Towards a Principled General Approach to Motion Planning under Uncertainty

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A major challenge in robot motion planning is the uncertainty inherent in robots control and sensing. As a result, a robot does not know its state exactly and cannot decide the best actions on the basis of a single known state. Incorporating uncertainty into planning leads to much more reliable robot operation.

One systematic approach to modeling and planning under uncertainty is the partially observable Markov decision process (POMDP), which models the state of a robot as a belief, i.e., a probability distribution over possible robot states and reasons in the space of all beliefs. Belief space plays a central role in motion planning under uncertainty, similar to that of configuration space in classic geometric motion planning, and it faces the same difficulty: the "curse of dimensionality". Lessons that have been learned about configuration space motion planning are invaluable in conquering the challenges in the new setting. In particular, probabilistic sampling is a powerful tool that allows us to use a small number of sampled points as an approximate representation of a high-dimensional belief space and reduce computational complexity. Additionally, natural structural properties of POMDPs can often be exploited to decompose a high-dimensional belief space into a collection of much lower-dimensional ones.