Adaptive Informative Planning for Mobile Robots with Deployable Sensors

P. Michael Furlong, Michael Dille, Uland Wong, Terry Fong
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Risk Constraints Planetary Robots

- Planetary missions have a risk posture which curtails directions for exploration.
- Scientific value is **inversely proportional** to terrain safety.
- But we don’t know what the terrain is like until we get there!
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Conflicting Priorities:
Killing the robot is bad! vs Learning is good!

Image source: Robotic Systems Lab
Can We Sample Without Sending the Robot?

- Yes! Small, remotely deployed daughtercraft containing sensors

- E.g., NASA Ames (Michael Dille and Uland Wong) has developed PHALANX, a deployable sensor system for mobile robots

PHALANX - A Brief Overview

- Extends robot sensing reach
- Small sensor packages
  - < 250g, < 75mm diam
- Different sensor types
  - Heterogeneous, mission-specific tailoring
- Payload of 25-50 sensors
- Mortar delivery system
  - 10-100m deployment range
But....how do you choose?

Need to play off the best deployment of sensors against your expectation of what the world looks like.

- Simulate risk and observations from precursor (e.g. pre-mission) data.
- React *in situ* as needed.
Concept of Operations - Collect Precursor Data

Science Utility

Safety
Concept of Operations - Identify Valuable Samples
Concept of Operations - Plan a Tour
Concept of Operations - Plan a Tour
How do we make good decisions?

Make the best decision now

Assuming we behave optimally later
How do we make good decisions?

Make the best decision now

Given average return over future deployments with sampled future terrain safety.
Simulation for Algorithm Comparison

- 100 Locations
- Probability of hazard ~ Uniform(0,1)
- 12 Classes of objects (science targets)
  - Modelling underlying distribution(s)
- Baselines:
  - Random: Sample unsafe locations on coin flip
  - Greedy: Sample unsafe locations as encountered
Performance - Uniform Abundance

Mutual Information (bits)

Max Projectiles

Class Abundance - Uniform

Abundance
Performance - Exponential Abundance

mutual information (bits) vs Max Projectiles

Class Abundance - Exponential Distribution
Performance - Dominating Class

[Graphs and plots shown]

- Mutual Information (bits) vs Max Projectiles
- Class Abundance vs Class number

Legend:
- vs Rand
- vs Greedy
Conclusions

1. As good or better for tested scenarios
2. Useful formalism for decision-making/mission-planning
3. Room for improvement
   a. Future estimated value implementation is naive
   b. On-line updating of safety estimate
Contact: michael.furlong@us.kbr.com
michael.dille@nasa.gov