Embracing Uncertainty: Risk-Aware Methods for Safe Control and Navigation

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Motivation

Main question: How can we reason about **safety** when our underlying robot / world models are **noisy**, **inaccurate**, or **uncertain**?

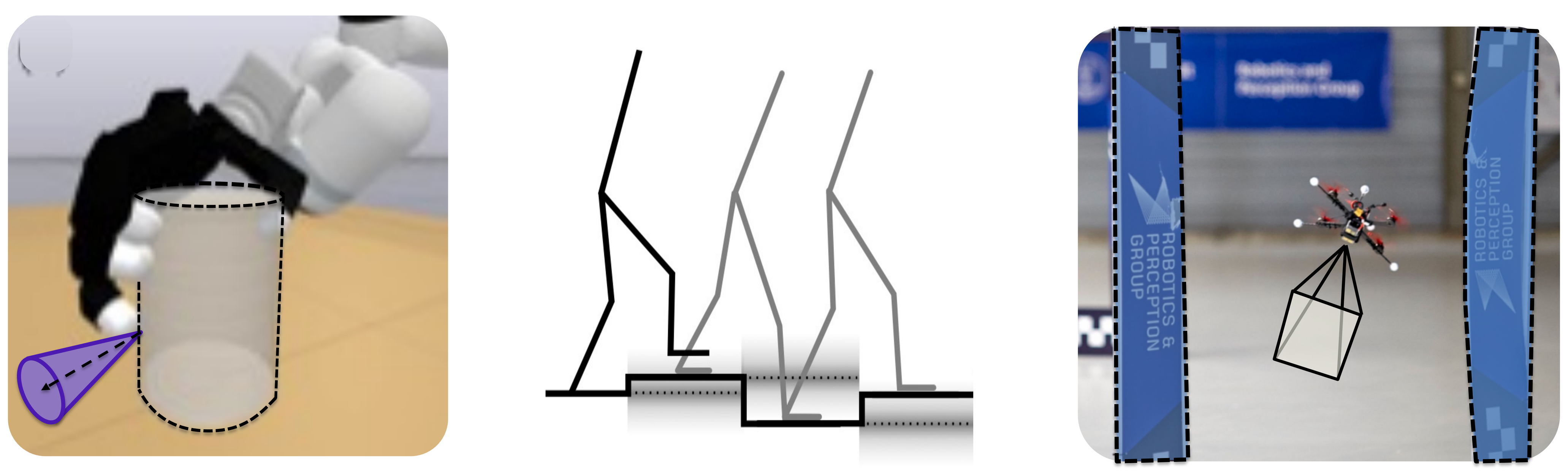

Fig. 1: Manipulation (noisy surface geometry), walking (rough terrain) and navigation (collision geometry / state est.) are problem areas of interest where robustness to uncertainty is a critical limiting factor in real-world performance.

State Estimation with Modern Vision

- **Current work:** Using Neural Radiance Fields (NeRFs) as a map representation for visual navigation [1].
- **Goal:** Build rigorous, model-based Bayesian filters on top of modern, learned perception stacks.

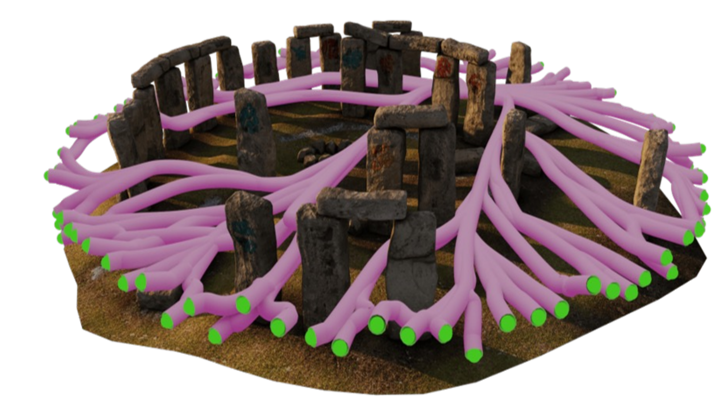

Fig. 2: Chance-constrained paths for a quadrotor through a NeRF scene.

Risk-aware, Reactive Control

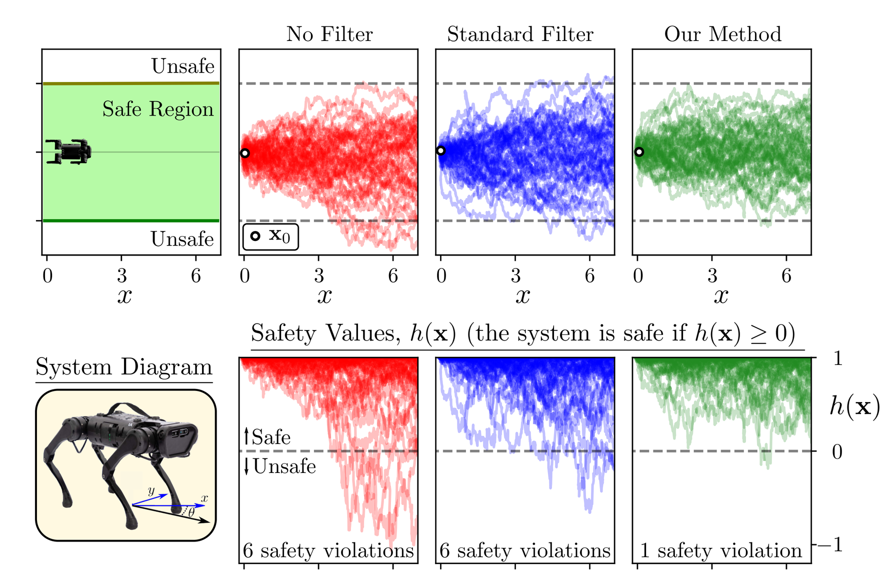

Fig. 3: Comparison of proposed and baseline controllers for quadruped on rough terrain.

- **Current work:** using martingales [2,3] to analyze safety of CBF controller; modify for process noise.
- **Goal:** Develop *both* theoretical tools and fast, risk-sensitive controllers.

Broader Impacts

- **Social:** Broaden situations where robots can operate under uncertainty (e.g., with humans).
- **Outreach:** Recruit, mentor, and retain a diverse research team; promote discussion of possible social outcomes of robotics research.

Fig. 4: Robust, vision-based robots have broad uses (e.g., logistics, assembly, healthcare).

References:

[1] M. Adamkiewicz, T. Chen, A. Caccavale, R. Gardner, **P. Culbertson,** J. Bohg, and M. Schwager. "Vision-only robot navigation in a neural radiance world," RA-L 2021.

[2] R. K. Cosner, **P. Culbertson**, A. J. Taylor, and A. D. Ames. "Robust safety under stochastic uncertainty with discrete-time control barrier functions," RSS 2023 (accepted).

[3] **P. Culbertson,** R. K. Cosner, M. Tucker, A. D. Ames. "Input-to-state stability in probability," CDC 2023 (under review).

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