A Particle Swarm Optimization Sampler for Probabilistic Roadmap Motion Planning

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Outline

Outline

Improving PRMP

- Key Idea: Estimate $\mathcal{C}_{free}$
- Probabilistic Motion Planning
  - Uninformed Sampling
  - Model Aware
- The Narrow Passage Problem
  - Uniform Sampling **sucks**
  - Gaussian Sampling/Bridge-Test sucks *less*
- Population Based Search to the rescue!

Outline

Why Particle Swarm Optimization

- Benefits of PSO
  - **Simple** to set up
  - Lots of parameters to tweak
- Drawbacks of PSO
  - Hard to adapt to **non-metric** problem domains
  - *Lots* of parameters to tweak

What is Particle Swarm Optimization

- Key idea: A set of **particles** moving in a **space** according to their **fitness**
  - Particles: $X = \{\mathbf{x_i} \in \mathbb{R}^m, i = 1, ..., n\}$
  - Velocities: $V = \{\mathbf{v_i} \in \mathbb{R}^m, i = 1, ..., n\}$
  - Fitness function: $f : \mathbb{R}^m \rightarrow \mathbb{R}$
- Things that affect a particle's velocity:
  - Current fitness
  - Personal best ($\hat{\mathbf{x}}_\mathbf{i}$)
  - **Neighborhood** best ($\hat{\mathbf{n}}_\mathbf{i}$)
  - Random noise

What is Particle Swarm Optimization

The Algorithm:

Initialize X, V, personal and neighborhood bests
while *not done* **do**
  foreach $\mathbf{x_i} \in X$ **do**
    $\mathbf{x_i} \leftarrow \mathbf{x_i} + \mathbf{v_i}$
    Create two random vectors $\mathbf{r_1}$,$\mathbf{r_2}$
    $\mathbf{v_i} \leftarrow \omega \mathbf{v_i} + c_1 \mathbf{r_1} \circ (\mathbf{\hat{x}_i} - \mathbf{x_i}) + c_2 \mathbf{r_2} \circ (\mathbf{\hat{n}_i} - \mathbf{x_i})$
    Calculate $f(\mathbf{x_i})$ and update $\mathbf{\hat{x}_i}$ and $\mathbf{\hat{n}_i}$
  end
end

- Select the components of $\mathbf{r_1}$ and $\mathbf{r_2}$ uniformly from $[0, 1]$
- ω is the **momentum** coefficient
- c_1 and c_2 are weights
- "$\circ$" is Hadamard matrix multiplication

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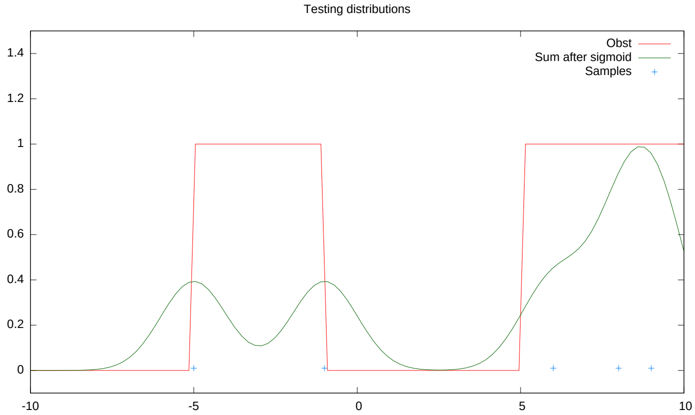
Keeping Track of Obstacles

- Key idea: map the **boundary** between $\mathcal{C}_{free}$ and $\mathcal{C}_{forb}$
- Keep a list of known collisions
- Try to estimate the expected probability of collision
- Define the probability $p_{c_i}(\mathbf{x_j})$ that $\mathbf{x_j}$ will collide with the obstacle $\mathbf{c_i}$ collided with.

Fitness Function: Visualization

- One such function: $f(x) = w(\frac{1}{1+e^{-\sum_c p_{c_i}(\mathbf{x_j})}} - 0.5)$



- But there are problems...

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Finding Narrow Passages

- Key idea: borrow techniques from the gaussian and bridge-test samplers, and **optimize**
- Use sub-samples to test if a configuration is in a narrow passage
- $f(x) =$ average number of sub-samples that pass

Outline

Results

What?! **NONE**?!

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Summary

- PSO *can* be used for PRMP (should it?)
- Parameter tweaking sucks
- Dynamic fitness functions are *bad*
- Could be applied to RRT?