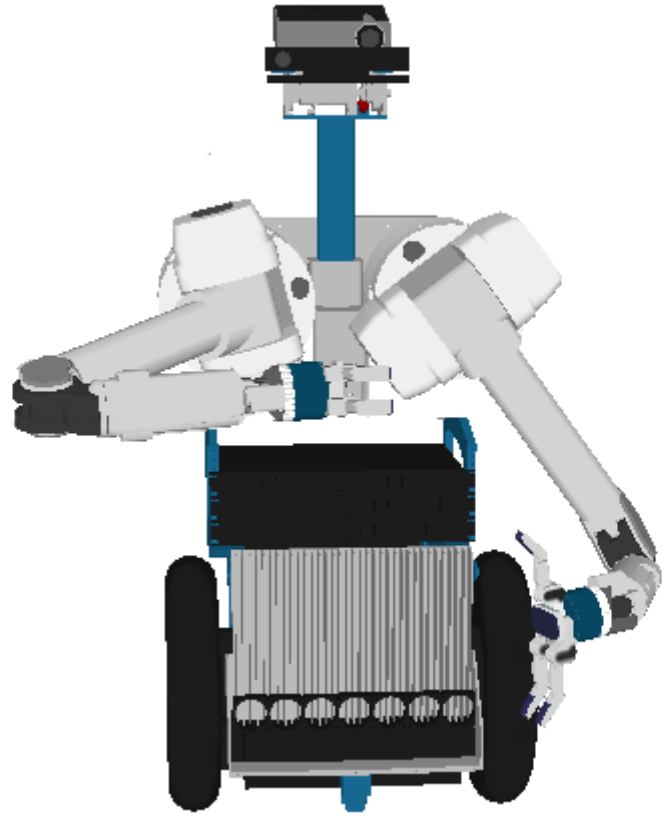
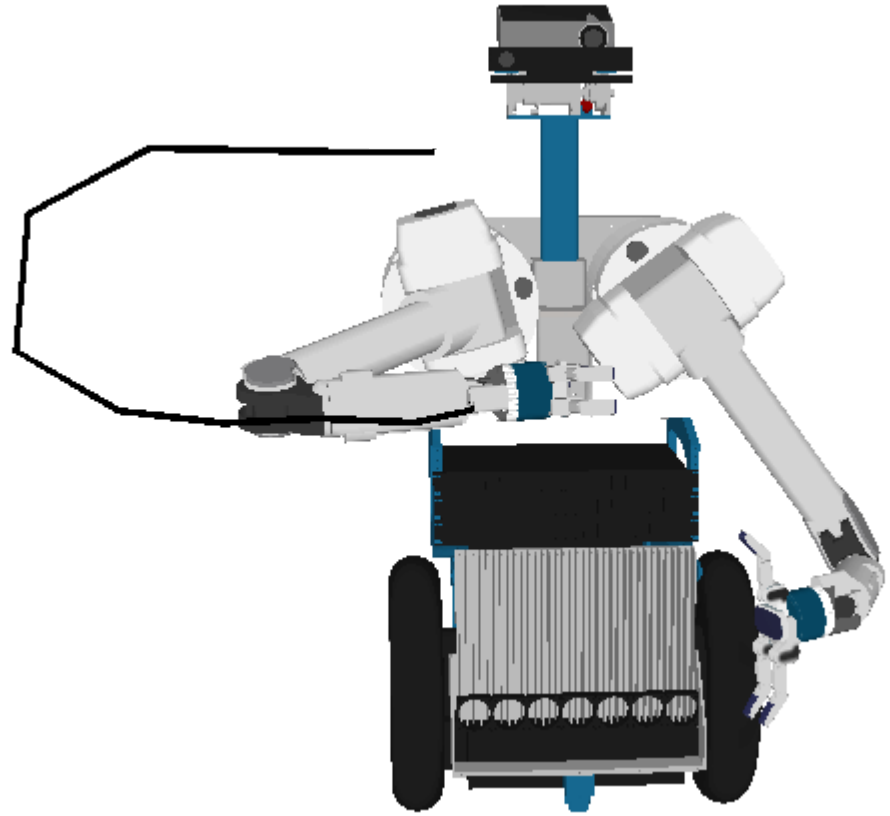
Distance Metrics and Algorithms for Task Space Path Optimization

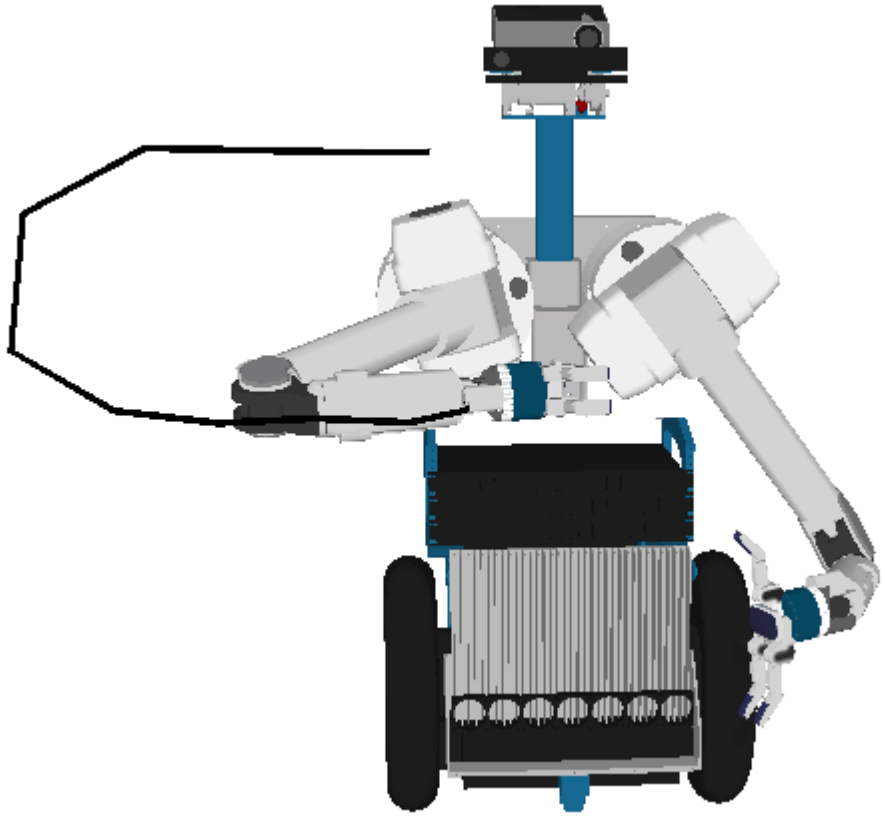
Rachel Holladay
Siddhartha Srinivasa

The Robotics Institute
Carnegie Mellon University

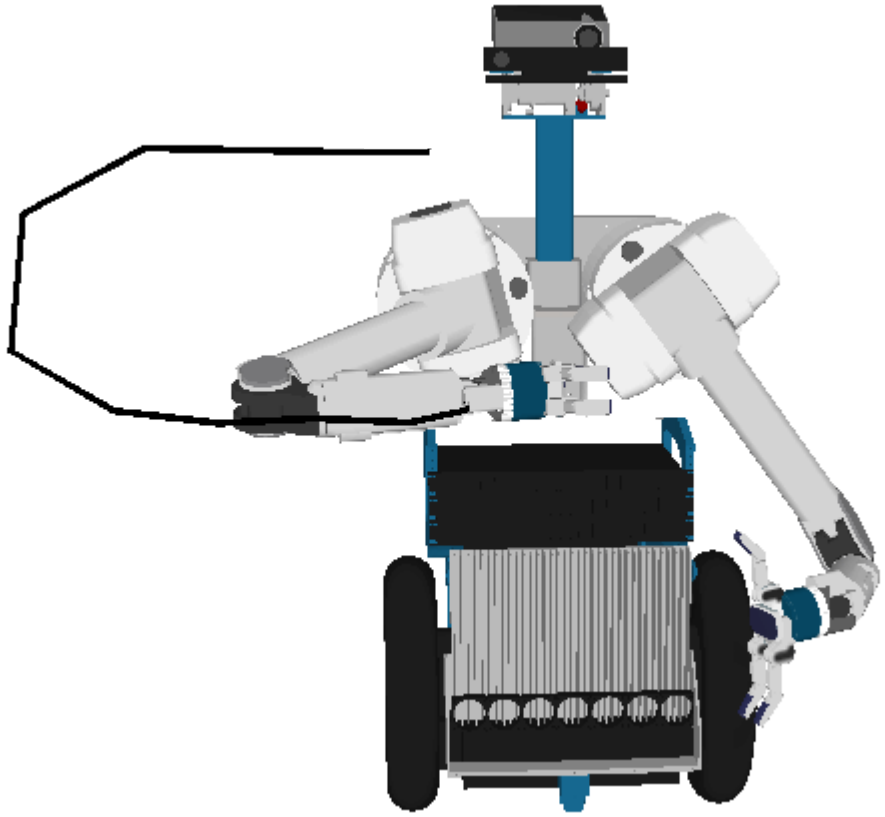
THE ROBOTICS INSTITUTE



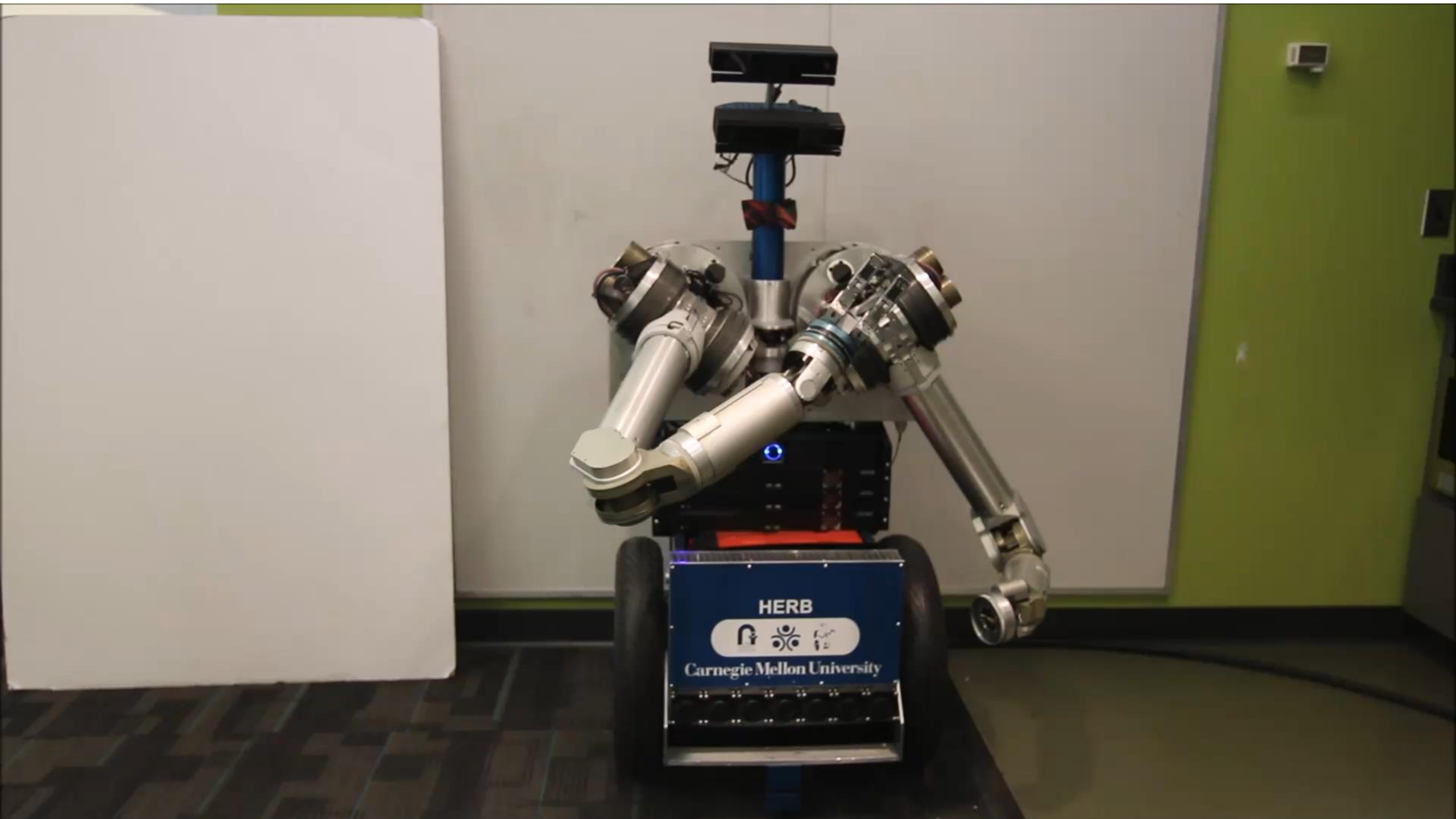


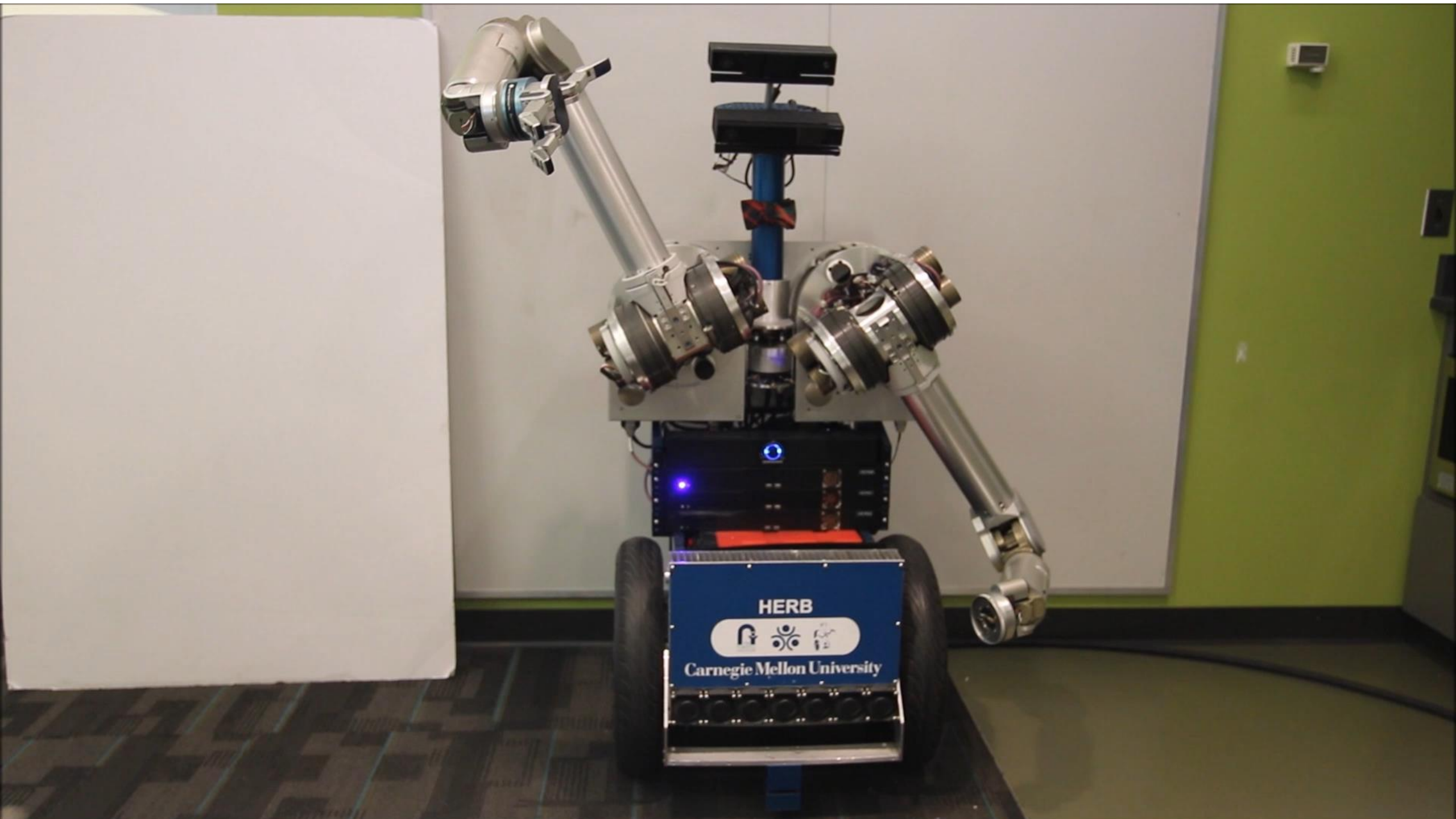


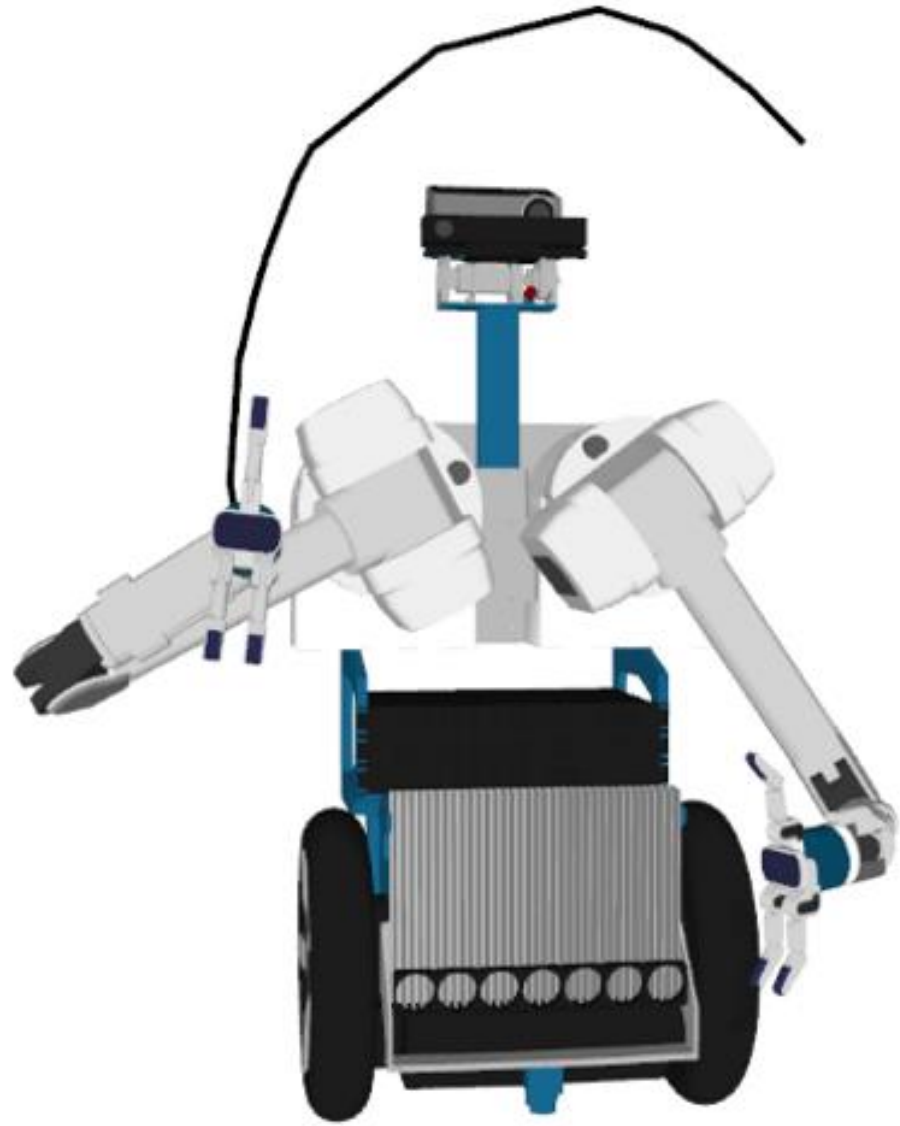
Goal: Follow End-Effector Path in Task Space

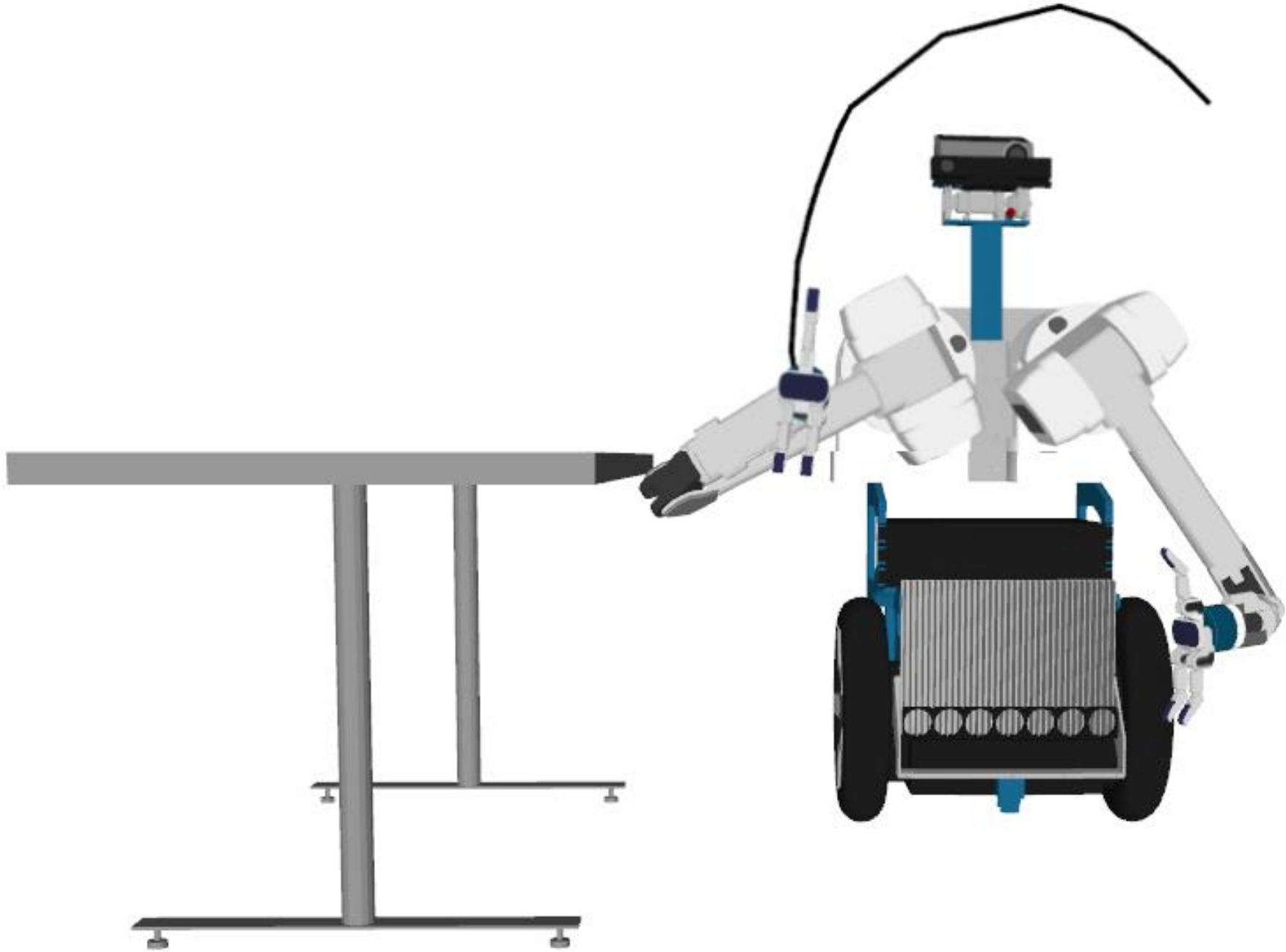


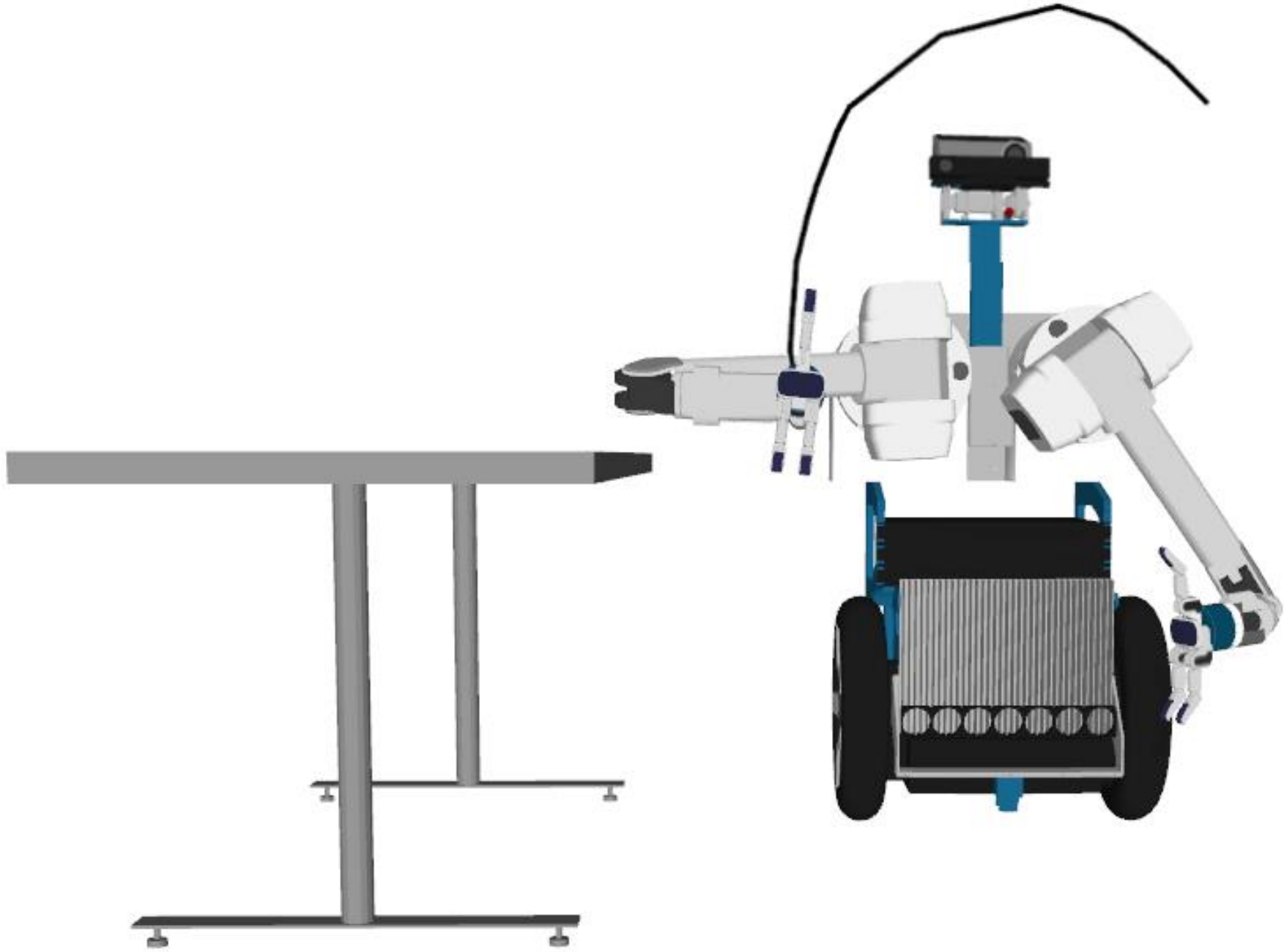
Goal: Follow End-Effector Path in Task Space *subject to constraints.*


HERB
Carnegie Mellon University


HERB
Carnegie Mellon University

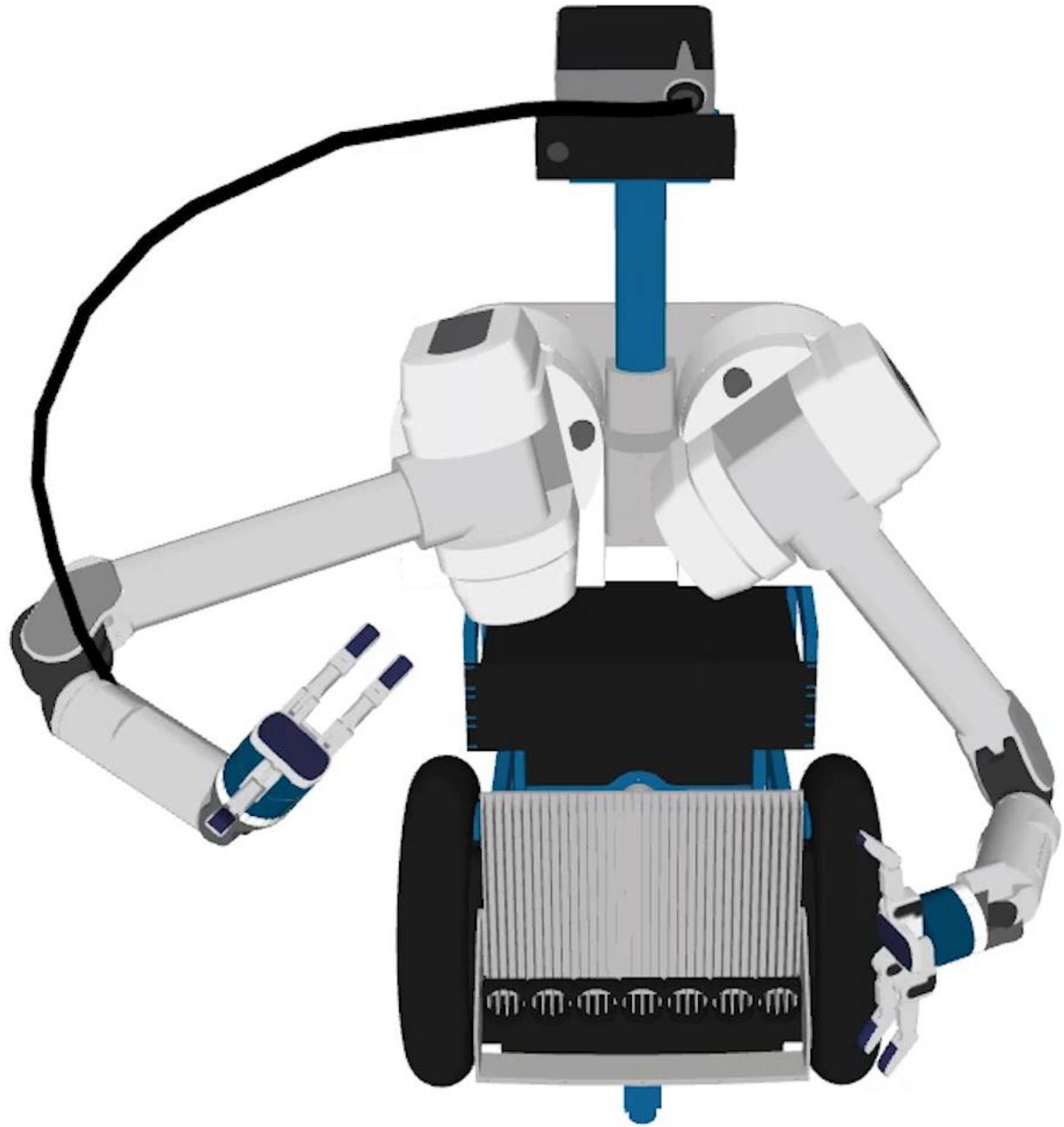






Goal:
Follow a Reference Path

Goal:
Follow a Reference Path
by leveraging motion planning.

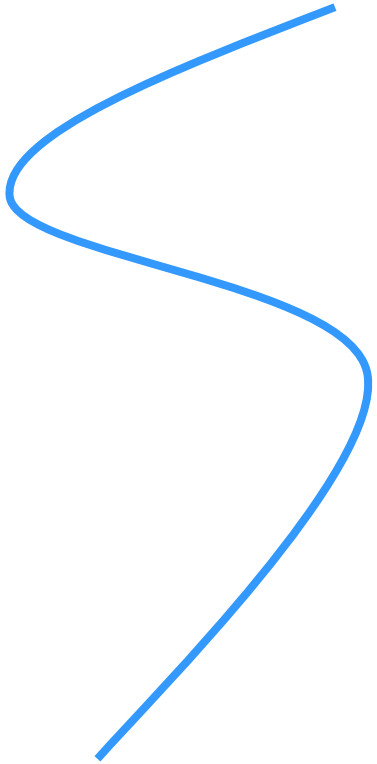


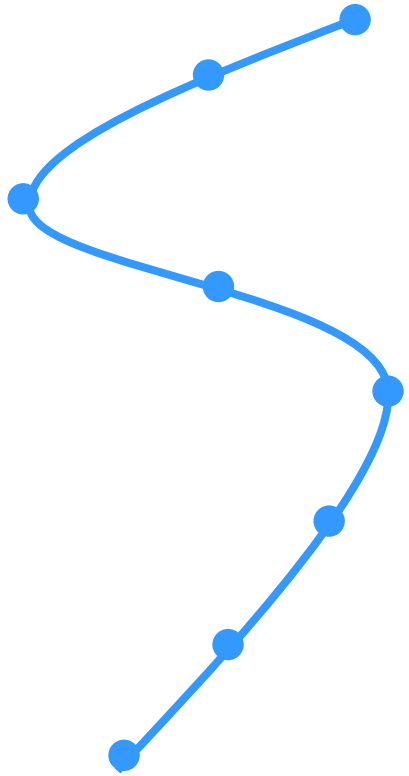
Key Insight

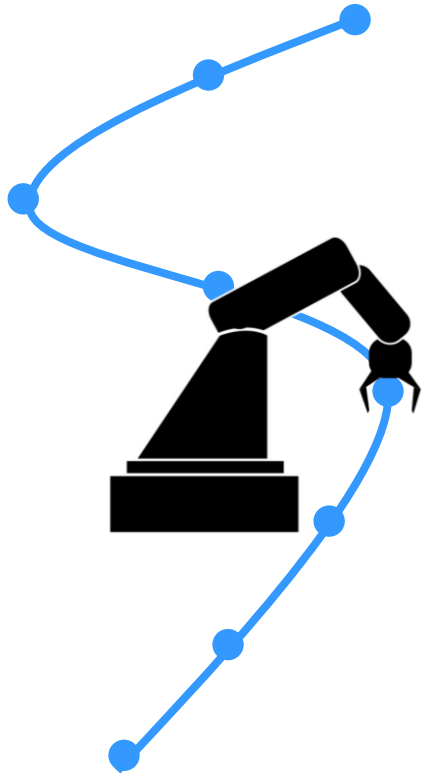
Use trajectory optimization to optimize our path to be close to our reference path.

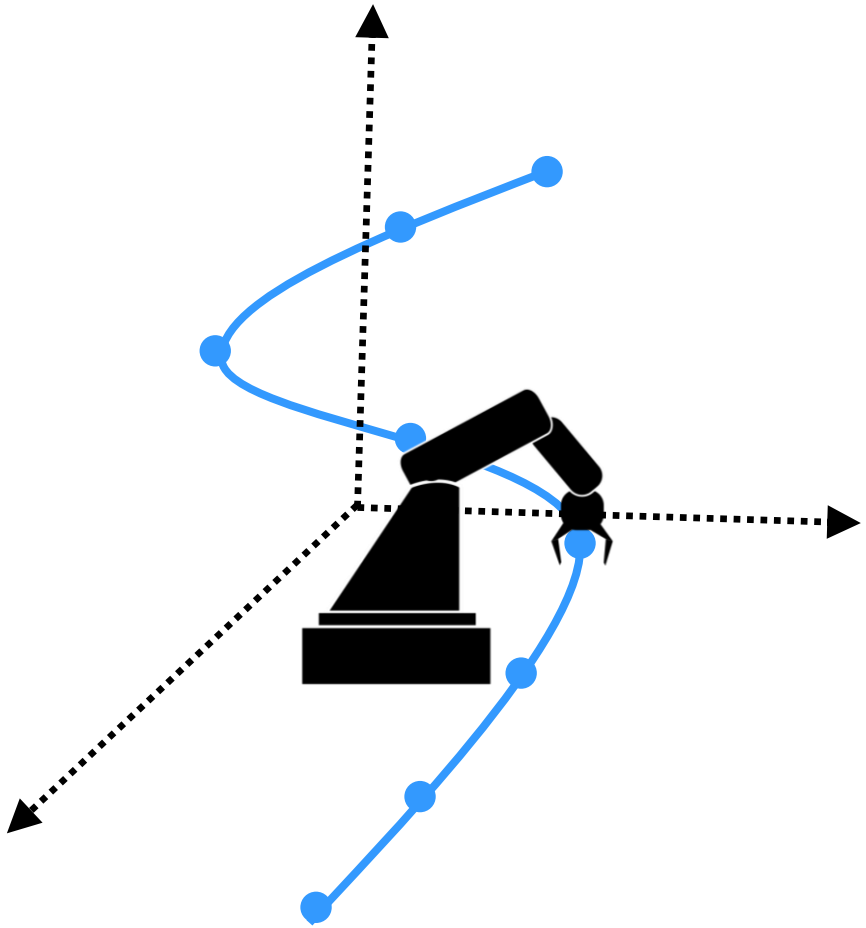
Key Insight

Use trajectory optimization to optimize our path to be close to our reference path.

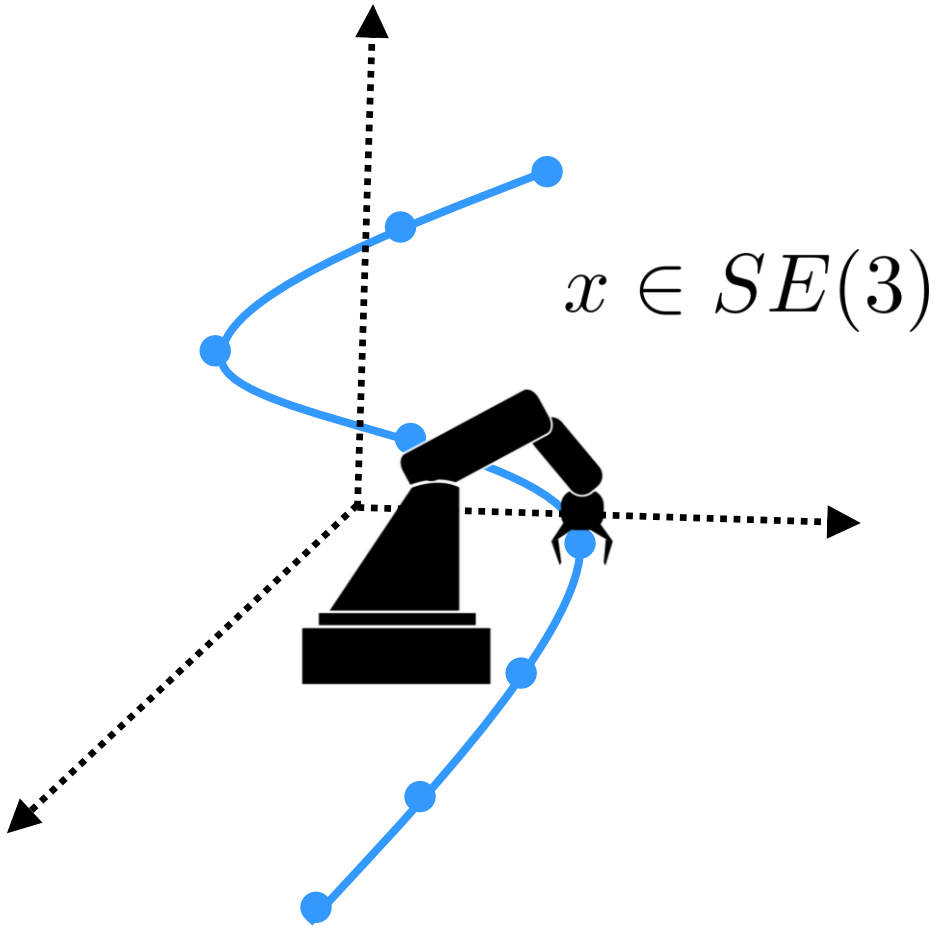




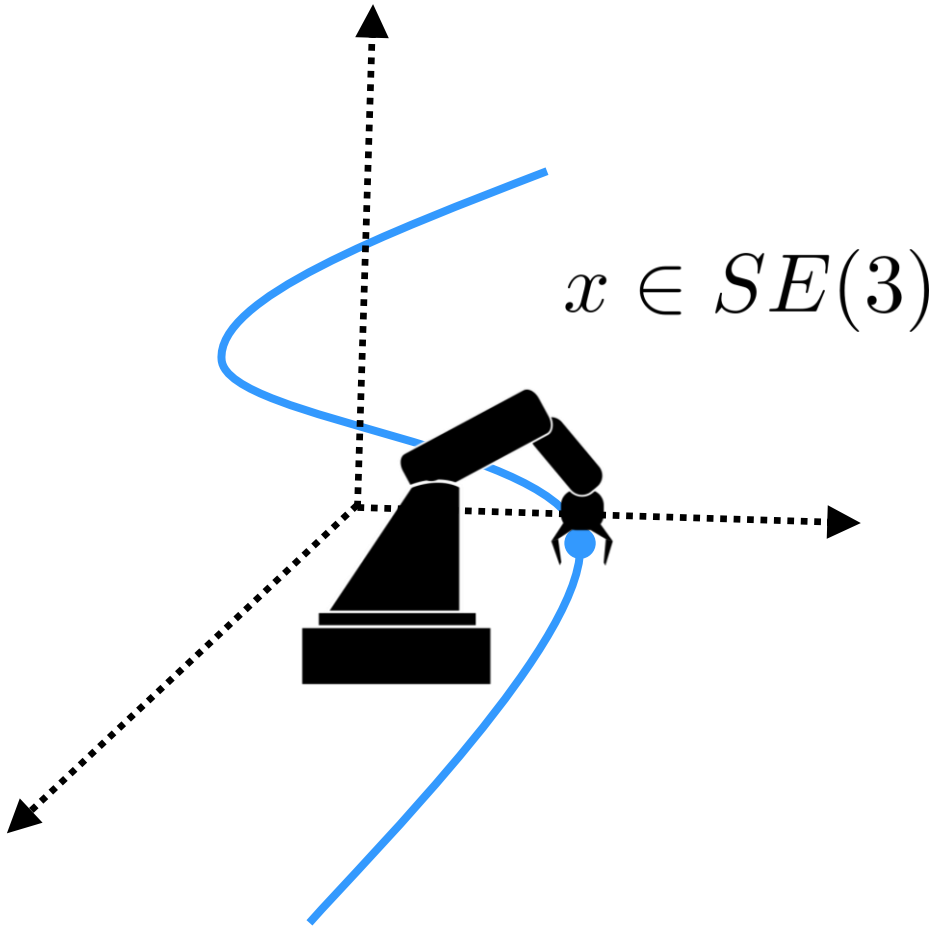




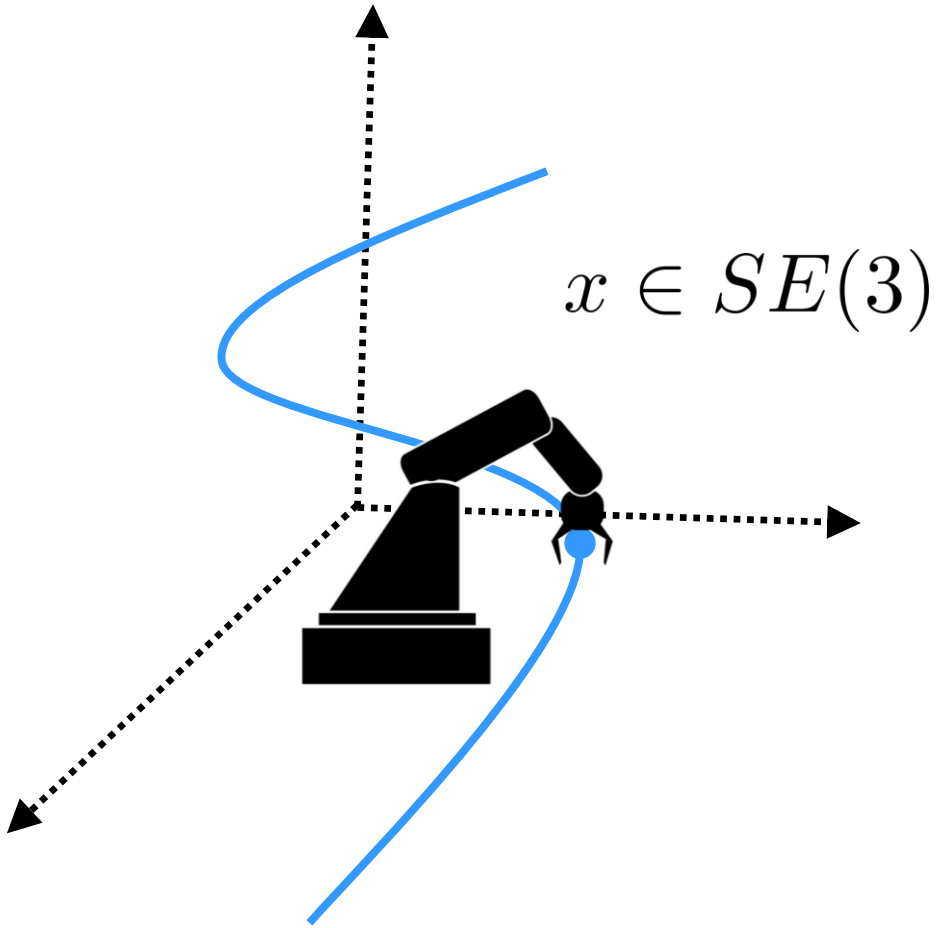
Task Space



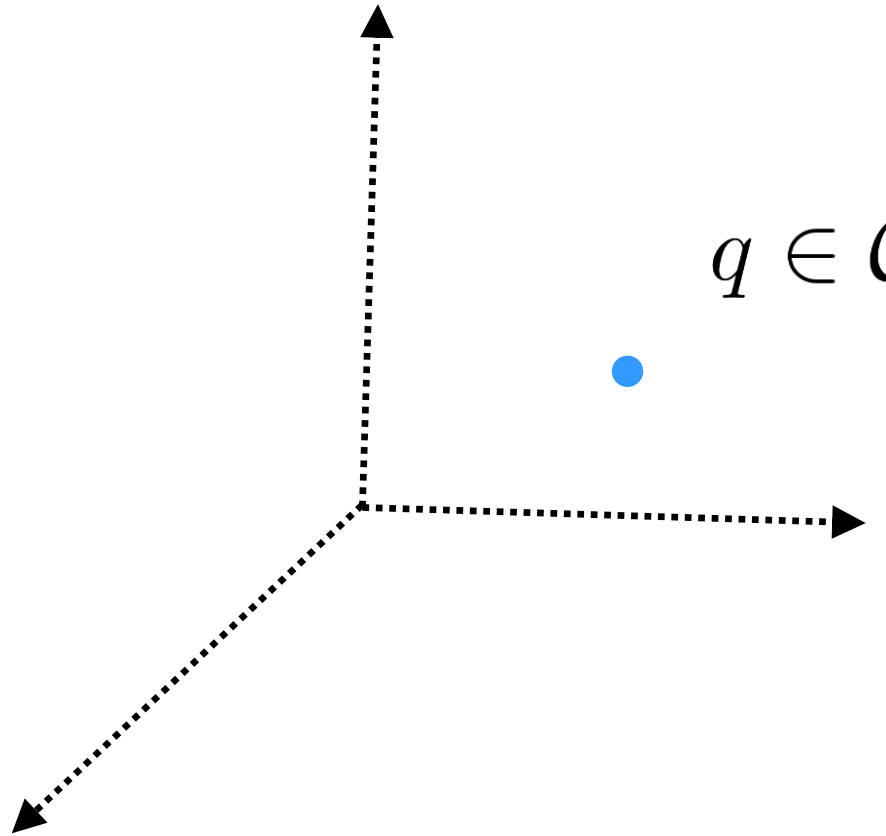
Task Space



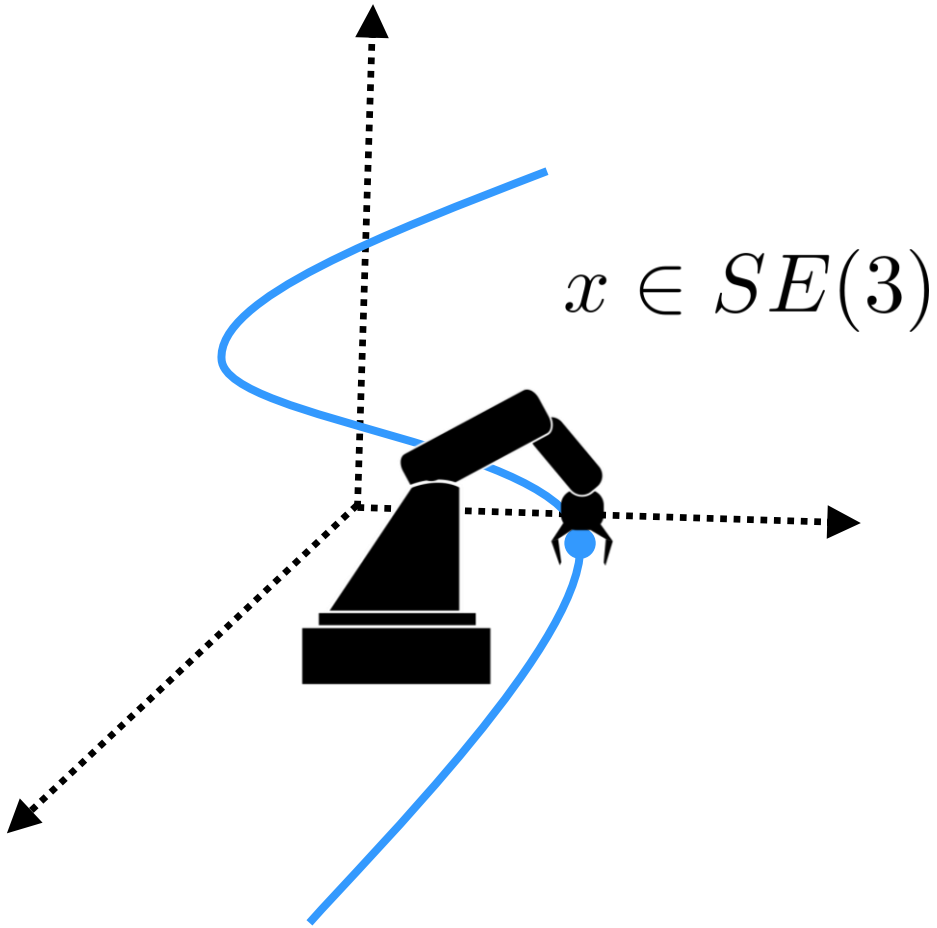
Task Space



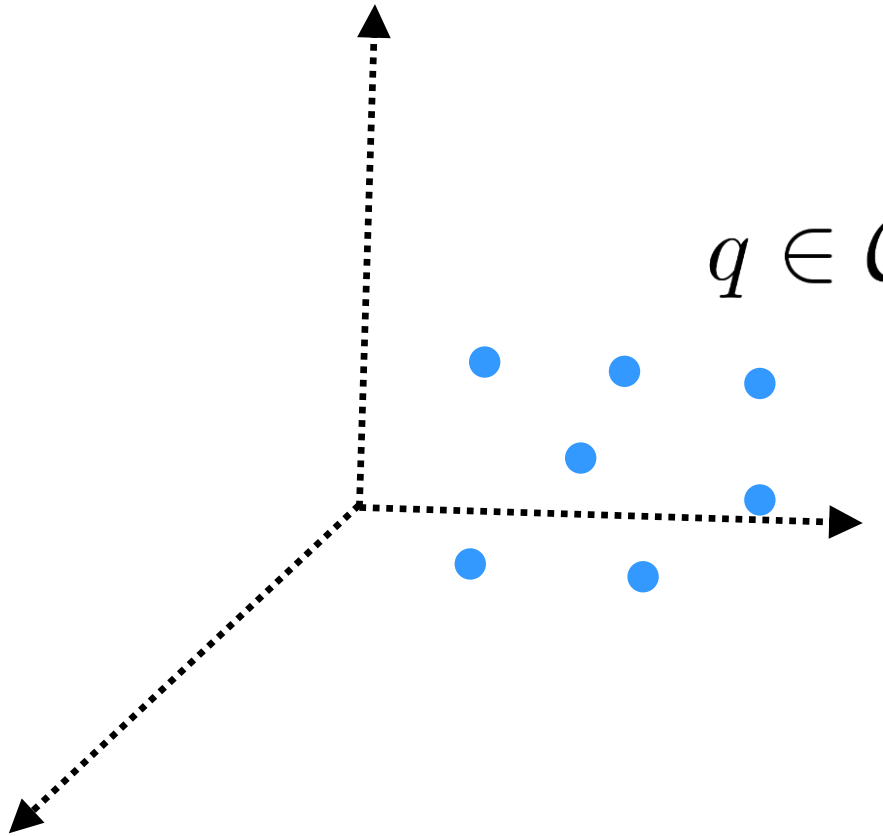
Task Space



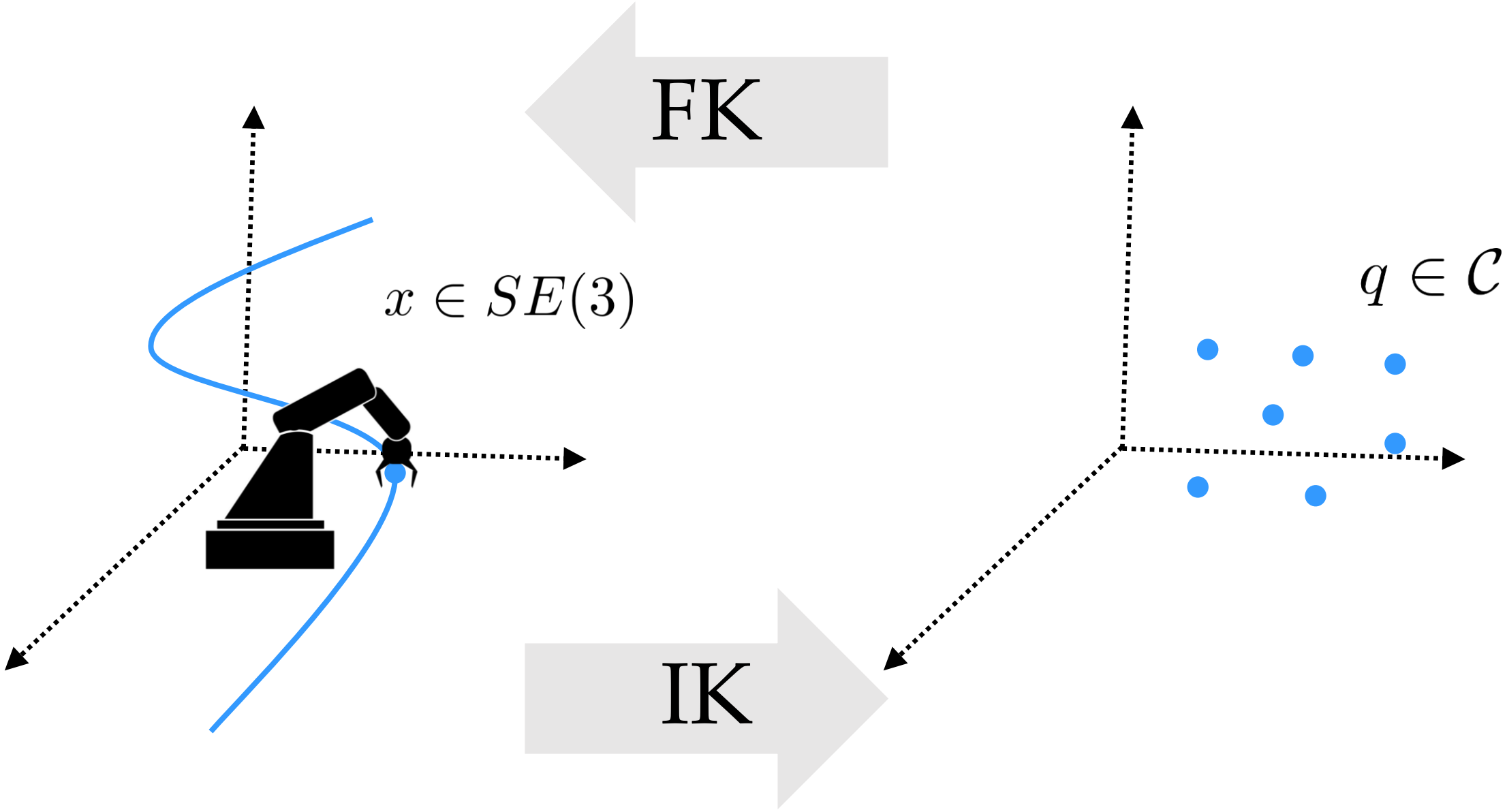
Configuration Space



Task Space



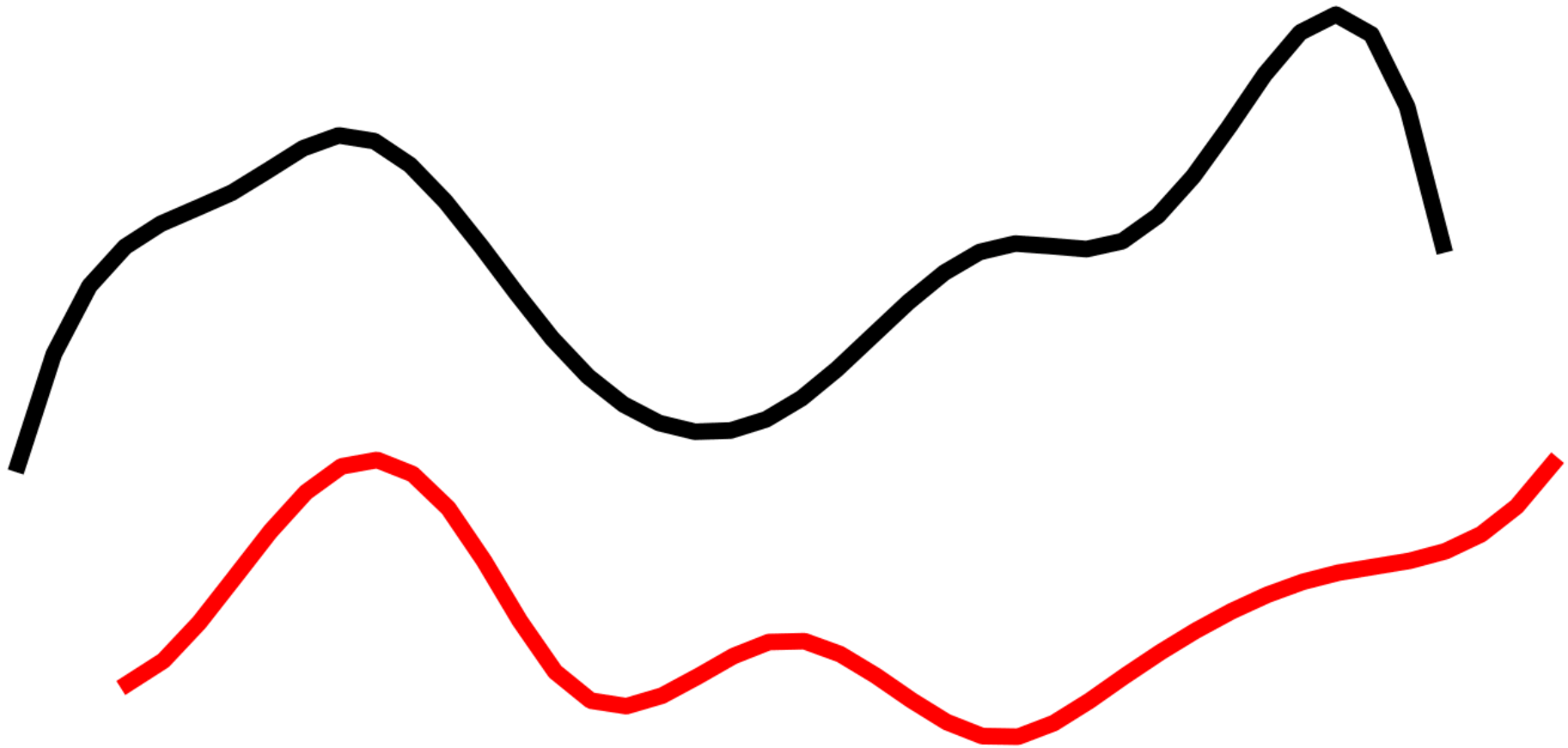
Configuration Space

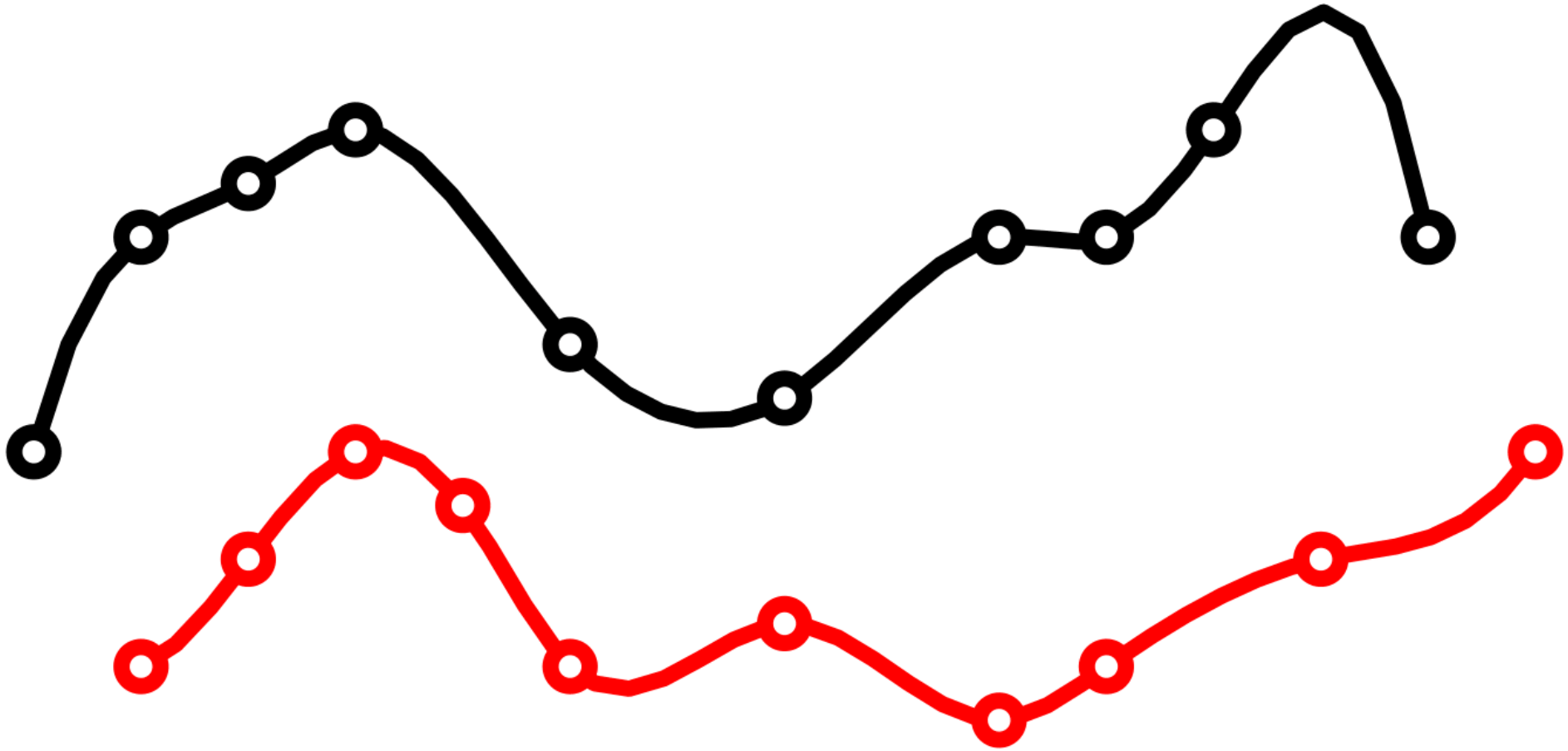

FK
$x \in SE(3)$
$q \in \mathcal{C}$
IK
Task Space
Configuration Space

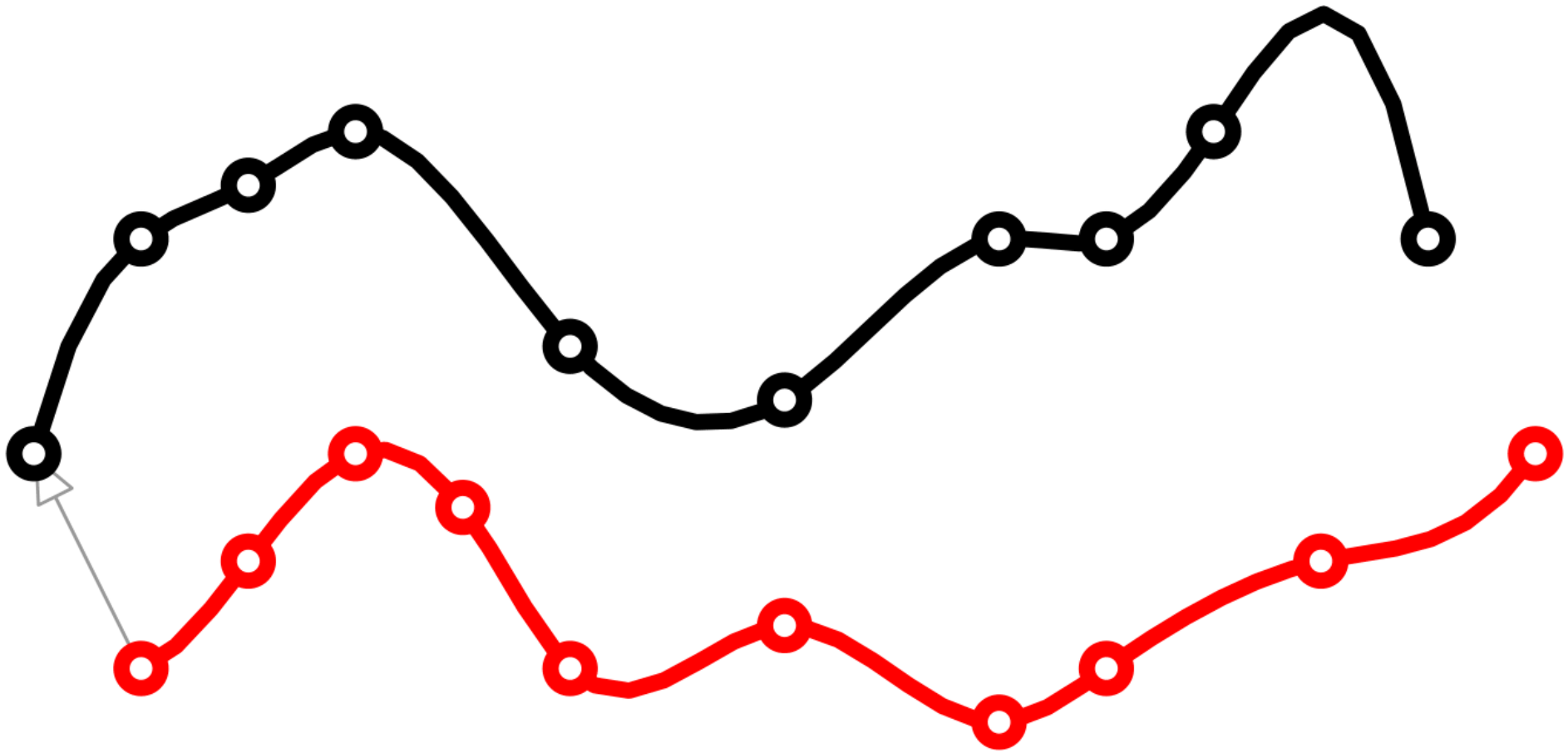
How to compare the distance between task space paths?

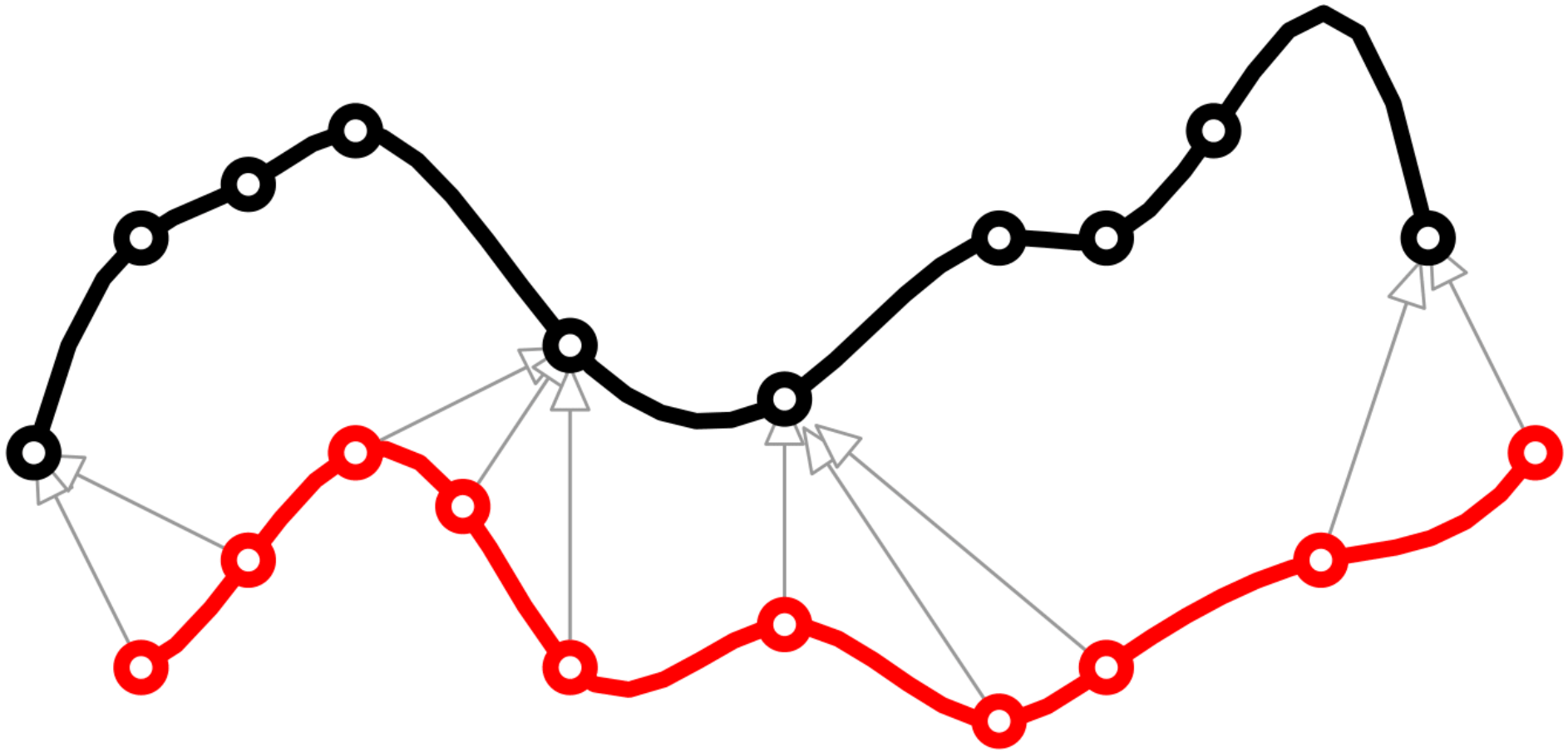
How to compare the distance between task space paths?

Borrow from computational geometry.

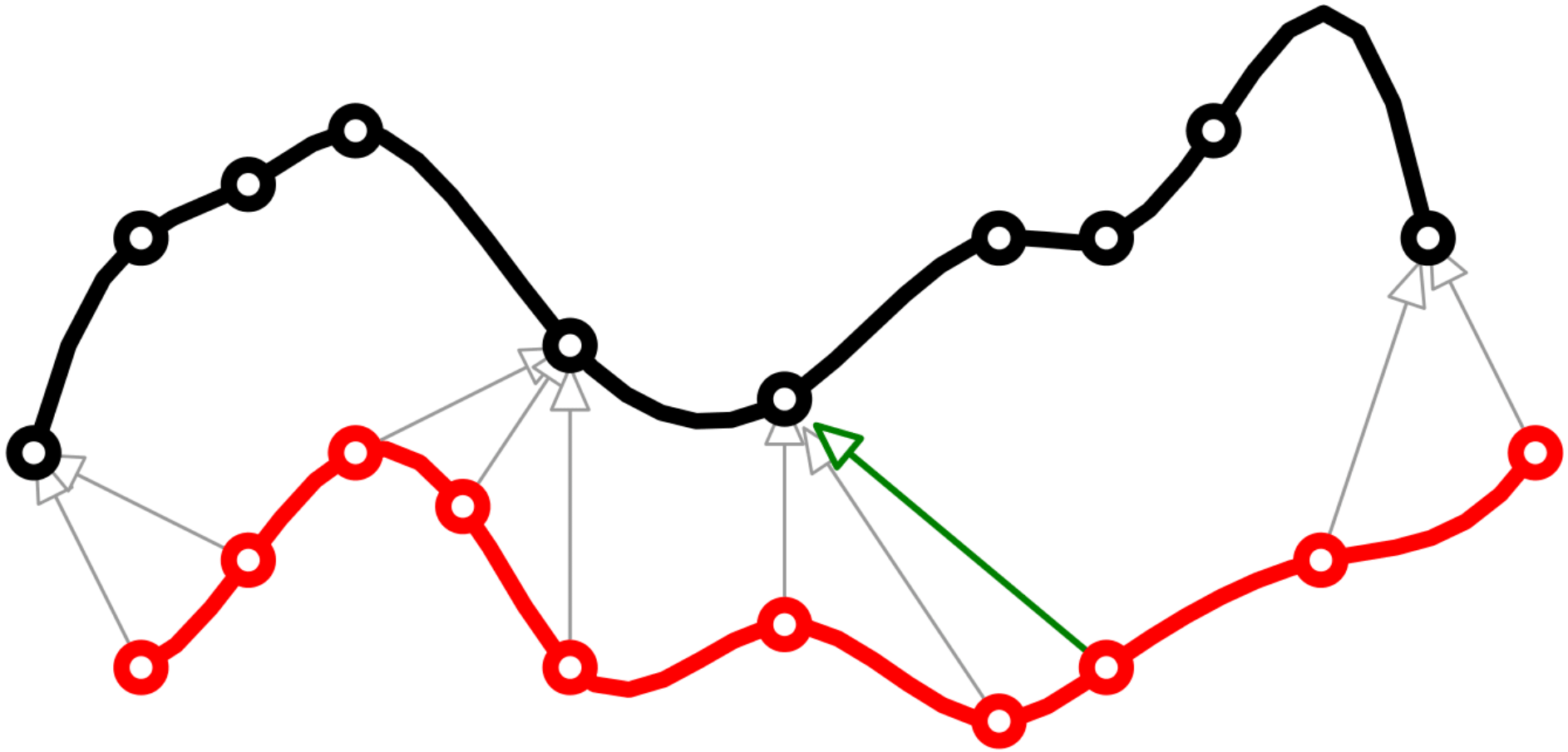


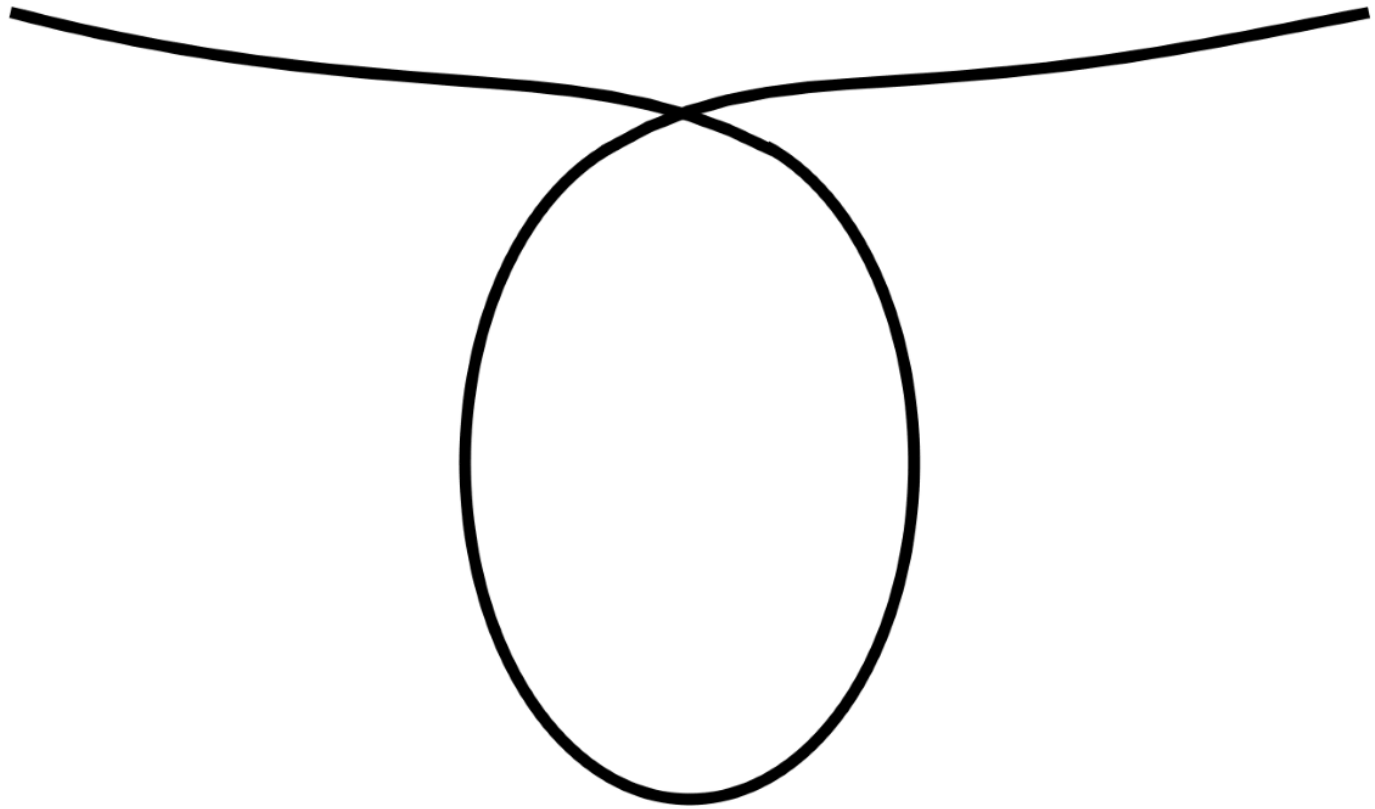


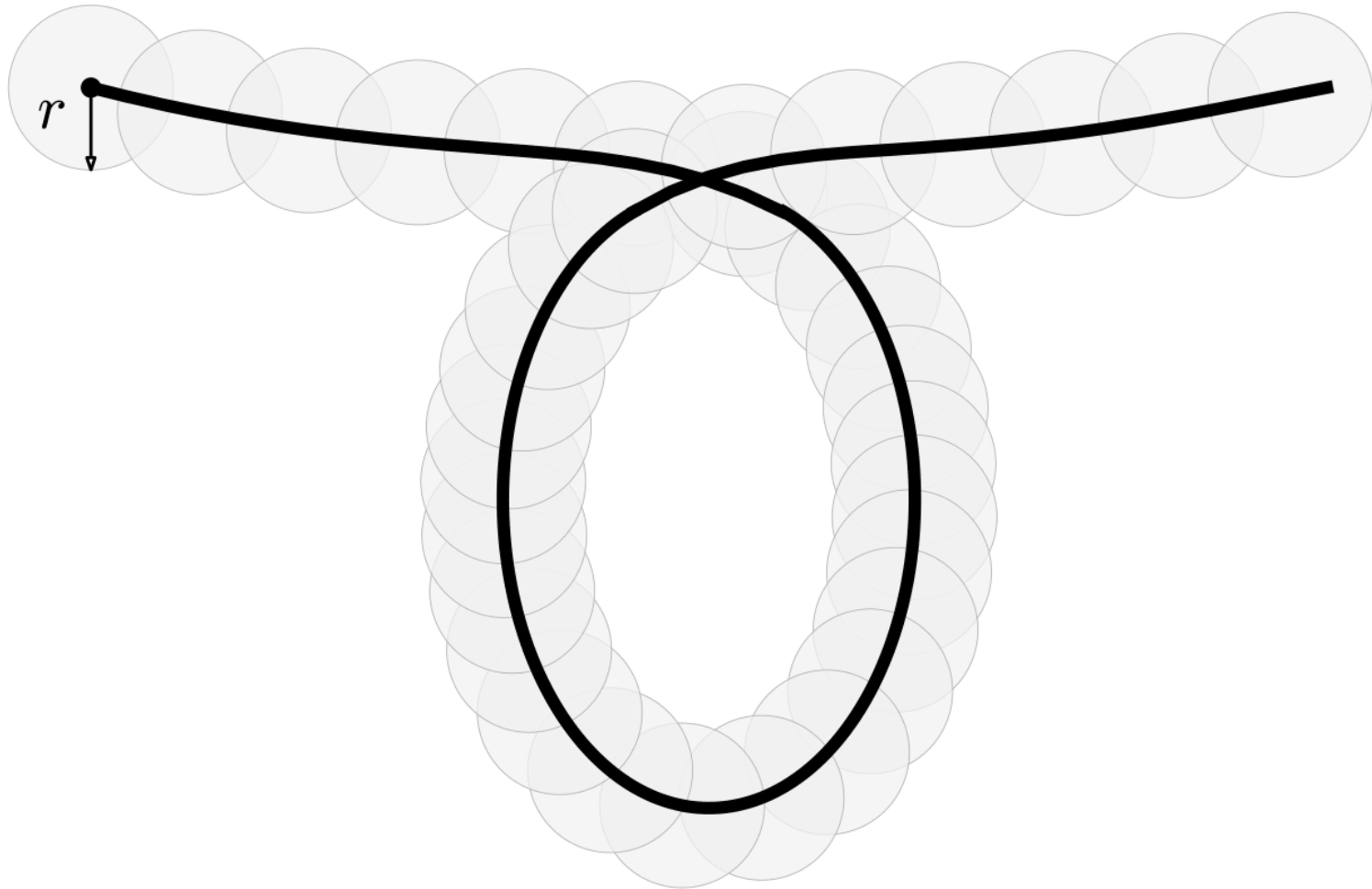




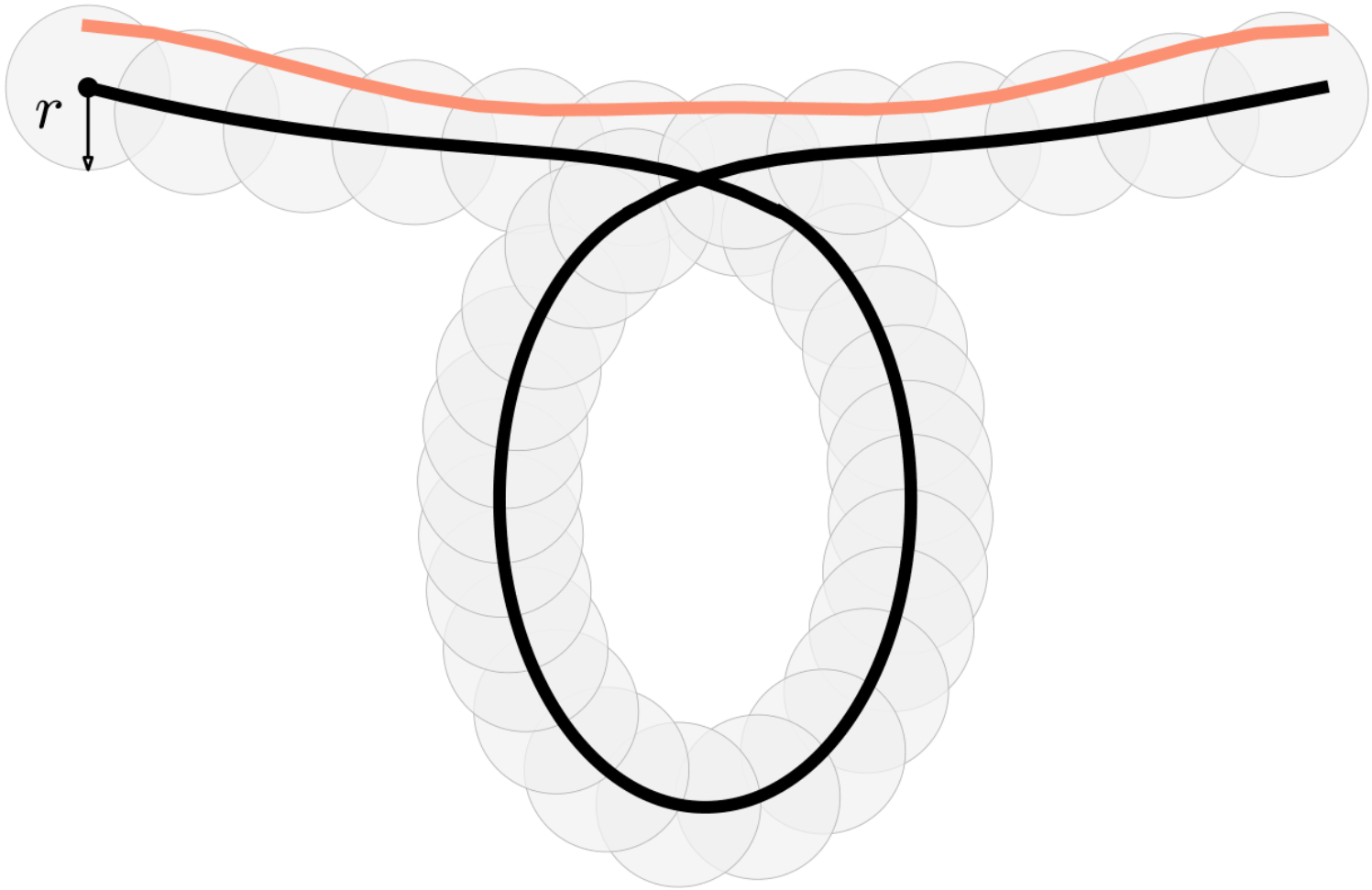
One-way Hausdorff Distance



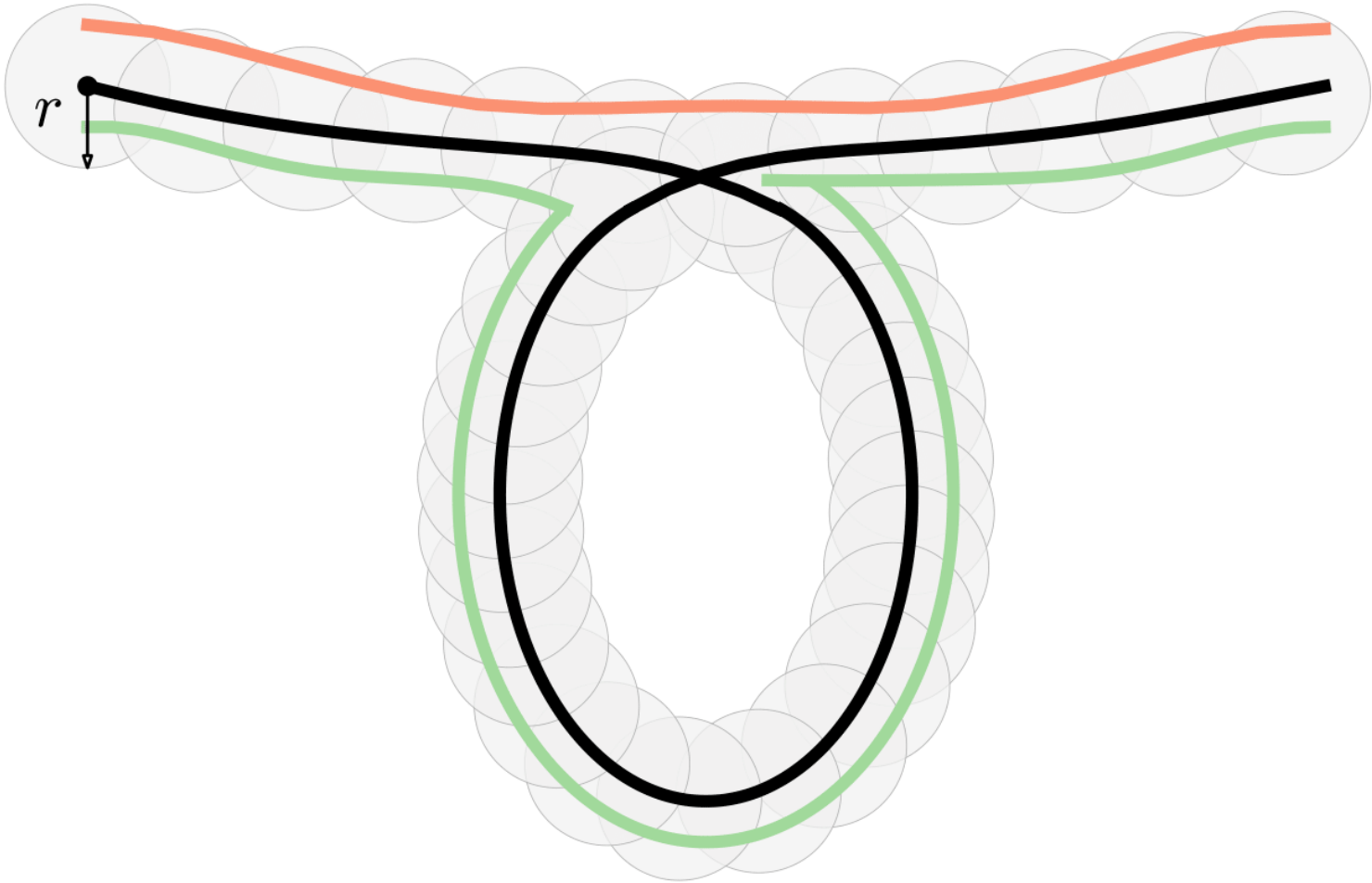



r

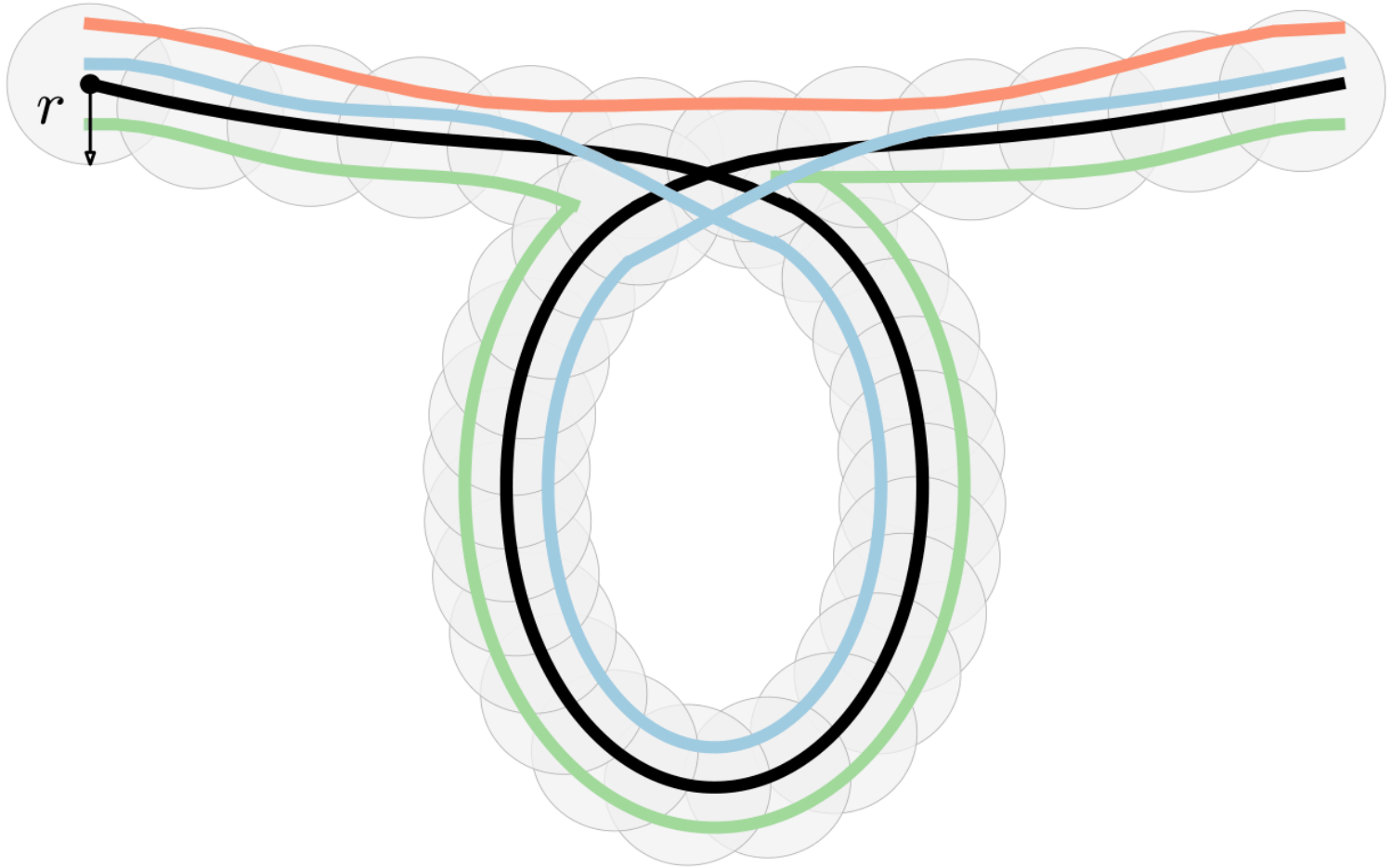
One-way Hausdorff Distance

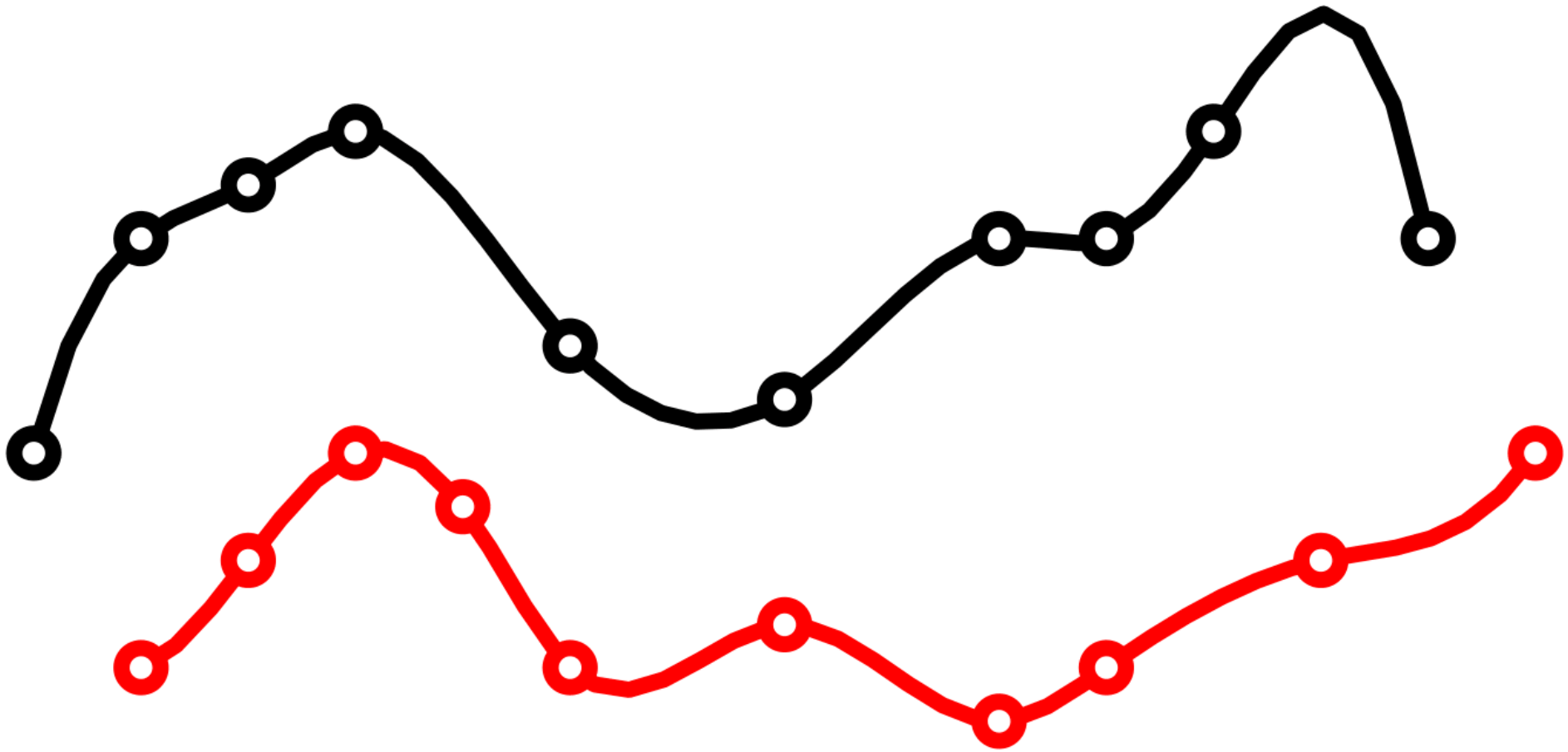


Two-way Hausdorff Distance



Follow Balls *in order*.

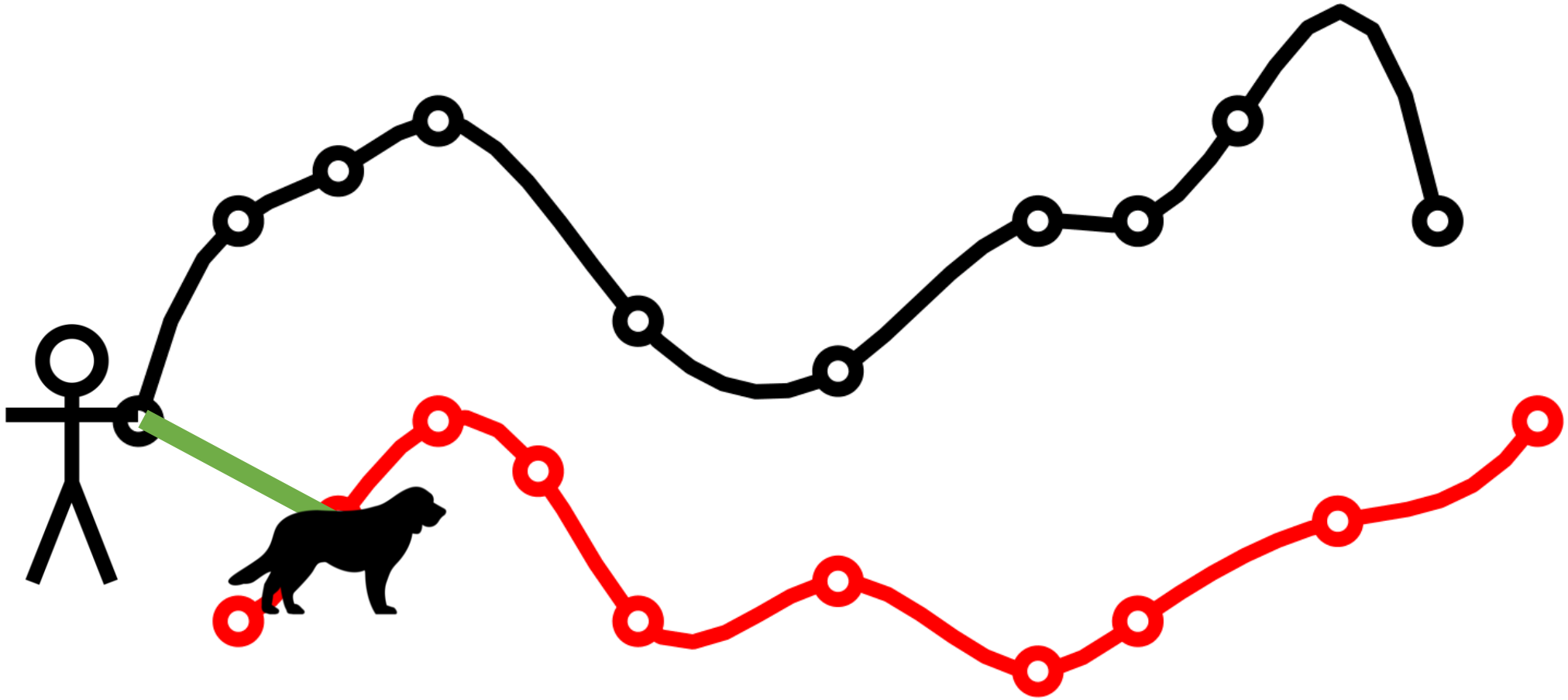




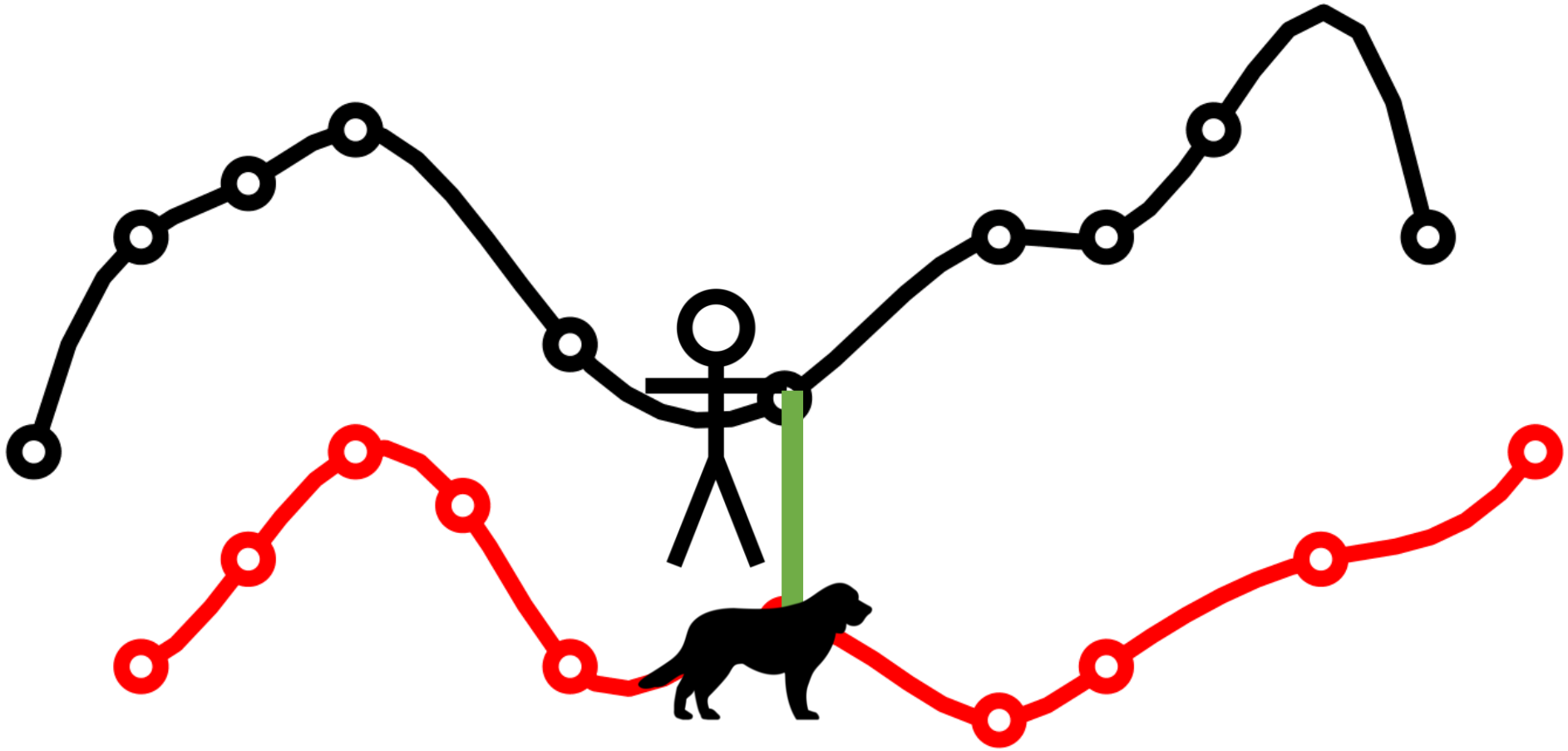
Fréchet Distance

Fréchet Distance

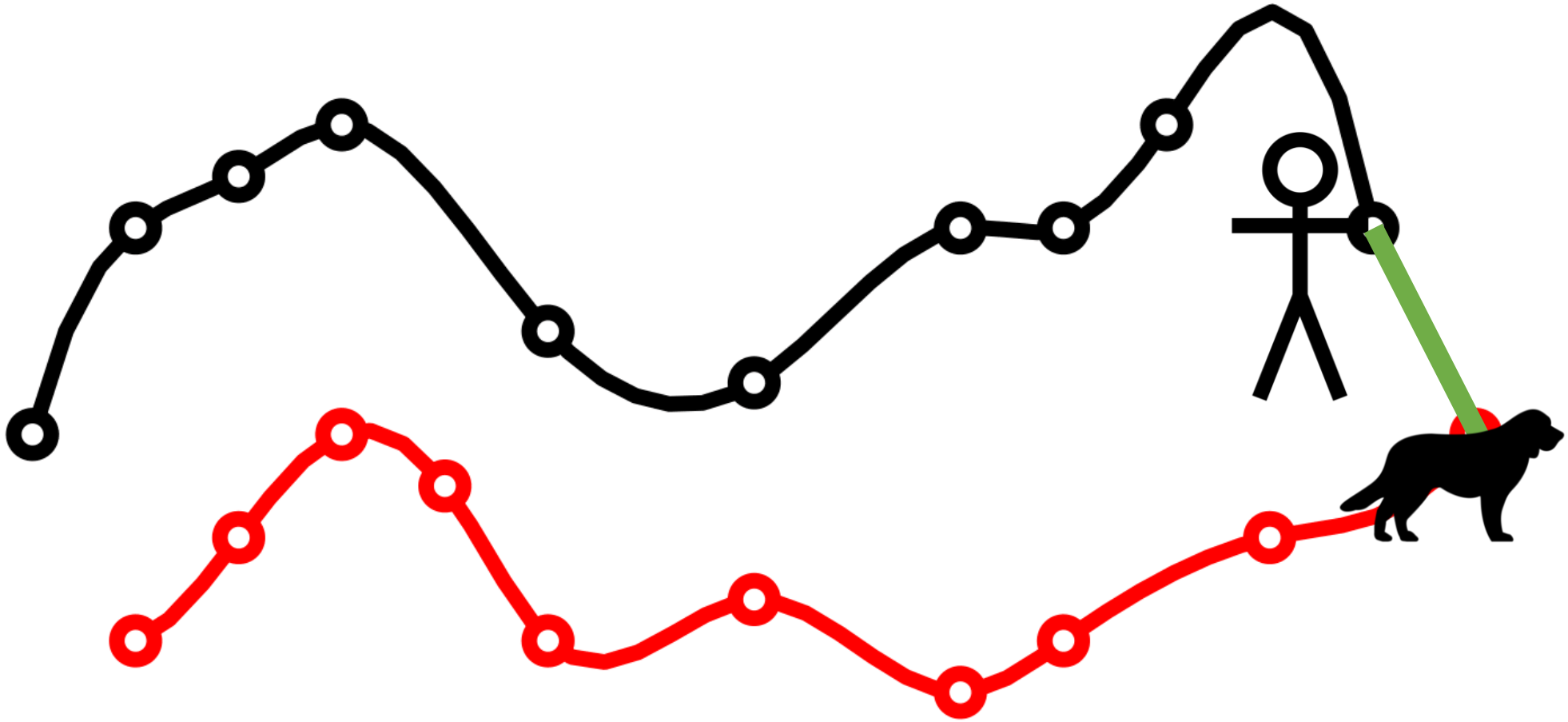
Fréchet Distance



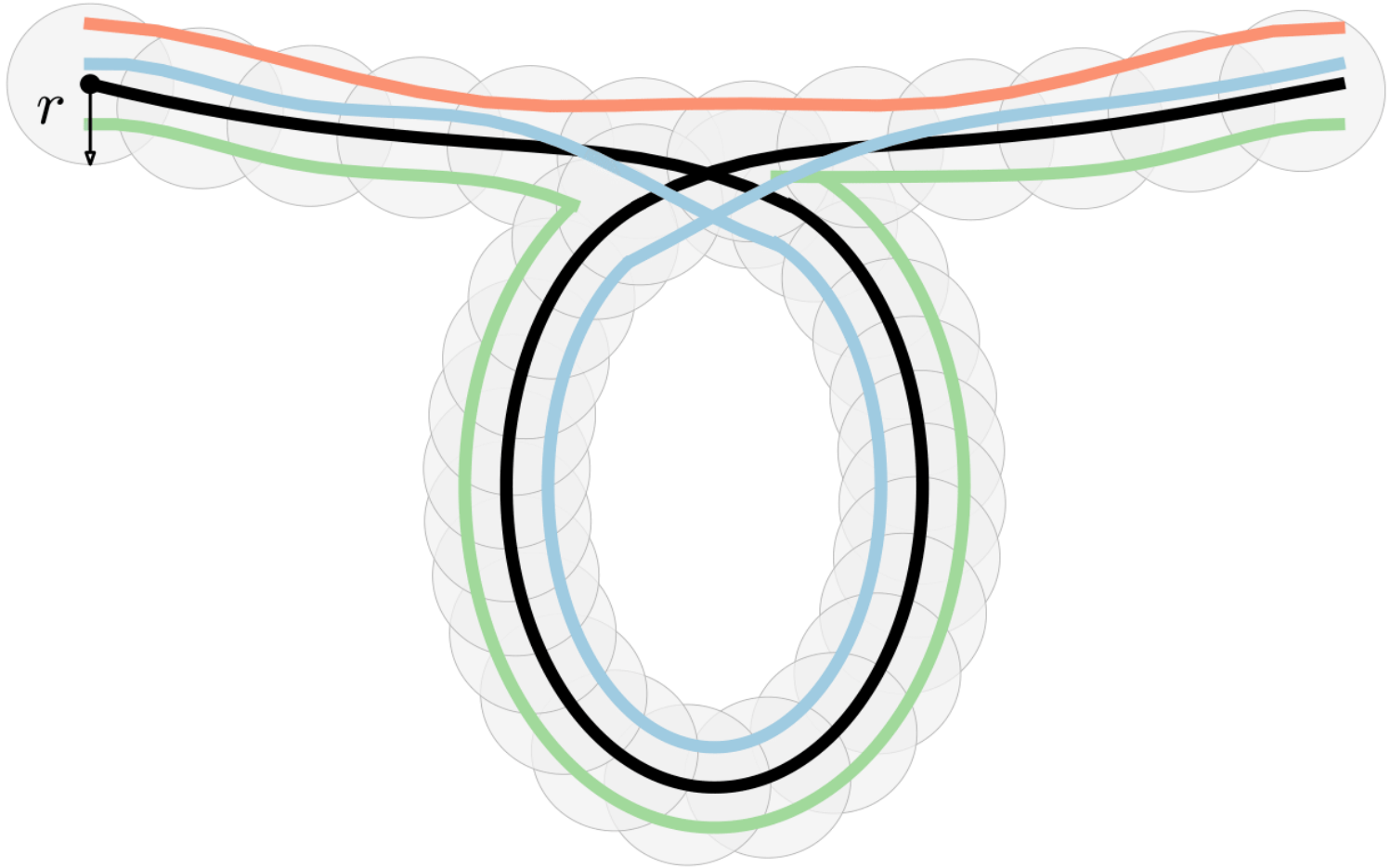
Fréchet Distance



Fréchet Distance

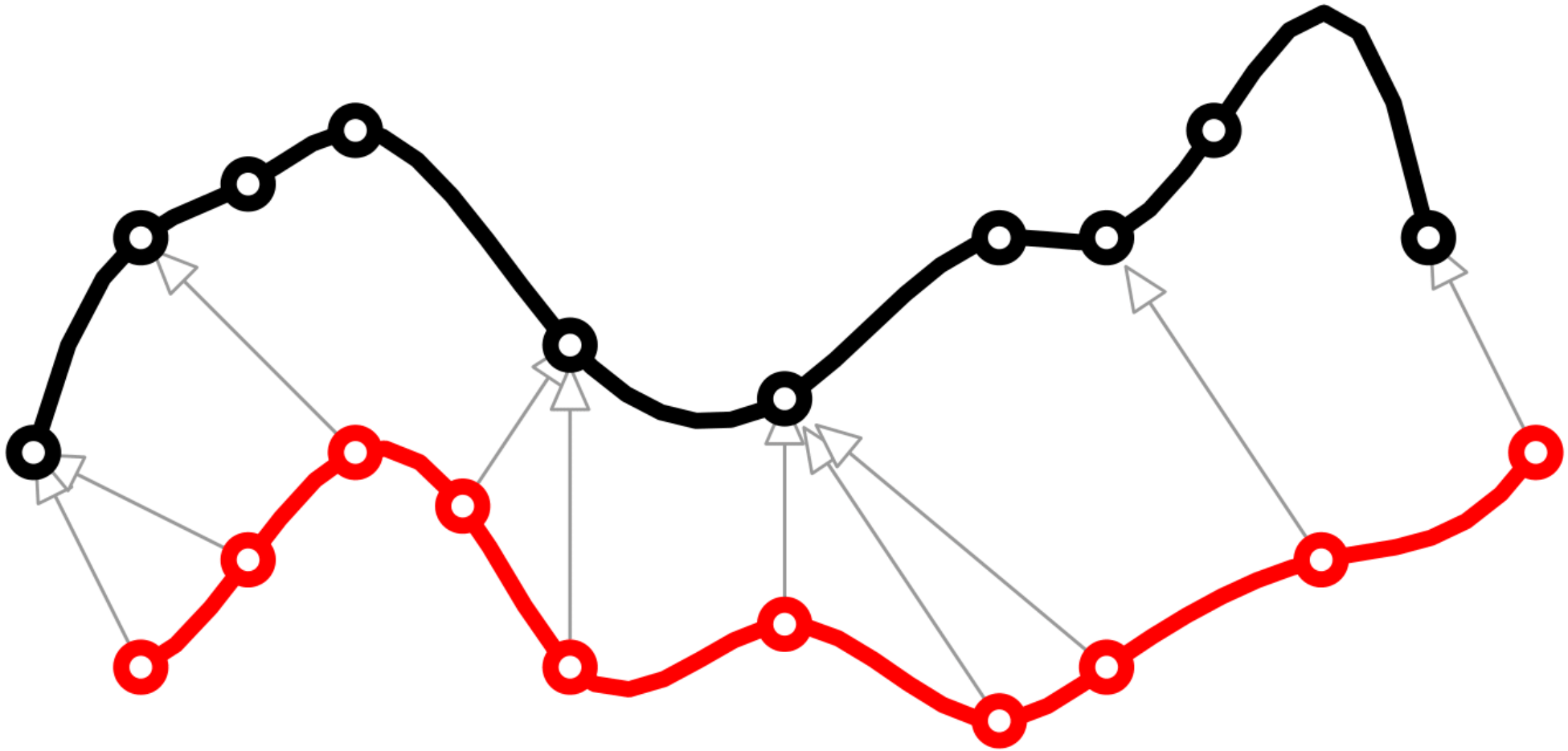


Fréchet Distance

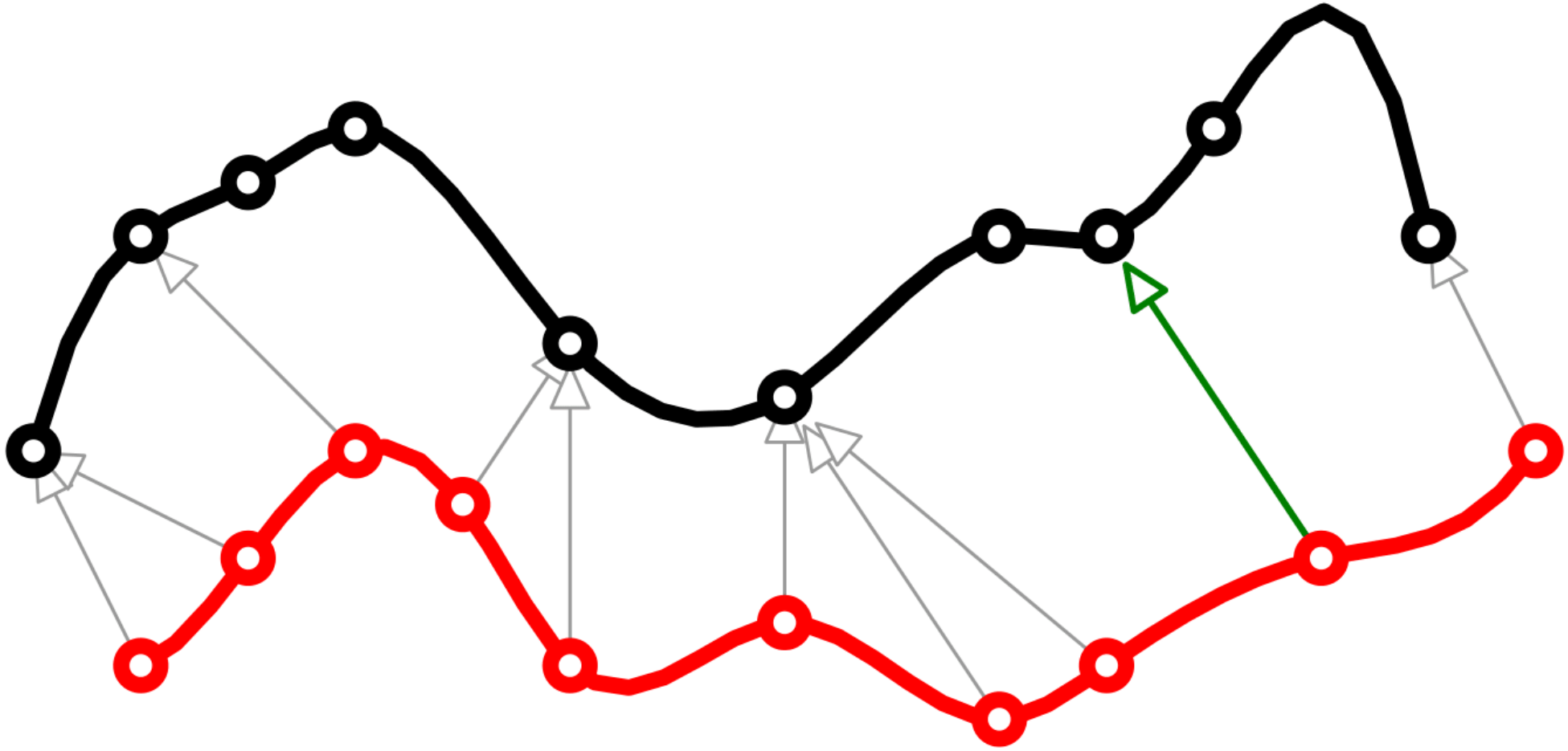


Use the Fréchet Distance to capture the task space distance between paths.

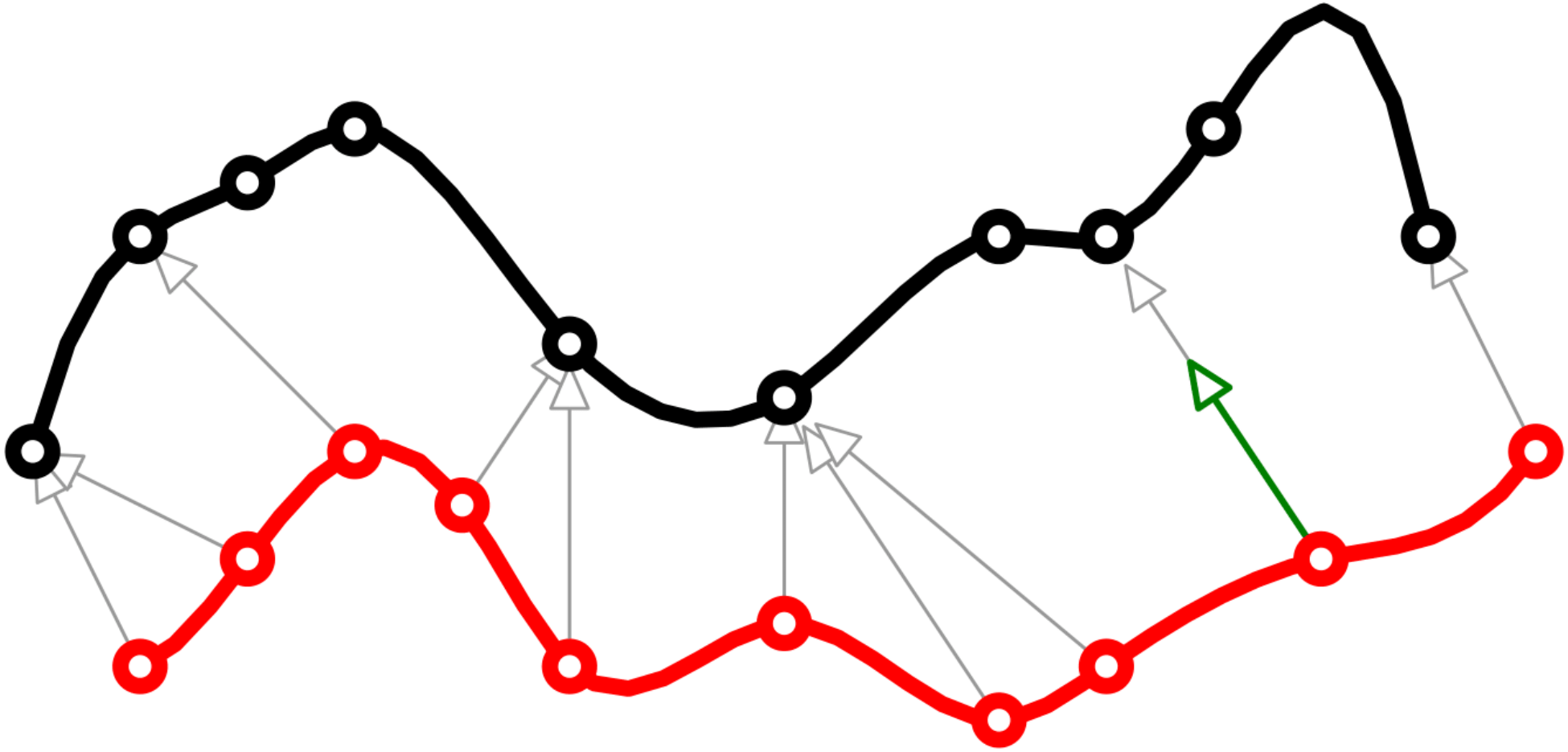
Gradient of Distance Function



Gradient of Distance Function



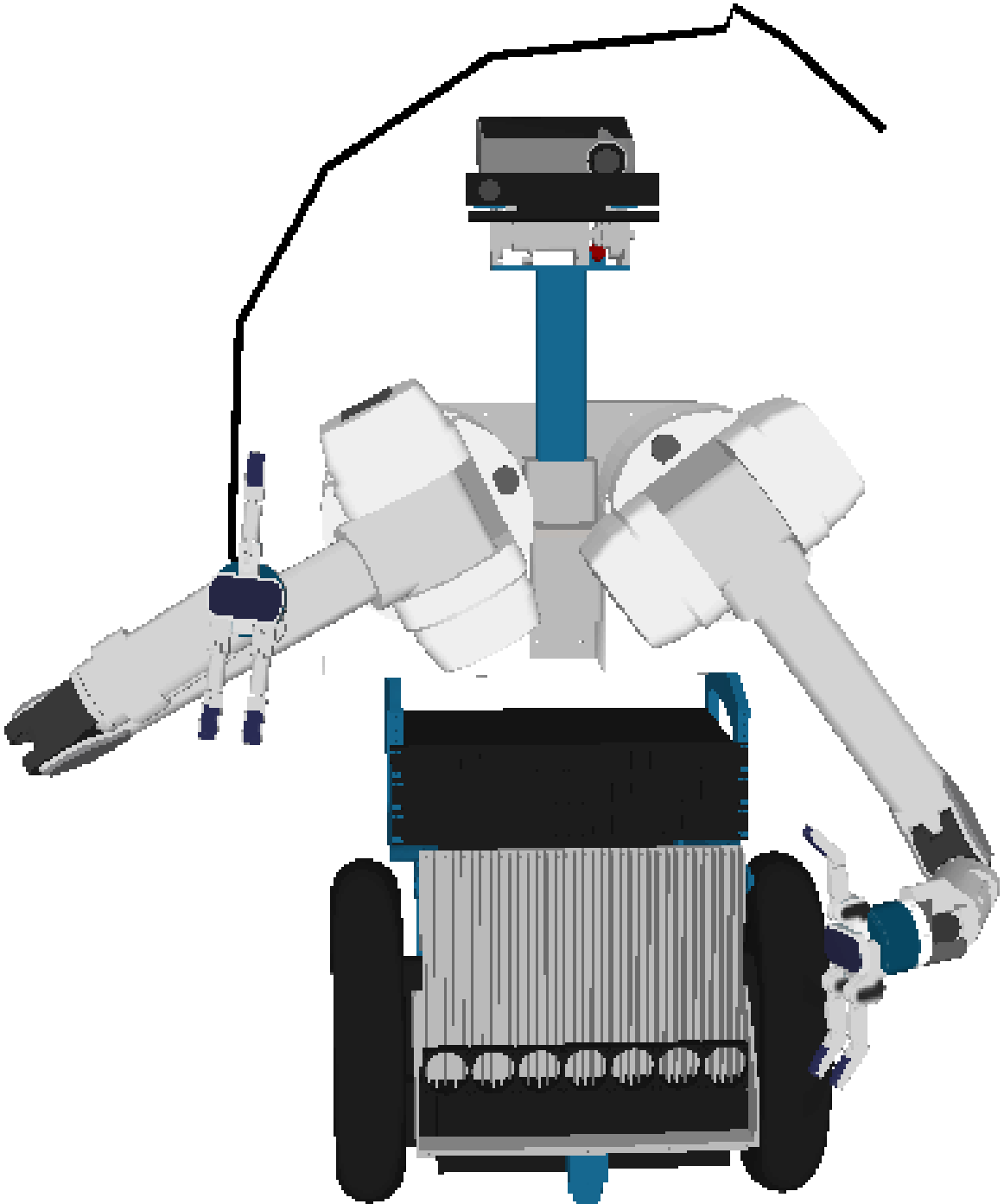
Gradient of Distance Function

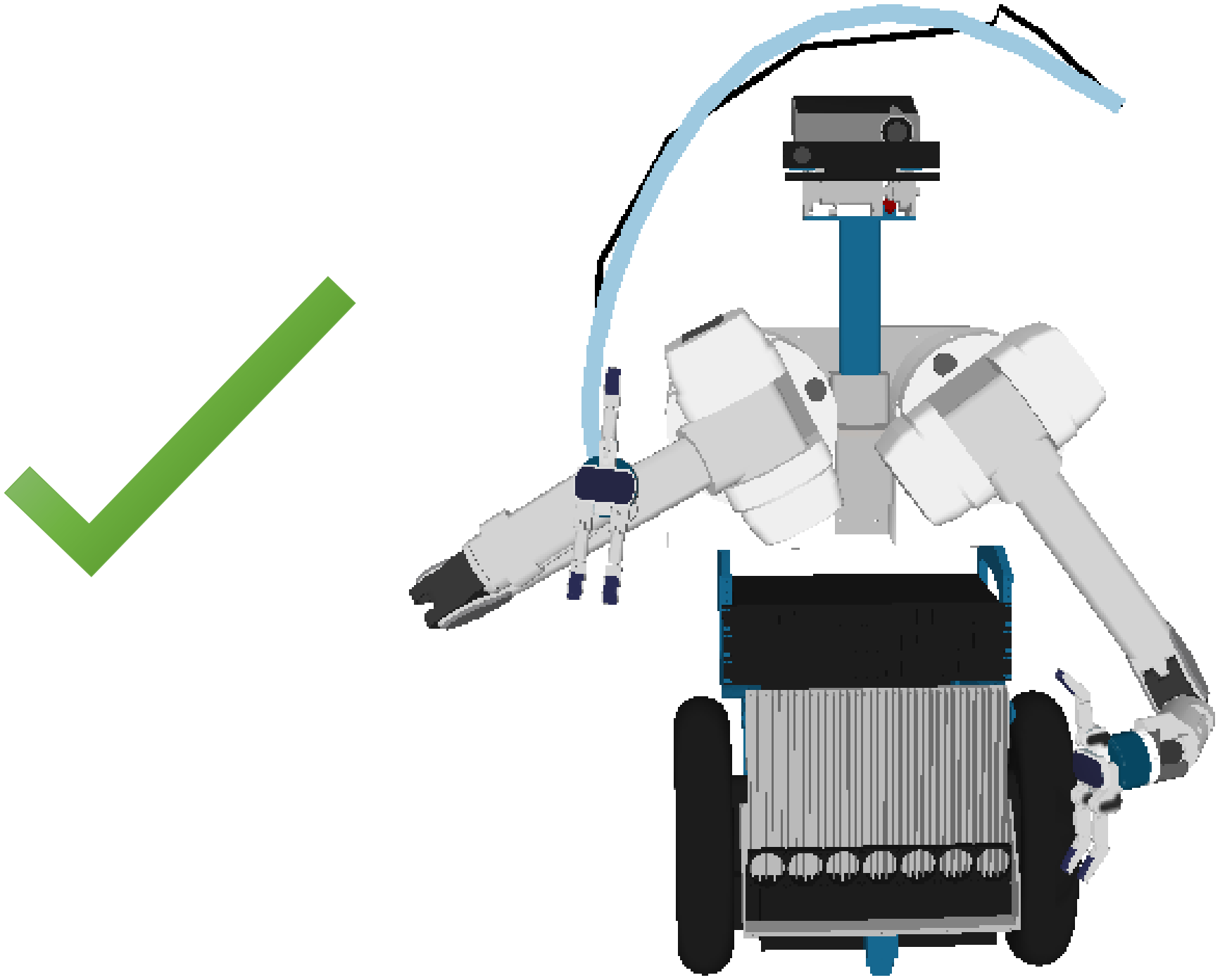


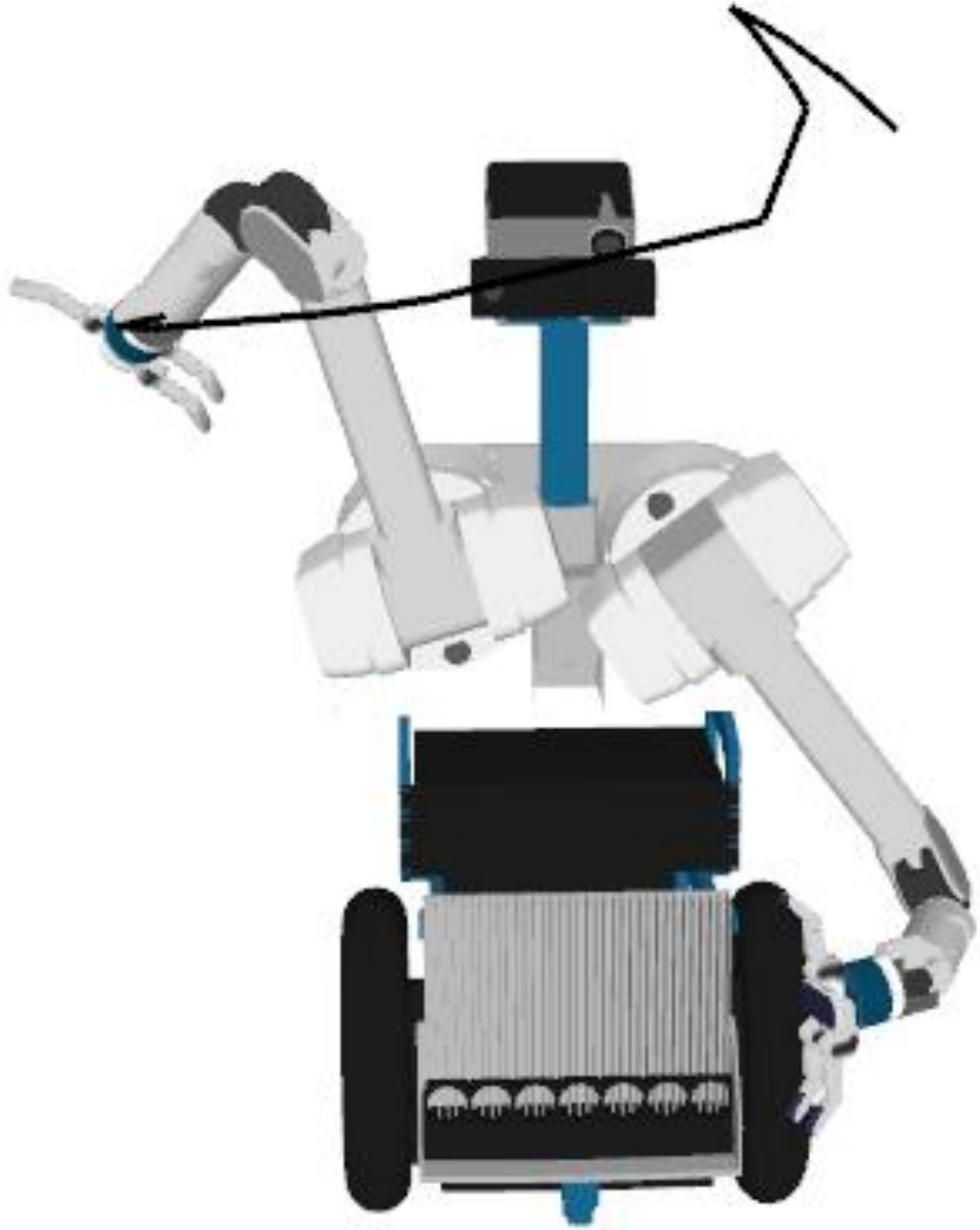
$$\xi^* = \arg\min_{\xi \in \Xi} ||\xi - \bar{\xi}|| \quad \text{s.t. constraints}$$

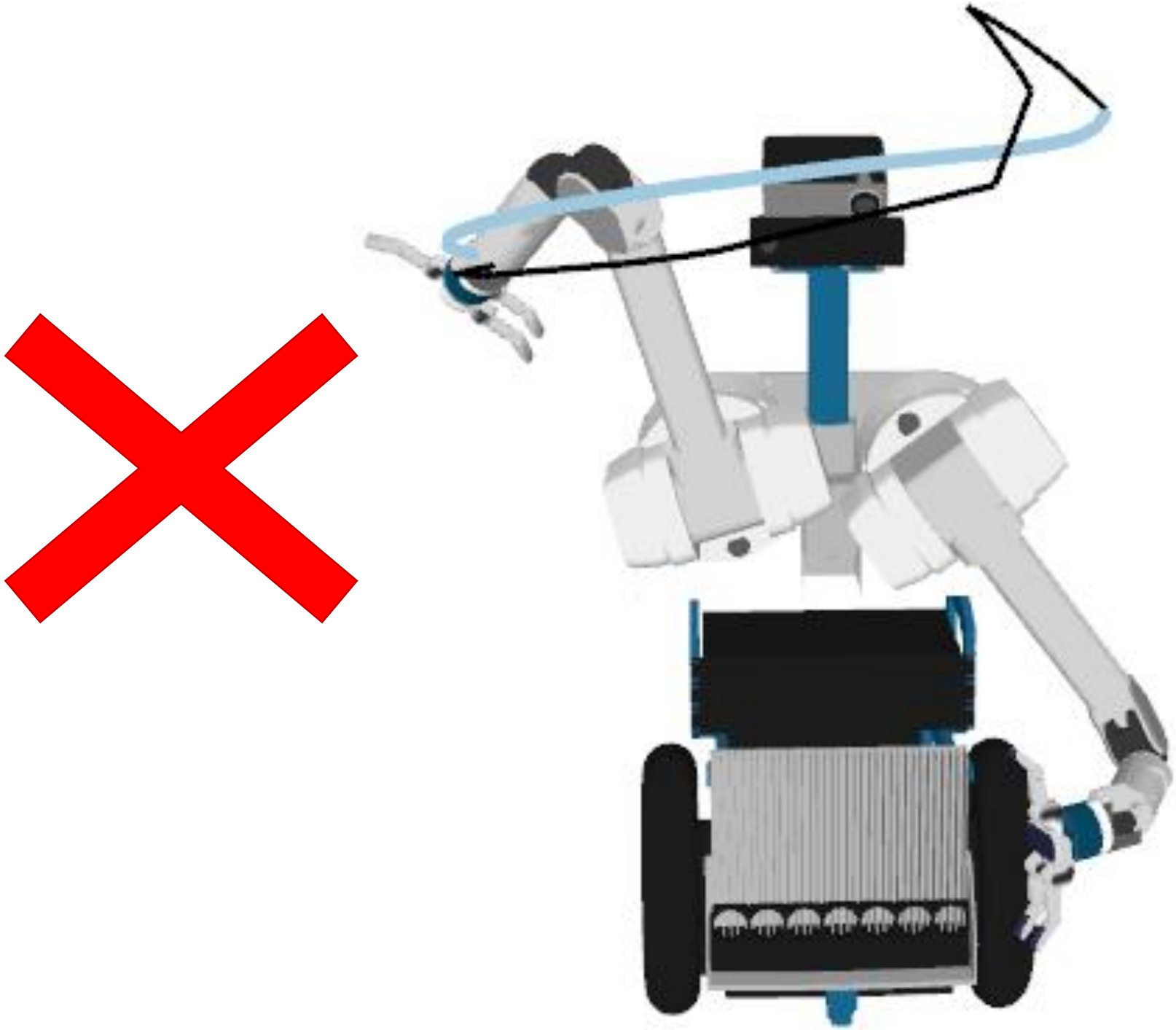
$$\xi^* = \arg\min_{\xi \in \Xi} ||\xi - \bar{\xi}|| \quad \text{s.t. constraints}$$

Discrete Fréchet

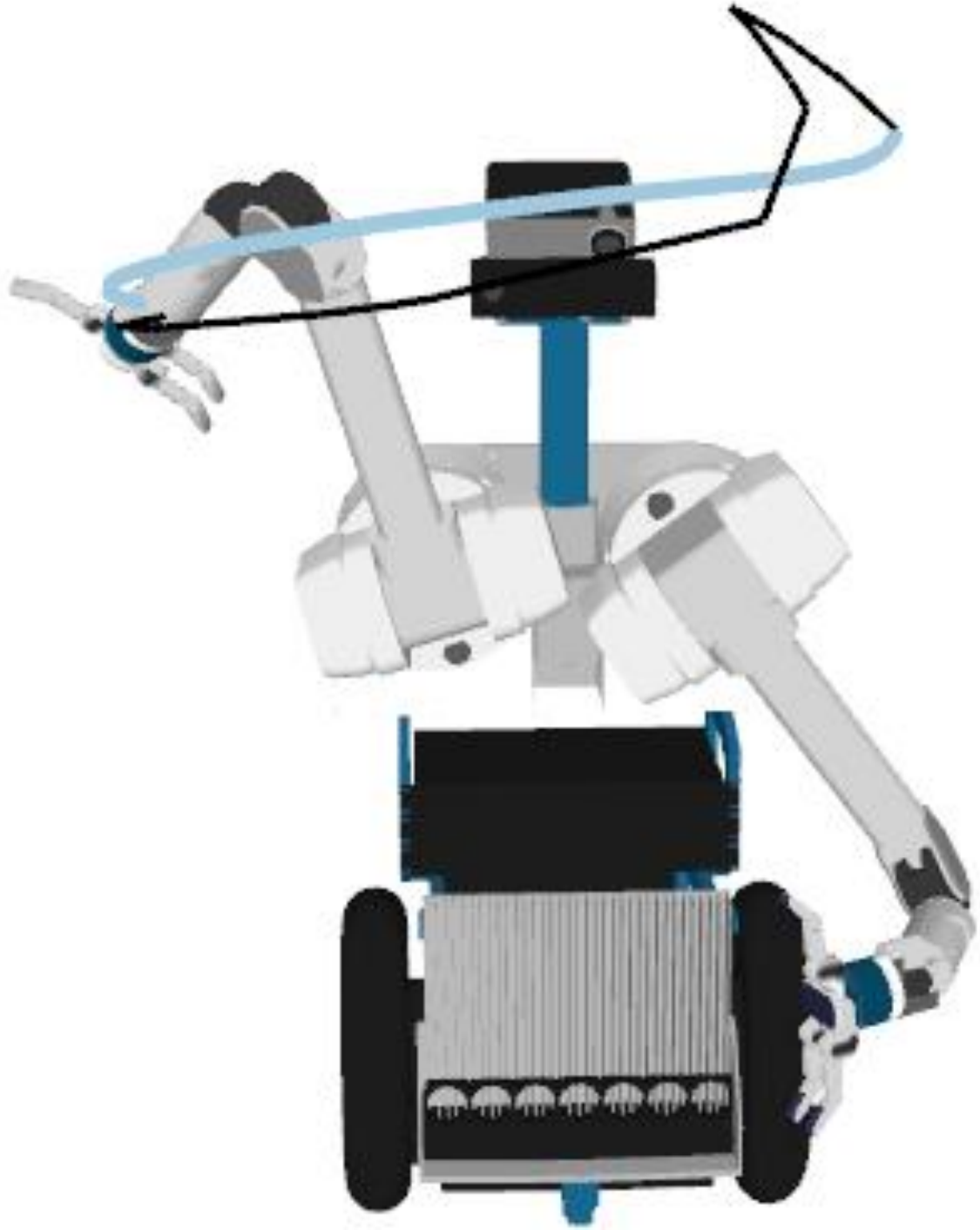


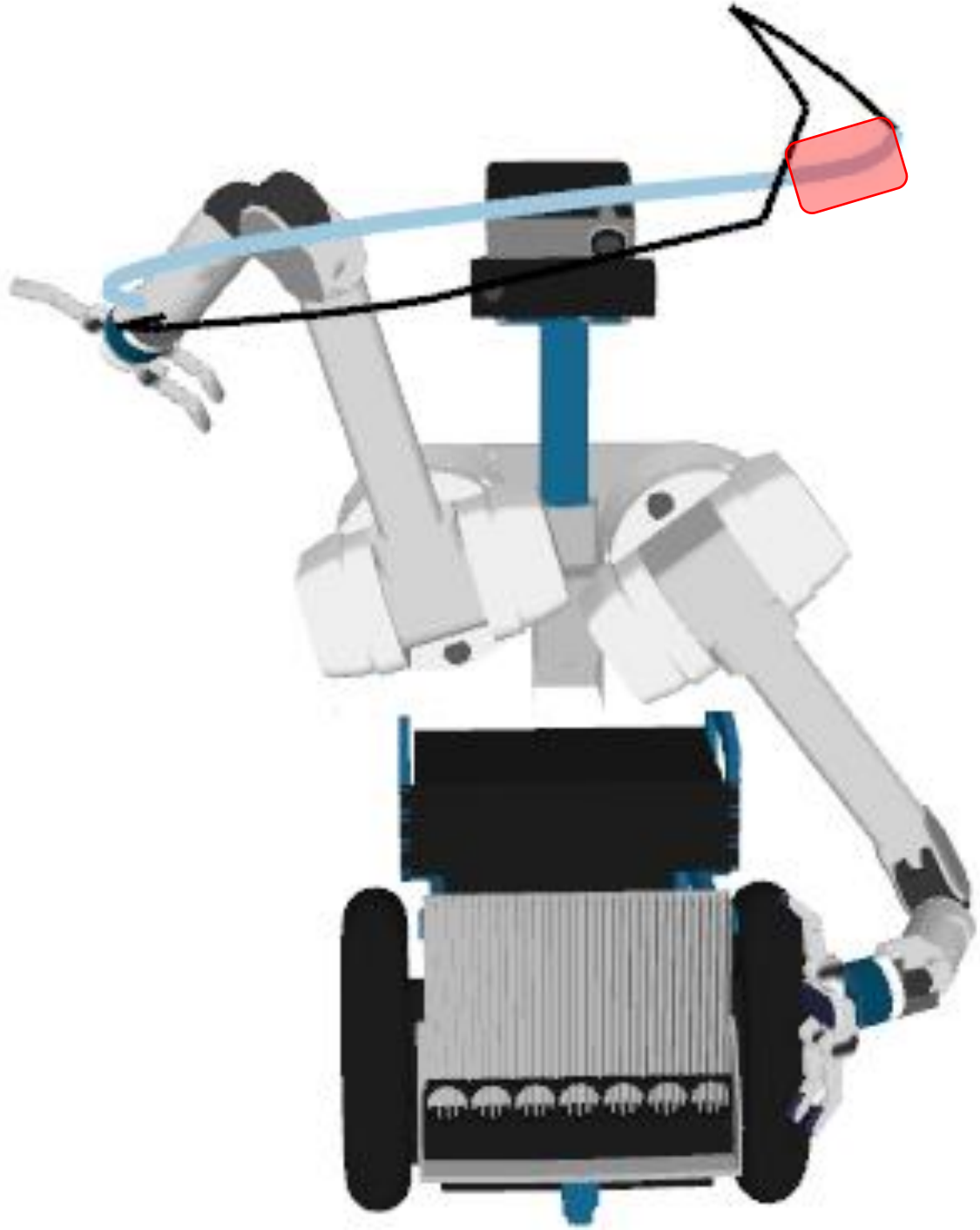




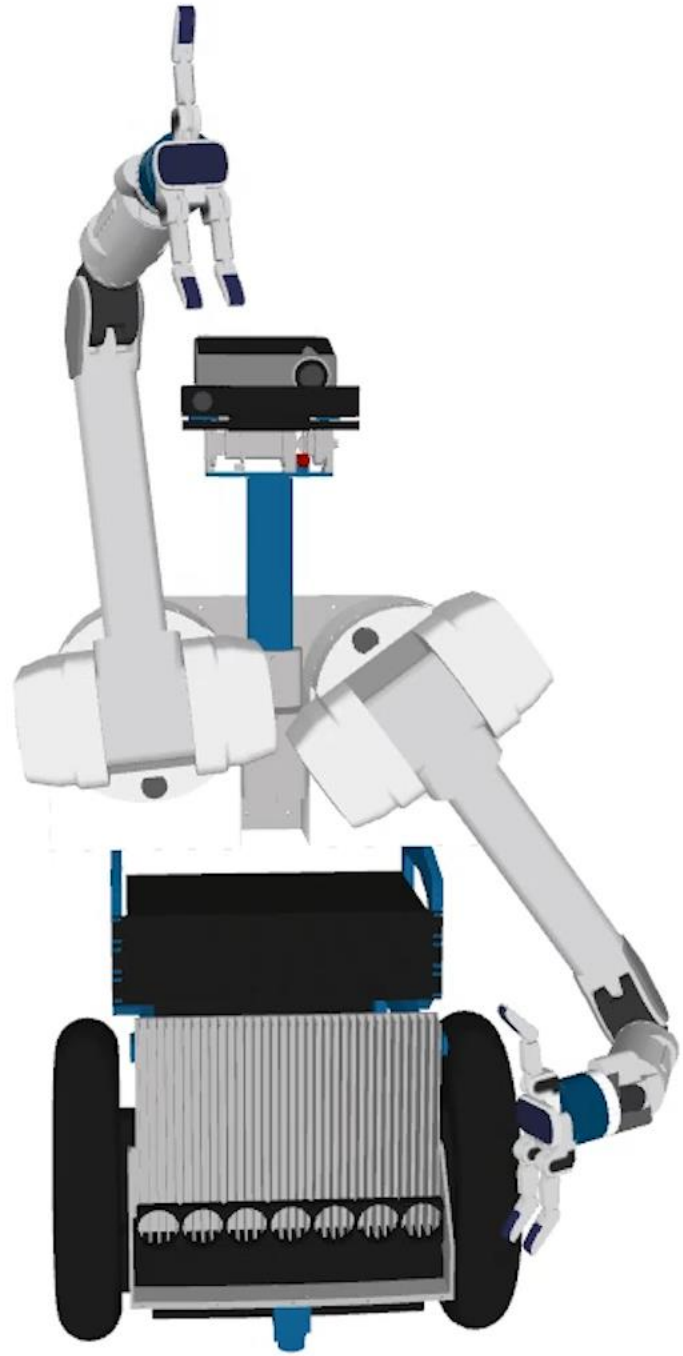


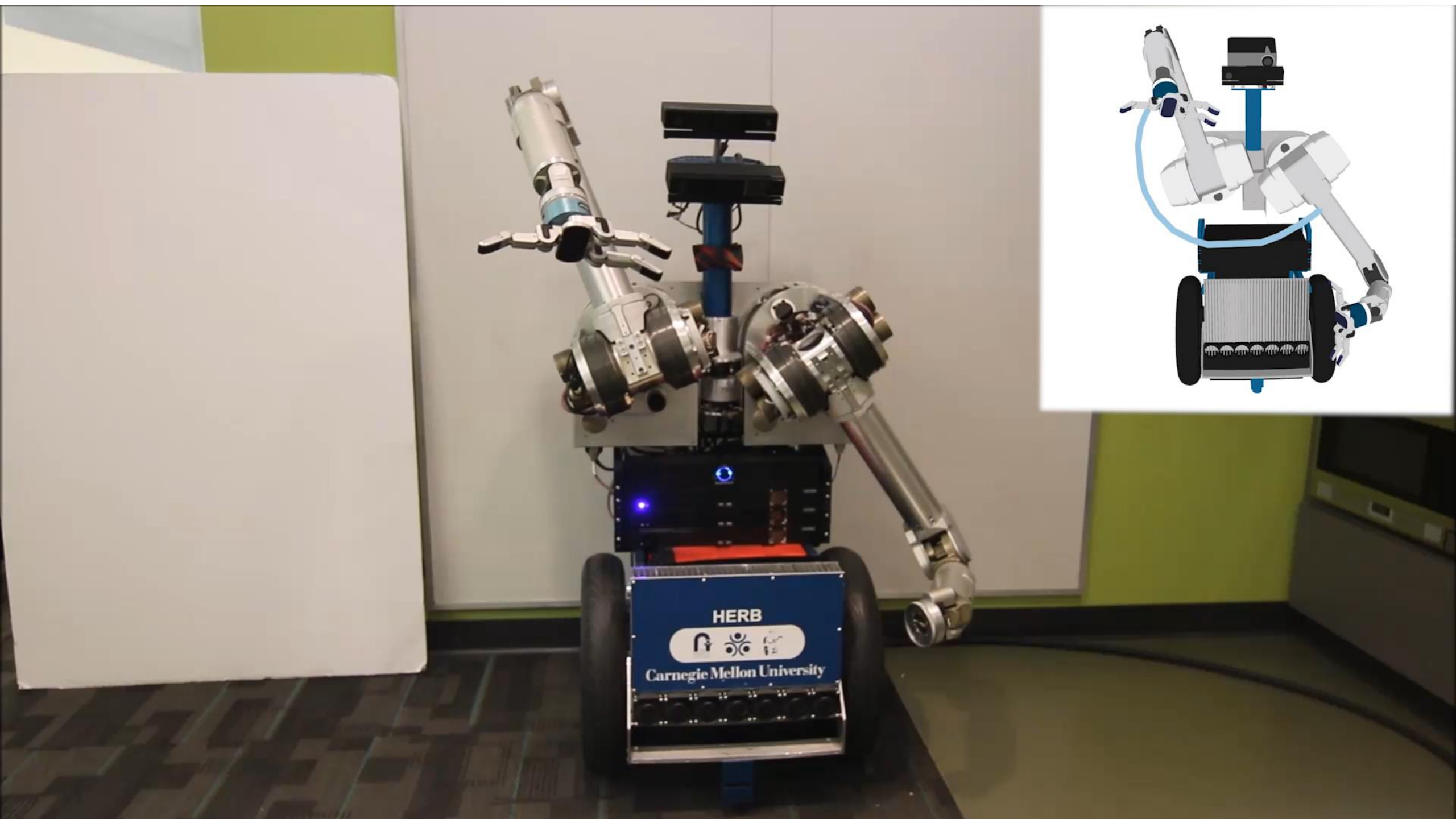
How can we assist our optimizer?





Use our distance metrics to find the areas that need additional constraints.

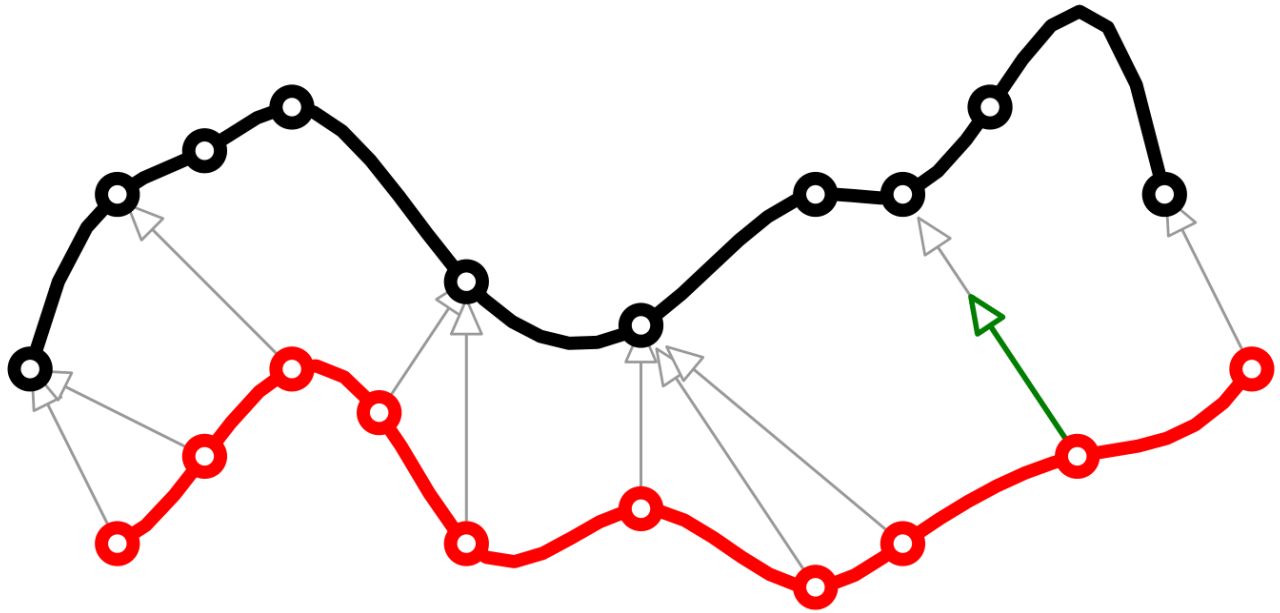



HERB
Carnegie Mellon University

Key Insight

Use trajectory optimization to optimize our path to be close to our reference path.

Use computational geometry techniques to measure task space distance between paths.



Distance Metrics and Algorithms for Task Space Path Optimization

Rachel Holladay
Siddhartha Srinivasa

https://www.personalrobotics.ri.cmu.edu
http://www.andrew.cmu.edu/user/rmh/

THE ROBOTICS INSTITUTE