National Aeronautics and Space Administration

FY23 Strategic University Research Partnership (SURP)

Communication-Adaptive Navigation for Autonomous Multi-Robot Systems

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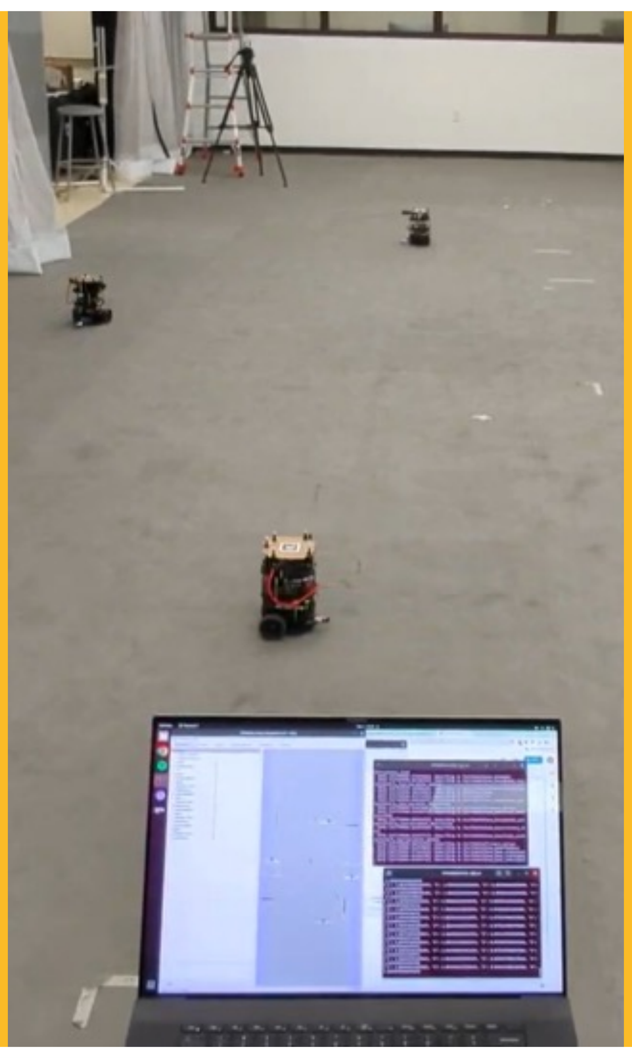
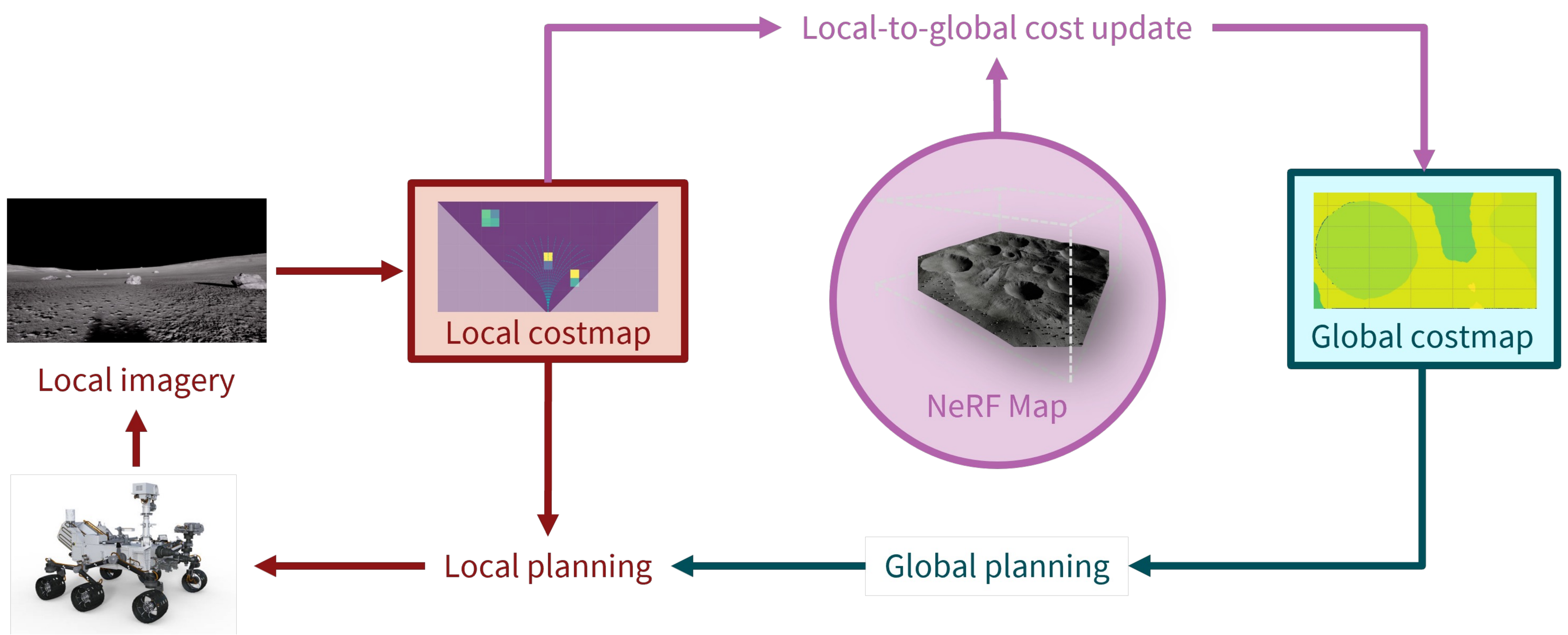


Objective

- *Create a multi-robot collaborative navigation algorithm that allows agents to navigate towards exploration goals while maintaining low position uncertainty and remaining collision free. FY23 focused on:*
  - Accounting for intent or faults of other rovers on the team in adapting motion plans using zonotope sets that allow for trading between probability in collisions and maximizing exploration.
  - Apply local costmaps to global costmaps using a (orbital) NeRF map for improving on-board path and motion planning.

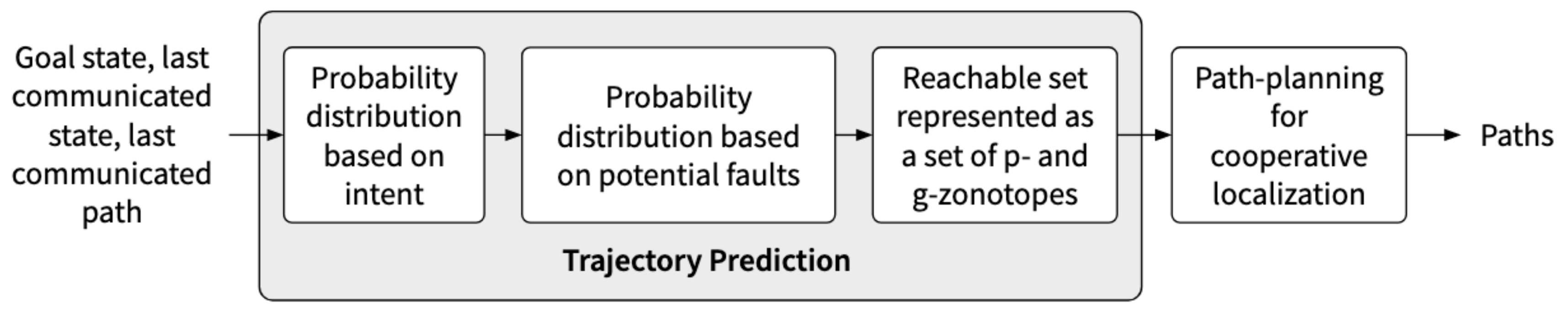


Background

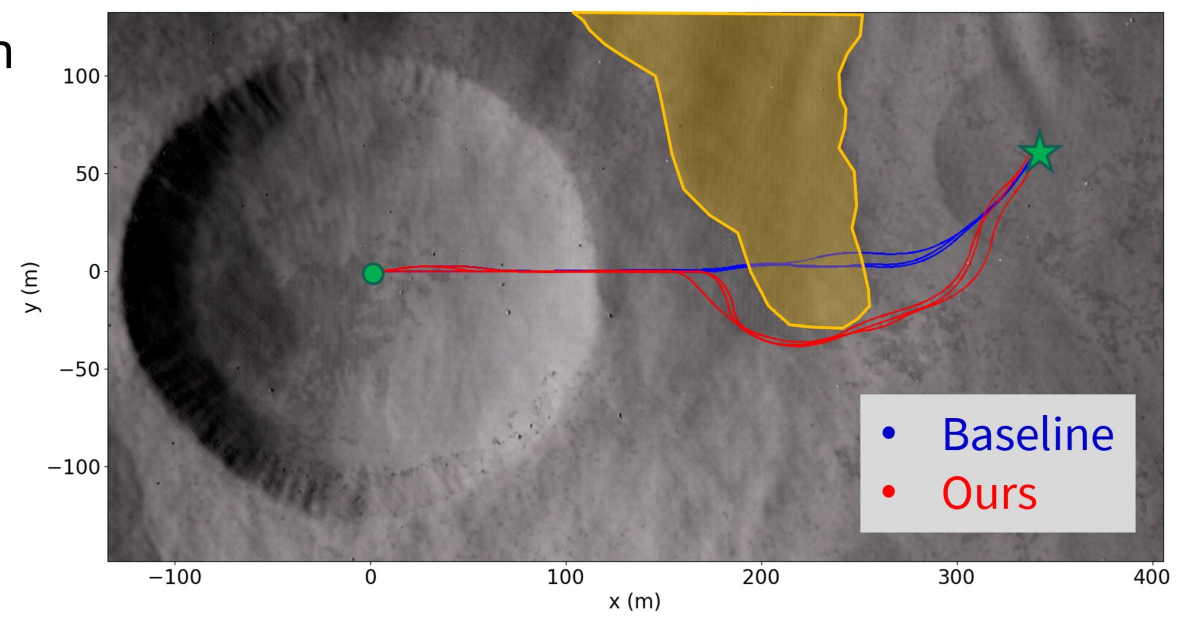
- Position uncertainty can increase while using vision-based navigation when there are rapid changes in lighting, sudden movements, or few visual features in the field of view.
- To take advantage of a multi-robot system, path planning and navigation algorithms must be carefully designed to increase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

Approach and Results

- **Mitigating plan conflicts due to communication loss:** Obstacles discovered by rovers, but during communication disruptions, may cause two rovers to plan colliding paths. Varying the weights of the intent-based zonotope and fault-based zonotope set allows the user to tradeoff the probability of collision with the ability for the rovers to maximize exploration.



- **Matching local features to global features to improve local planning:** For online motion planning, local imagery is captured from a rover's on-board cameras. Next, the local imagery is used to construct a local costmap using depth information. The local costmap values are then propagated to the global costmap using the NeRF map to segment similar areas where the local cost values should apply to the global costmap. Finally, the global and local maps are then used in combination for improved waypoint selection and local motion planning.



Significance/Benefits to JPL and NASA

- Significant improvement to motion planning for multiple rovers when operating with limited on-board information.
- Applicable to any future multi-agent missions, such as CADRE or Mars Sample Return Helicopters, whenever position accuracy is critical.

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Publications:

Isabella Torres and Grace Gao, "**Intent- and Fault-based Trajectory Prediction for Cooperative Localization and Collision Avoidance in Swarms**," Proceedings of the Institute of Navigation GNSS+ conference (ION GNSS+ 2023), Denver, CO, Sep 2023.

Adam Dai, Shubh Gupta, and Grace Gao, "**Neural Radiance Maps for Extraterrestrial Navigation and Path Planning**," Proceedings of the Institute of Navigation GNSS+ conference (ION GNSS+ 2023), Denver, CO, Sep 2023.

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