NRI: FND: Life-long Learning for Motion Planning in Human Populated Environments

Bradley Hayes
Bradley.Hayes@Colorado.edu

Christoffer Heckman
Christoffer.Heckman@Colorado.edu

Key Challenges Addressed by This Work

Robots in human populated environments require **context-aware predictive models** of human activity that **adapt to shifting distributions over time**.

Robots that perform motion planning in these spaces need to adhere to **risk-minimizing heuristics** and requirements of **real-time computation**.

Outcomes and Key Results

The novel contributions of this effort have led to improvements in:

- SLAM robustness in dynamic environments
- Safe and efficient online social navigation in dense crowds
- Navigation robustness through improved traversability estimation
- Sequential Manifold Planning for Constrained Motion Planning
- State-of-the-art, freely available undergraduate robotics materials/curricula

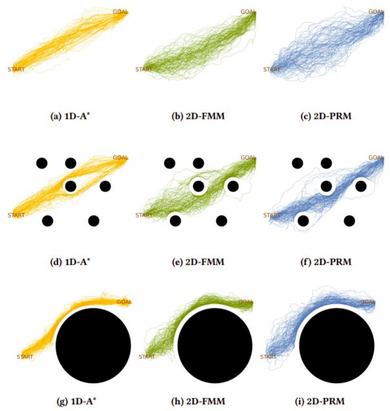
Broader Impact

This work contributes toward the deployment of robots that can safely sense, think, and act without requiring external computational infrastructure in human-populated, potentially unstructured spaces.

Online POMDP Based Social Navigation

- Using an online POMDP solver and precomputed RRT over the static elements of the scene, we solve for short-horizon control solutions that account for dynamic obstacles, informed by an inexpensive long-horizon plan to improve solution quality.

- Our method outperforms online social navigation approaches, capable of producing **faster** (higher maximum velocity) **and safer** (fewer "close calls") **behavior more quickly** (higher re-planning frequency) than existing POMDP methods.



Intention-Aware Navigation in Crowds with Extended-Space POMDP Planning
To Appear: AAMAS 2022.

Risk-Aware Dynamic Motion Planning

Fast Intersection-Dependent Online Sequential Manifold Planning

- Constrained motion planning provides a route to human-predictable behaviors that mitigate risk

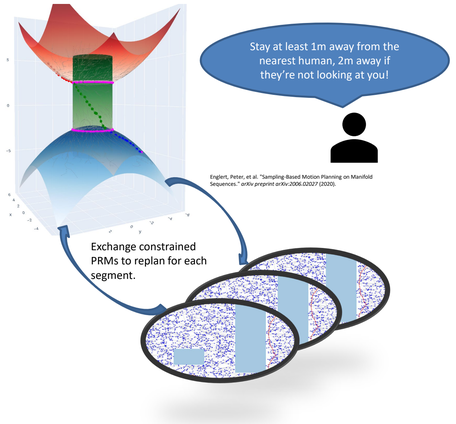
- Sets of applicable constraints can change throughout a task, introducing a ***sequential constraint manifold planning problem.***

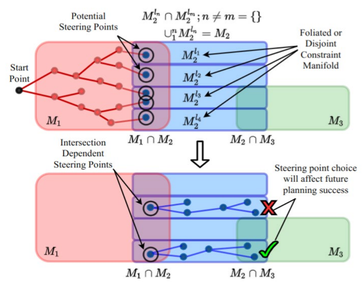
- Manifold projection techniques enable sampling-based planners to produce constraint compliant trajectories but changing applicable constraints during task execution *without end-to-end replanning* is currently infeasible.

- Planning roadmaps approximate constraint manifolds through sampling-based coverage...but this process is ***computationally expensive and sometimes infeasible***.

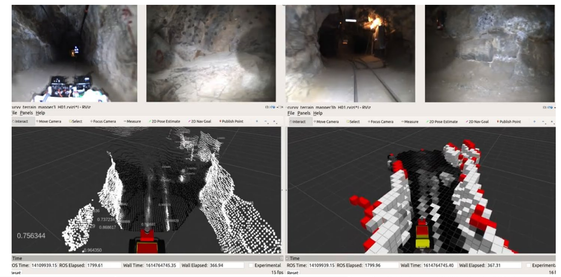
- **Approach:** Use observed behavior to seed generation of an atlas of constrained PRMs offline for problem-specific constraint sets, transitioning roadmaps when constraints change. Demonstrations also provide samples at productive manifold intersections (those with routes to goal states, as opposed to dead ends).

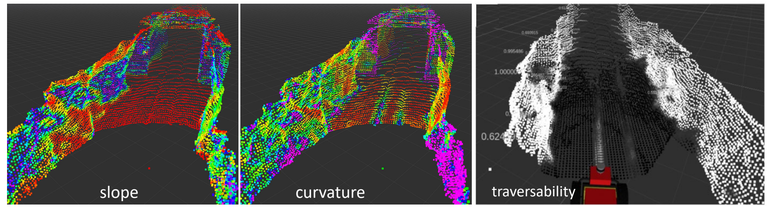
- **Benefit:** Availability of multi-constraint models that can inexpensively adapt to changes in the environment (e.g. new collision objects) and constraint requirements, making online constrained motion planning feasible.





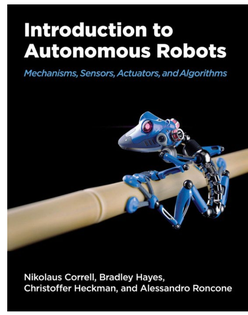
Traversability Estimation for Robust Navigation





Broader Impact (Education/Outreach)

The work developed through this effort has been incorporated into a new textbook and open curriculum for undergraduate robotics, available in print this year through MIT Press.



2022 NRI & FRR Principal Investigators' Meeting
April 19-21, 2022

Award ID#: 1830686