

UNCERTAINTY-AWARE AND SEMANTICS-COGNIZANT SAFE EXPLORATION OF UNKNOWN ENVIRONMENTS

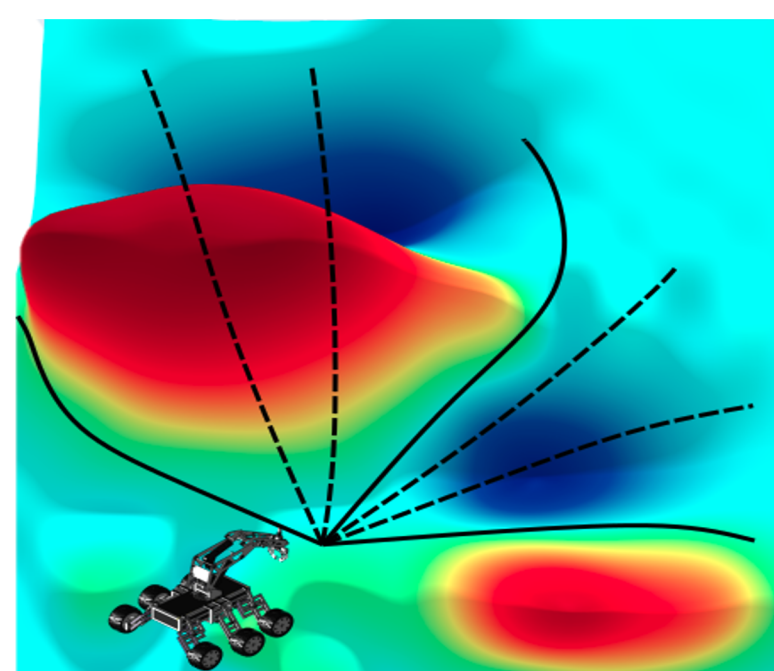
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Program: FY21 SURP

Strategic Focus Area: Localization and Mobility

Objectives

- Develop situational awareness algorithms that **encode the uncertainty and semantics** of the environments
- Develop **perception-aware decision making methods** for safe exploration of unknown environments



Background

Key capabilities needed for lunar concept missions based on Design Reference Mission (DRM), Decadal Survey, and Lunar Surface Innovation Initiative (LSII):

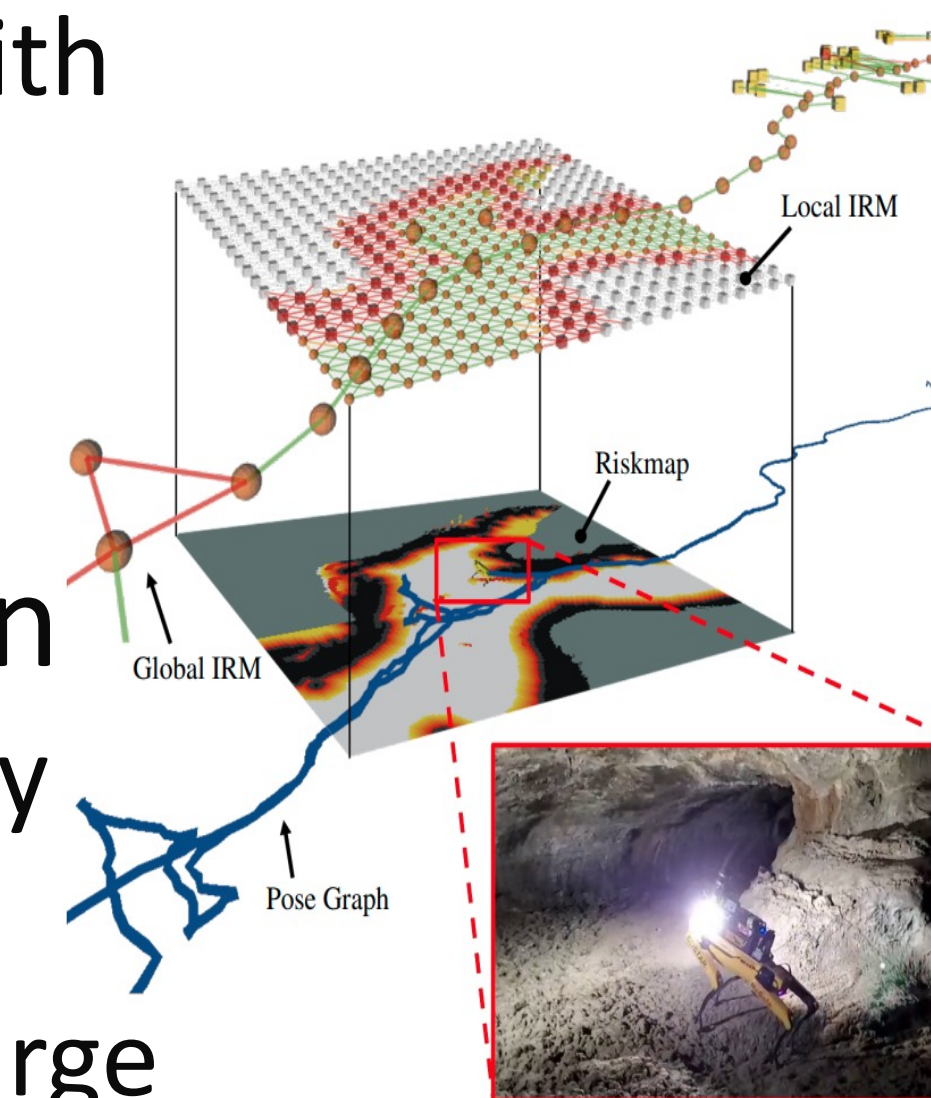
- Long traverse and wide-area sampling
 - For volatile and magnetic field mapping (long-duration and high speed)
- Exploration into comm-denied areas (into lunar pits/skylights/tubes)
 - Wide-area / multi-site sampling in the Marius Hills volcanic crater region



Approach

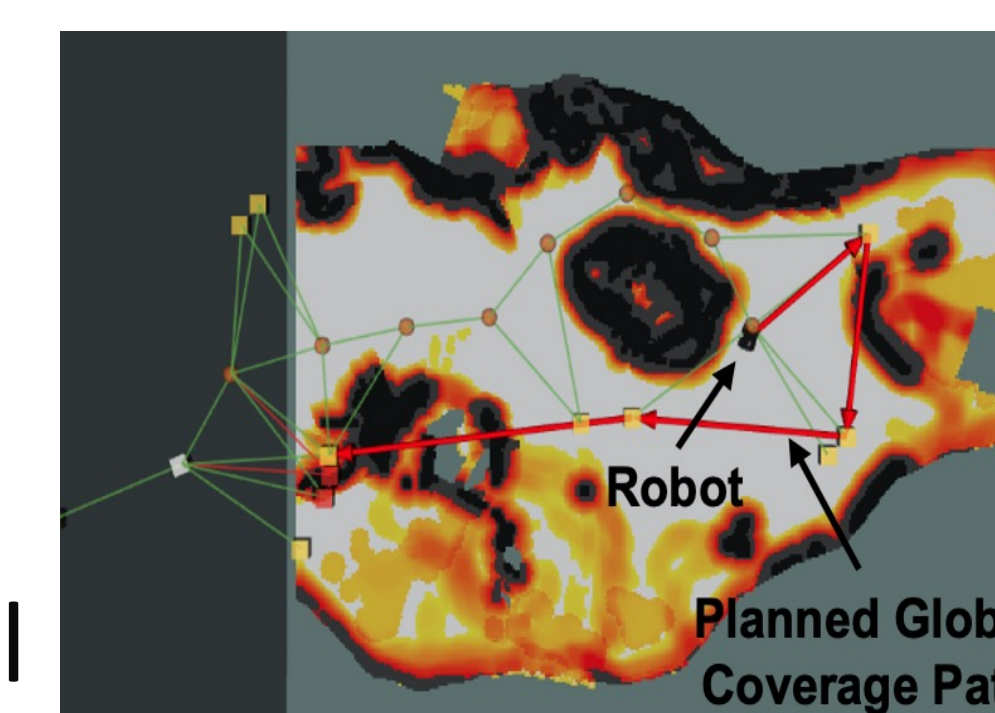
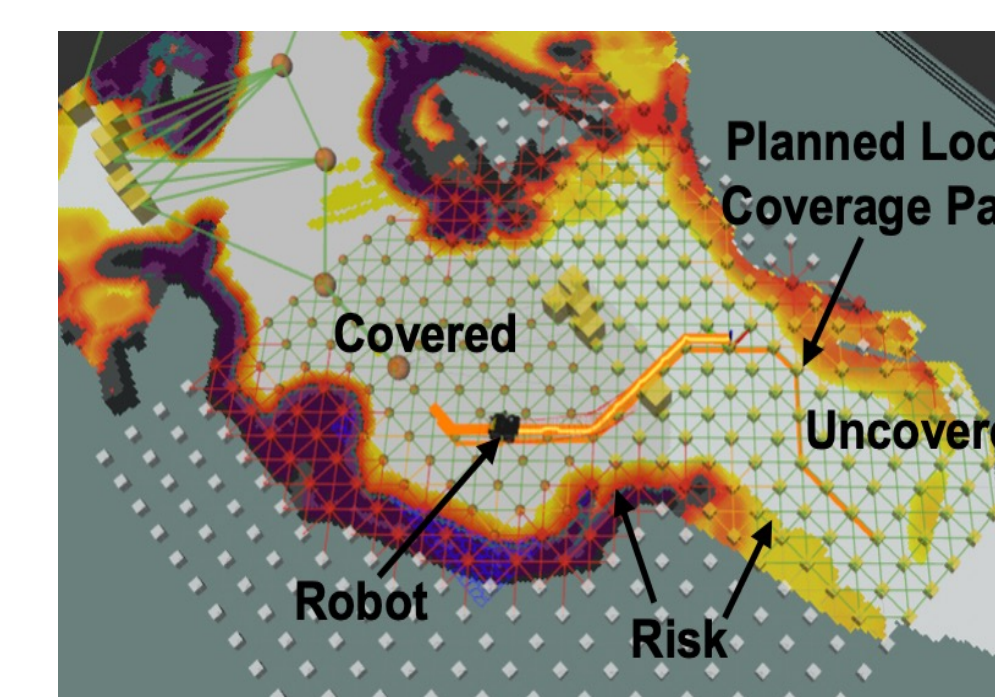
Uncertainty and Semantics Representation

- Information RoadMap (IRM)
 - Generic graph representation with **probabilistic** attributes
 - Encodes **semantics**, including traversability and spaciousness
- **Hierarchical** decomposition
 - Local IRM to capture high-fidelity semantic information
 - Global IRM to scale up to very large environments (~kms)

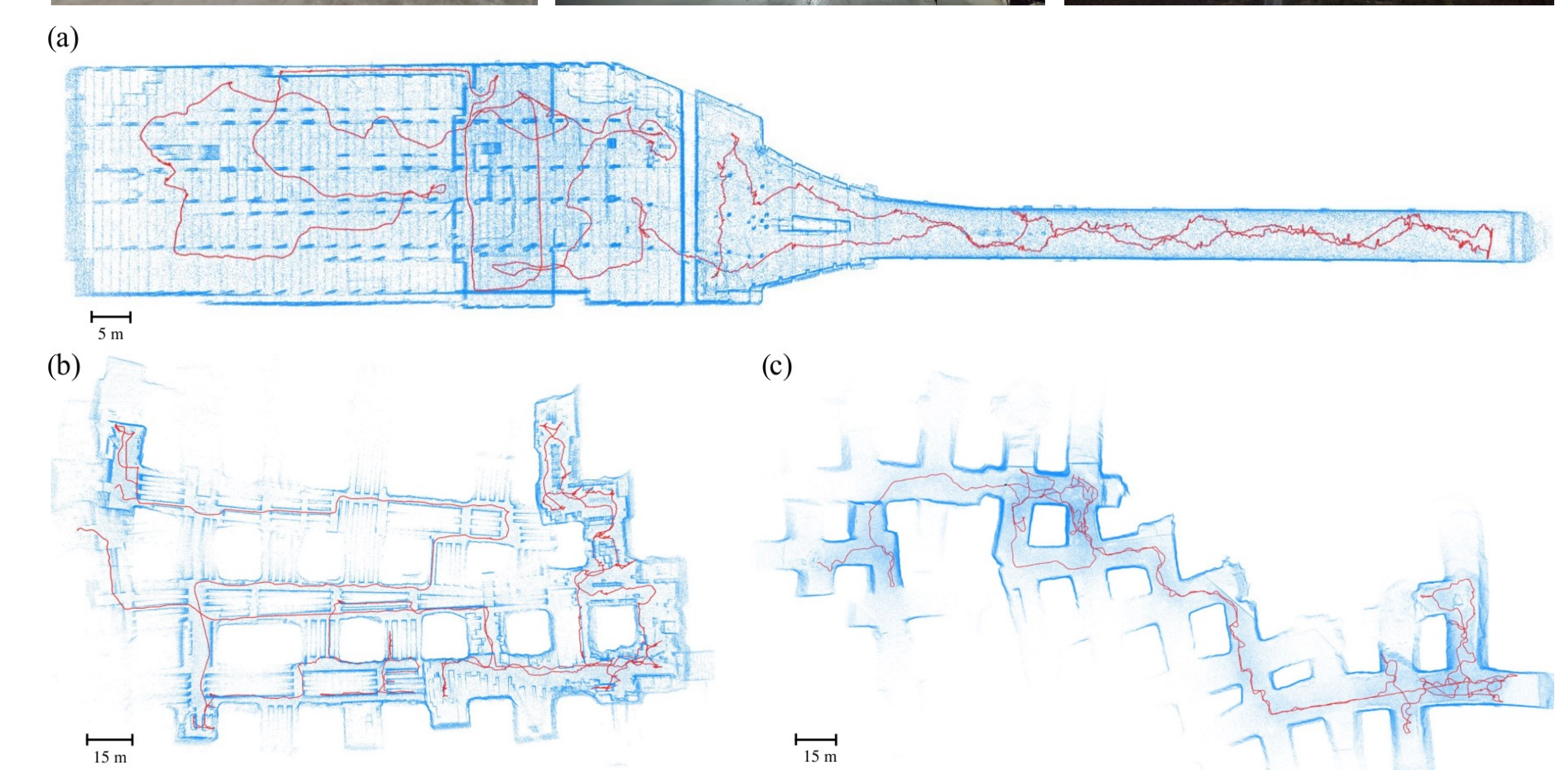


Semantics-Cognizant Planning under Uncertainty

- Local Coverage Planner
 - Multi-heuristic dynamic programming solver
 - Finds a path on Local IRM that maximizes the info gain based on semantics
- Global Coverage Planner
 - Orienteering solver
 - Find the best sequence of frontier nodes to visit on Global IRM



Results



- Successfully demonstrated the semantic-cognizant exploration of large unknown environment with physical robots
 - Underground of LA Subway Station (a) (Narrow and cluttered with complex topology)
 - Kentucky Underground Storage (b) and Mine (c) (Huge, wide open spaces with muddy terrains)

Significance/Benefits

- Semantics-aware safe exploration capability
 - Scalable representation of uncertainty and semantics
 - Real-time multi-resolution planning under uncertainty
 - Hardware validation both in large and narrow spaces
- Publications
 - Kim, et al., "PLGRIM: Hierarchical value learning for large-scale exploration in unknown environments," ICAPS, pp. 652-662, 2021.