

HW 4: Grasping

Due March 20, 2020

We don't mind if you work with other students on your homework. However, each student must write up and turn in their own assignment (i.e. no copy & paste). If you worked with other students, please **acknowledge who you worked with** at the top of your homework.

1. Force-Closure

Consider the part below

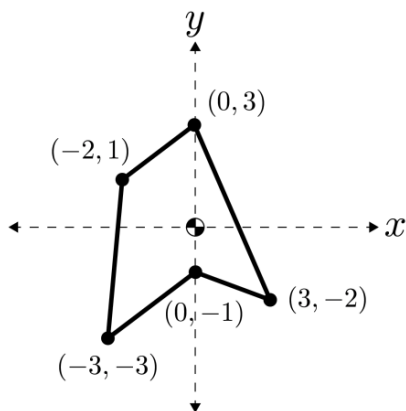


Figure 1: Concave part with CoM at (0,0)

- Construct a frictionless force closure grasp of the part with four contacts using instantaneous construction (showing that no valid centers of rotation exist).
- Draw the convex hull of the part.

2. Intro to Grasping

Prove Theorem 5.6 in MLS: Show that a planar grasp composed of two point contacts with friction is in force closure if and only if the line connecting the contact points lies inside both friction cones. *Hint: Consider proving the contrapositive — if the line between the contacts is not in the cones, then the grasp cannot be in force closure*

3. Task-based Grasping

While force closure considers the ability of a grasp to resist any wrench, in some real world cases we may desire to resist only a specific set of wrenches.

- Let's say you want to resist some wrench F_e using a grasp G . In this case you would need to find f_c such that $Gf_c = -F_e$. How do we solve for f_c using constrained least squares?
- When would you expect your solution to have nonzero cost?
- Regression can be formatted as a minimization of square error

$$\min_{variables} F(f_c)$$

What does adding this second term do?

$$\min_{variables} (F(f_c) + \lambda \|f_c\|^2)$$

Why would you use it? There's no need to prove anything.

- (d) Since the level sets of the friction cone are circles, the friction cone constraint is quadratic. How would you modify this constraint to make it linear? Write an algorithm to do this below. Feel free to use pseudocode.

4. Short Problems

- (a) *Static Equilibrium* Let's say you have three non-zero forces applied to a 2D object. What condition must apply for the net force on the object to be zero?
- (b) *Convex Hulls and Force Closure* For a grasp to be in force closure, the convex hull of the forces must contain the origin of the part.
- i. Explain what this means intuitively, supplementing your explanation with pictures.
 - ii. What is the minimum number of frictionless contacts needed to put a 2D object in force closure?
- (c) *Grasp Metrics* What is the difference between the Force Closure grasp metric and the Ferrari-Canny grasp metric? Explain in a couple sentences.

5. Research Comprehension

Read this [paper](#) and answer the following questions:

- (a) What grasp quality metric are they using. Explain how it works intuitively.
- (b) What is Thompson sampling and how is it used in DexNet?