What formal guarantees should practical motion planners provide?

Kostas Bekris
Computer Science, Rutgers

A grand challenge for robotics is the development of systems that safely operate next to humans in unstructured environments and effectively construct structures given access to individual parts, tools and high-level instructions. Examples include teams of robots and people deployed after a natural disaster to set up temporary housing or deployed in small-business factories to build custom-made products.

The above challenges require the generation of high-quality and safe robot motions in a computationally efficient manner, while addressing the following complexities:

- real-time response in partially-observable, dynamic scenes;
- uncertainty;
- high-dimensional spaces with complex constraints, e.g., closed chains, deformations, dynamics;
- integration with control and task-planning;
- rearrangement of manipulable objects in cluttered scenes;
- interaction with people and other robots;

Desirable solutions should go beyond heuristic methods that empirically work well in small-scale experiments. They should provide formal guarantees and reproducible results. Even basic motion planning, however, is computationally hard. Thus, an important tradeoff between performance guarantees and computational cost arises.

This realization has led in the past to practical sampling-based planners that construct roadmaps and sacrifice completeness for quickly computing solutions. These methods were recently shown to be asymptotically optimal for kinematic challenges given dense enough roadmaps. We need to build on top of this progress and utilize advances, such as cloud computing, to produce powerful planners for important applications. Towards this objective, we are considering the following strategies:

- Finite-time computation properties: We have recently shown that sampling-based planners are "probably near-optimal" after finite computation, which is useful to practitioners, replanning tasks and guarantees for task-planning.
- Compact roadmaps: Effective representations that can be queried fast, have small memory footprint, provide communication benefits when using vast but remote computing resources while still providing formal guarantees.
- Complex systems: Providing formal guarantees for systems without a steering function, which can also have an impact on planning under uncertainty.
- Multi-robot planning: We work towards bridging the gap between coupled and decoupled planners in discrete domains by achieving completeness and polynomial complexity at the cost of suboptimal solutions. These results can benefit object rearrangement challenges.
- Interactive planning: Planning robot motion among other agents, and potentially people, brings additional considerations for planners, such as information requirements, deadlock avoidance, and game-theoretic optimality notions.

In all of the above research efforts, the key issue relates to the impact that computational limitations have in providing performance guarantees.