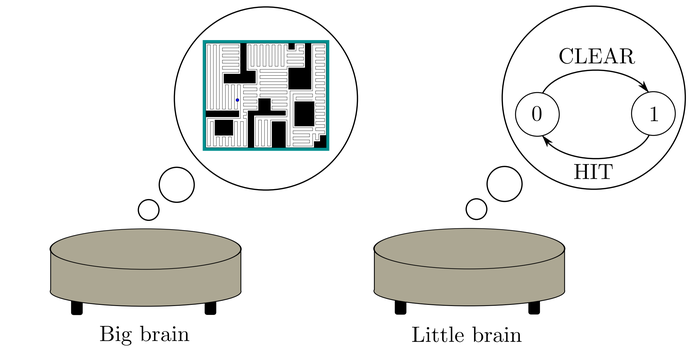
Robust Planning Over Simple Boundary Interactions

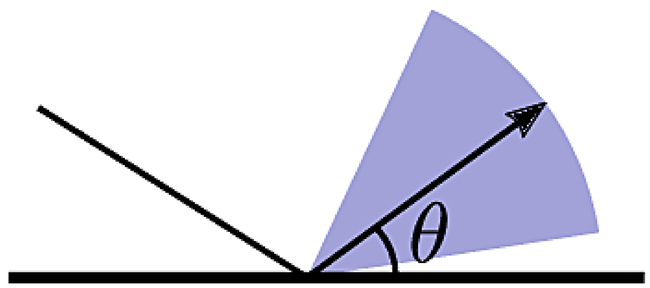
Alexandra Q. Nilles, Samara Ren, Israel Becerra, Steven M. LaValle
Department of Computer Science, University of Illinois, Urbana-Champaign

Motivation

- Many robots can travel forward in straight lines, identify boundaries, and turn in place.
- Can we create robust plans for such robots? What about simple plans, for robots with minimal sensing and state estimation?
- How to specify tasks for these systems?

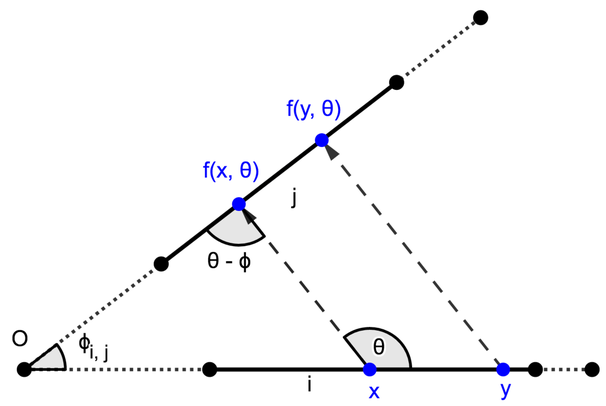


Model



- **Planning problem:** Given start and end states, generate actions for each stage as subset of action set $U = [0, \pi]$.
- **Geometrical Approach:** Discretize environment boundary based on visibility events.
- **Dynamical Approach:** Construct edge-to-edge mapping functions, compose and find fixed points and contraction ratios

Contraction



$$c(\theta, i, j) = \frac{|f(x,\theta) - f(y,\theta)|}{|x - y|} = \frac{\sin(\theta)}{\sin(\theta) \pm \phi_{i,j}}$$

Nice properties:

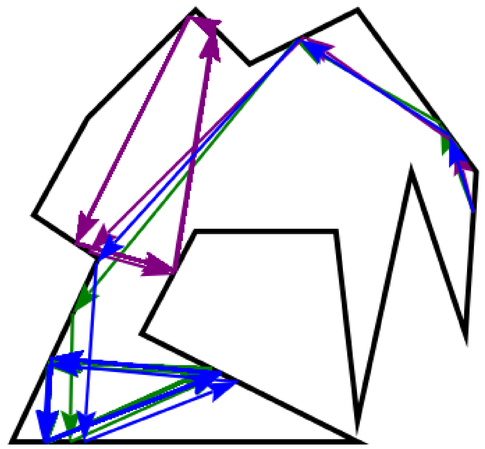
- $c(\theta, i, j) < 1$ indicates shrinking set.
- Given θ and a pair of segments, holds for everywhere along segments.
- Composition: transition from edge i to j to k has contraction coefficient $c(\theta, i, j) * c(\theta, j, k)$.

Tasks and Behaviors

General approach: discrete search in visibility graph while checking constraints and criteria.

- **Navigation:** Strategy gets robot from start to goal states (points on boundary).
- **Patrolling:** Repeatedly visit a set of target states (possibly in specific order).
- **Criteria:** Fewest bounces, max-min action sets, maximally contracting paths.

Example



Critical Angles

- $c(\theta, i, j)$ easy to check for a single θ...
- How to reason about sets of actions $\tilde{\theta} \subset [0, \pi]$?
- As θ sweeps, visible edges will shrink and grow, and occasionally appear and disappear. Contraction property may also change.
- This information can be pre-computed and stored in the roadmap.

Language Design

- Want user to specify spatial tasks and behavioral constraints.
- Tool should give feedback on feasibility and dynamical structure of resulting behavior.
- Visual, interactive interface?

Acknowledgments

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