PRACSYS group: Physics-aware Research for Autonomous Computational SYStems

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Workshop on Progress and Open Problems in Motion Planning, IROS
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Asymptotically Near-Optimal Planning

Asymptotic Optimal $k$-PRM*: connect new samples with approx. $\log n$ neighbors, where $n$ is the number of nodes in the roadmap.

Asymptotic Near-Optimal Roadmap: The $t$-spanner of $k$-PRM*
- A $t$-spanner is a sparse subgraph
- For every shortest path in the original graph
  - There is a path in the spanner that is no longer than $t$ times the original length

$[kPRM^* - Karaman, Frazzoli '10$]

$[Marble, Bekris IROS '11$]
Asymptotically Near-Optimal Planning

- Start with the asymptotically optimal k-PRM*
- Interleave an incremental spanner algorithm
- Result: An asymptotically near-optimal planner
  - Smaller average increase in path length than the stretch factor
  - Sparse roadmap with smaller memory footprint
  - Faster construction and online query resolution

Challenge: Finite size roadmaps with near-optimality guarantees
Issues arising from the lack of an appropriate metric:

- **Optimal metric**: cost-to-go function
- **Often used**: Euclidean distance in configuration space

**Bias due to gravity and drift**

- $q_1 = 0$  $q_2 = 0$
- $q_1 = \pi/2$  $q_2 = \pi/2$

After 5000 iterations the goal region is not reached

**Use an offline-learned roadmap with gaps to guide RRT online**

[Li, Bekris ICRA ‘10]

**PCA-RRT**

[Li, Bekris ICRA ‘11]
Improving Planning with Dynamics

3-link Acrobot:
• All joints actively controlled (AAA mode)

- Regular RRT
- PCA-RRT

[Li, Bekris ICRA ‘10]

[Li, Bekris ICRA ‘11]

Direction: Efficient Asymptotically Optimal Planning with Dynamics
(i.e., no steering function, metric issue)
Safe Replanning with Dynamics

Examples of problems that require replanning:
- Unexpected or dynamic obstacles
- Decentralized motion coordination
- Sensor-based applications

Challenge: Inevitable Collision States

Proposed replanning schemes that minimize the cost of safety checking using contingency plans
Safe Decentralized Replanning

Communication-based solution

Rice University Collaborators

Devin Grady

Mark Moll

Lydia Kavraki
Safe Decentralized Replanning

[Grady, Bekris, Kavraki WAFR ’10]
Decentralized Deconfliction

Considering also control-based and reactive solutions for decentralized deconfliction and providing liveness guarantees:

30 Airplanes

[Krontiris, Bekris IROS ’11]

Challenge: Communication-less solution with liveness properties
How can agents move on a graph from an initial assignment to a goal assignment without two of them occupying the same node simultaneously?

- NP-Complete problem in the general case
- Coupled methods: complete but intractable
- Decoupled methods: efficient but incomplete

Provided a method that is:
  - complete but suboptimal,
    - for a minor relaxation of the problem: at least two nodes of the graph have to be free.
  - has polynomial complexity $O(n^4)$

[Luna, Bekris IJCAI, IROS ’11]
Complete & Tractable Multi-Robot Path Planning

![Graphs showing computation time and ratio against number of robots]

**Challenge:** Transfer framework to the continuous case

Efficient and Complete Centralized Multi-Robot Path Planning

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