities and validating through hardware experiments, including test and deployment of ultrawide-band ranging radios for inter-rover, line-of-sight, measurements.

Background

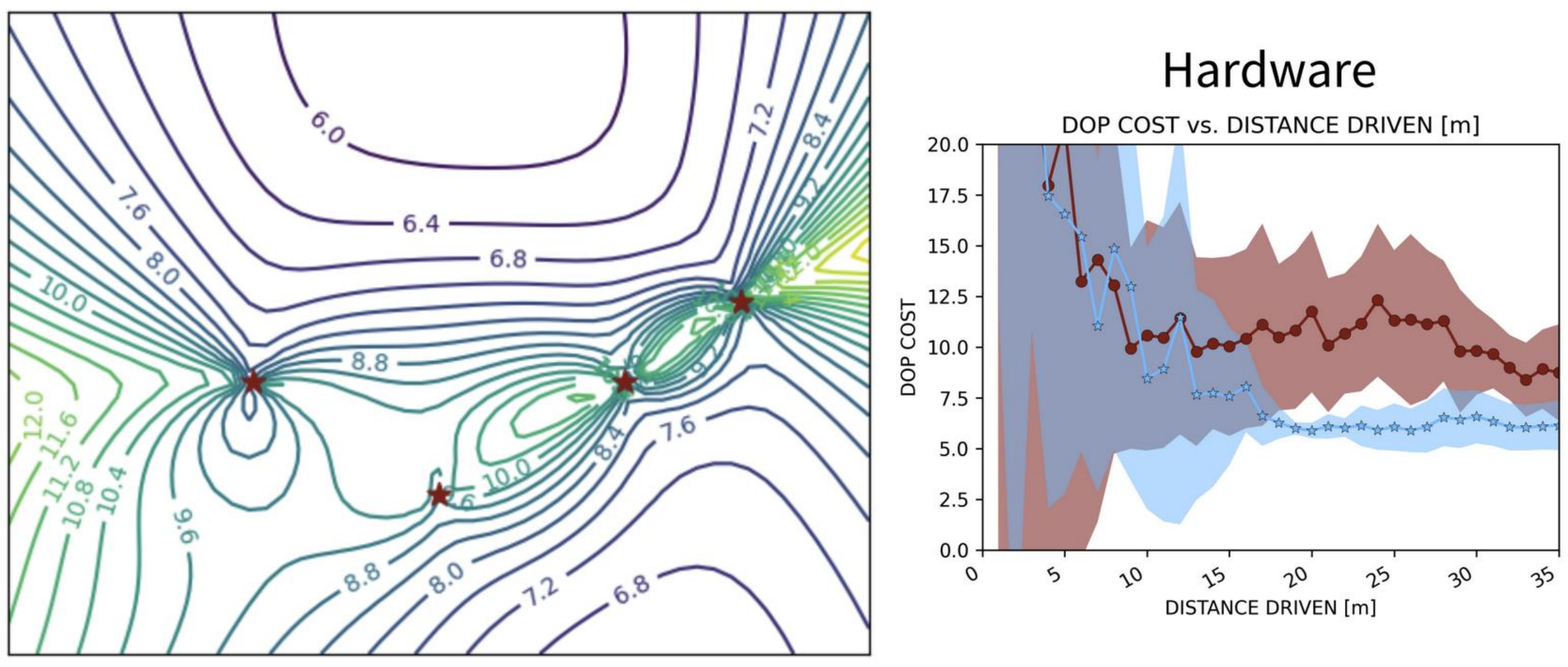
- Position uncertainty can increase while using vision-based navigation when there are rapid changes in lighting, sudden movements, or few visual features in the field of view.
- To take advantage of a multi-robot system, path planning and navigation algorithms must be carefully designed to increase exploration coverage while minimizing positioning and map uncertainty as best as possible.



Hardware demonstration of the algorithm with on-board sensing

Approach and Results

- **Leveraging relative ranging geometry multi-robot coordination:** The cost function for the multi-robot coordination has three (3) key costs:
  - Cost to goal as a function of the team's physical distance to the goal
  - Cost for collisions as a function of the proximity between robots
  - Cost for the dilution of precision (DOP) as a function of the line of sight between robots (key for the ultrawide-band ranging radios).
- The robots minimize a weighted sum of these costs to decide on a direction to move towards, and thus improve localization.



Visualization of cost function, and performance of algorithm

Software: ***https://github.com/Stanford-NavLab/navlab_turtlebot***

- **Hardware experiments validated algorithms:** The implemented algorithms were validated on JPL TurtleBot's built and upgraded by Stanford's NAVLab for experiments.
  - At the start of the experiments, the rovers are in non-ideal geometries by travelling in a line formation, which occludes some of the inter-rover measurements.
  - Their intermediate configuration shown on the left is an adjustment by the algorithm to achieve a more favorable configuration for sensing before reaching the final goal locations.

Significance/Benefits to JPL and NASA

- Significant improvement to motion planning for multiple rovers when operating with limited on-board information and communication.
- Applicable to any future multi-agent mission, such as a multi-static ground penetrating radar system, whenever position accuracy is critical.

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Publications:

Derek Knowles, **Leveraging Relative Ranging Geometry for Fault Detection and Multi-Robot Coordination**, *Ph.D. Dissertation,* 2024.

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