Planning with Unreliable Controllers
William Edwards, Dhruv Saxena, Dr. Maxim Likhachev
Robotics Institute, Carnegie Mellon University

Motivation
- Traditional search-based planning methods depend on reliable execution of metric motion primitives.
- Existing work [1] allows for search-based planning to reason over controllers such as wall-following or visual servoing.
- In some cases, it can be desirable to reason over unreliable controllers.

Motivating Example
The robot must travel from the start to the goal, but there is a variable wind (blue) blowing across the room. The robot can either execute a series of reliable wall-following controllers or an unreliable proximity controller.

Problem Statement
Input: State space $S$, start state $s \in S$, goal region $G \subseteq S$, set of controllers $\pi$, stochastic cost function $\delta(c_1, \ldots, c_n)$ (which gives $\infty$ if the final state is not in $G$), $p \in [0, 1]$.
The robot must travel from the start to the goal, but there is a variable wind (blue) blowing across the room. The robot can either execute a series of reliable wall-following controllers or an unreliable proximity controller.

Output: Controller sequence $(c_1, \ldots, c_n)$ which minimizes the $p$th quantile of $\delta(c_1, \ldots, c_n)$.

Approach
Our approach is a branch-and-bound algorithm which uses multiple forward simulations to estimate the cost of each controller sequence.

- Edges represent controllers, and nodes represent sequences of controllers.
- First an initial solution is found using an inflated heuristic.
- Then, all other branches are explored until the sub-optimality bound can be probabilistically met.

Results

<table>
<thead>
<tr>
<th>Environment</th>
<th>Planning Time (s)</th>
<th>Cost (90th percentile)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LCB</td>
</tr>
<tr>
<td>Small (No Noise)</td>
<td>2.47</td>
<td>22.13</td>
</tr>
<tr>
<td>Small (Low Noise)</td>
<td>2.55</td>
<td>25.28</td>
</tr>
<tr>
<td>Small (High Noise)</td>
<td>7.15</td>
<td>33.15</td>
</tr>
<tr>
<td>Large</td>
<td>609.68</td>
<td>125.61</td>
</tr>
</tbody>
</table>

The planning times and solution costs for four environments are given. Since the cost can only be approximated, a lower and upper confidence bound are given.

Discussion and Future Work
- Initial results are promising, but planning times required for large environments may be prohibitive in some applications.
- Methods for improving performance are being explored by the authors.
- More rigorous simulation experiments on a wider variety of environments are planned.
- Physical experiments using the UBTECH Yanshee humanoid robot are also planned.

References

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Contact Information
- Name: William Edwards
- Email: williamedwards314@gmail.com

Test Environments and Solutions
(a) In the small environment (17 x 20 m), the optimal solution without noise is to execute a proximity controller followed by a wall-following controller. (b) With a low amount of noise (wind), the optimal solution is unchanged. (c) With high noise, the optimal solution is to execute a series of wall-following controllers around the boundary. (d) For the large environment (30 x 85 m), the optimal solution is a series of wall-following controllers. Note that for all examples, only the endpoints (red) of each controller are drawn, so the path may appear to cut corners.