Risk-Sensitive Learning and Decision-Making for Autonomous Space Robots

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- **Co-I: Sergey Levine, UC Berkeley**
- Graduate students:
  - Stanford: 1 full-time, 2 part-time
  - UC Berkeley: 1 part-time

Team strength: team of experts on decision-making under uncertainty, machine learning for control, optimal control theory, and space robotics.

Approach

- Adopt a Bayesian framework to online learning to express prior knowledge about the environment and system dynamics and adapt to new data.
- Develop probabilistic dynamics models rooted in deep and meta learning that can capture "known unknowns" and "unknown unknowns."
- Leverage such probabilistic dynamics models along with techniques from Bayes-adaptive planning, risk theory, computational game theory, and reinforcement learning to generate risk-sensitive control actions online.
- Validate on space manipulation and navigation applications (Figs. 1 and 2).

TRL: from TRL 1.5 at the start of the investigation to TRL 3 at the end of the investigation.

Research Objectives

Goal: Develop and demonstrate a risk-sensitive framework for learning and decision-making that allows intelligent physical systems (IPS) to operate in unknown and uncertain environments without continuous control or supervision.

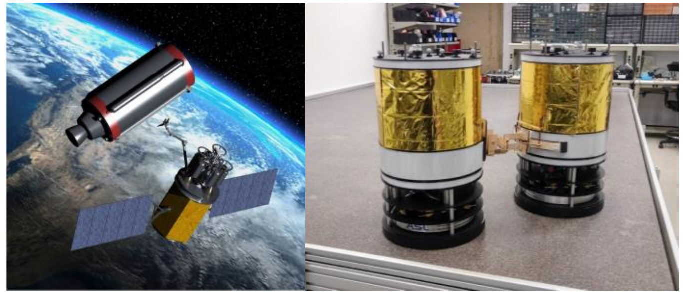

Figure 1 – (Left) Application to free-flying robotic spacecraft grasping and manipulating partially uncharacterized non-cooperative objects, (Right) Stanford Spacecraft Robotics Facility, one of the test beds that will be used in this investigation.

Technical objectives:

1. Design probabilistic dynamics models that can rapidly adapt to incorporate data gathered online.
2. Devise learning and decision-making algorithms that generate risk-sensitive control actions in a scalable manner.
3. Validate this framework on two key IPS scenarios of interest to NASA: 1) spacecraft manipulators and 2) rover navigation.

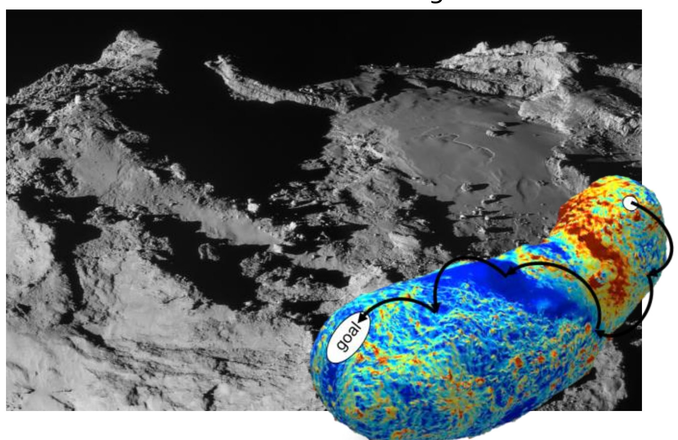

Figure 2 – (Left) Example of complex and uncertain terrain that may need to be traversed by an autonomous rover, (Right) Application to wheeled or hopping rover autonomous navigation.

Potential Impact

- Enable the next generation of IPS to autonomously reason about the environment, learn from experience, and choose risk-sensitive actions.
- Pave the way for robust, agile, opportunistic, and autonomous robotic exploration in complex and extreme space environments.

Innovation: Leverage recent advances in machine learning for decision-making and control from the robotics community to the planning and control of autonomous space systems.