EECS 106B/206B

Discussion 7

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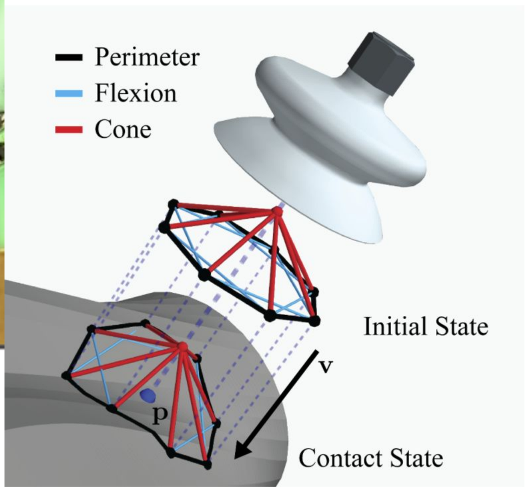
Action Items

- Concurrent Enrollment lab access?
- Homework 2 due this weekend
- Lab Due in 5 days!!!!

Intro to Grasping



Problems with grasping:

- Perceiving and identifying objects
- Designing end effectors
- Grasp planning (will the grasp work) ******
    - Shape
    - Density
    - Material
- Grasp execution (how do we know it worked?) ***
    - Applying forces
    - Manipulating objects
    - Regrasping

Finger Contacts

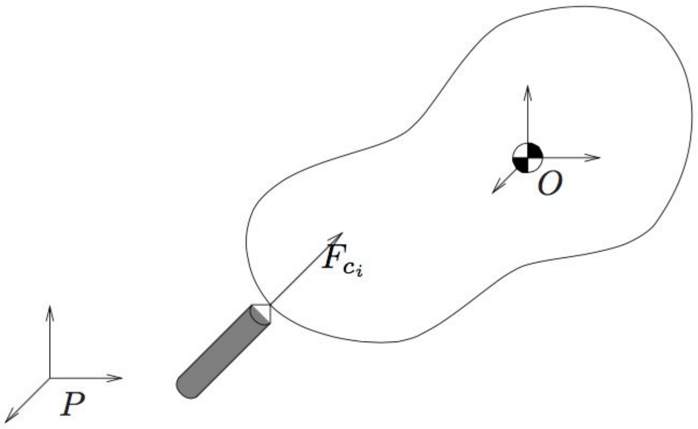
- How do we measure the effect of a multifingered grasp?

$$F_{c_i} = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} f_{c_i} \quad f_{c_i} \geq 0,$$

Force

Wrench Basis (B)

Weights

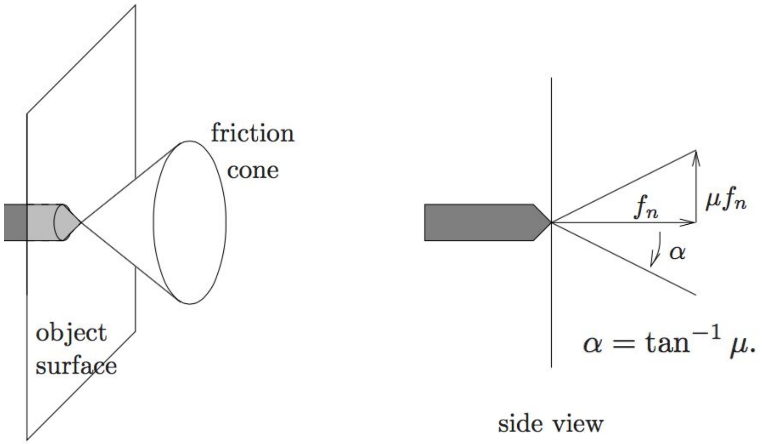


$$\boxed{F_{c_i} = B_{c_i} f_{c_i} \qquad f_{c_i} \in FC_{c_i}.}$$

Grasps with Friction

$$F_{c_i} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} f_{c_i} \qquad f_{c_i} \in FC_{c_i},$$

$$FC_{c_i} = \{f \in \mathbb{R}^3 : \sqrt{f_1^2 + f_2^2} \leq \mu f_3,\ f_3 \geq 0\}.$$



Torsional Friction

$$F_{c_i} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} f_{c_i} \qquad f_{c_i} \in FC_{c_i}$$

$$FC_{c_i} = \{f \in \mathbb{R}^4 : \sqrt{f_1^2 + f_2^2} \leq \mu f_3,\ f_3 \geq 0,\ |f_4| \leq \gamma f_3\},$$

Multiple Fingers: Grasp Maps

Having multiple fingers means we should use the world frame, rather than individual contact frames. So we use the Adjoint:

$$F_o = \mathrm{Ad}^T_{g^{-1}_{oc_i}} F_{c_i} = \begin{bmatrix} R_{oc_i} & 0 \\ \widehat{p}_{oc_i} R_{oc_i} & R_{oc_i} \end{bmatrix} B_{c_i} f_{c_i}, \qquad f_{c_i} \in FC_{c_i}.$$

First, we define a contact map G:

$$G_i := \mathrm{Ad}^T_{g^{-1}_{oc_i}} B_{c_i}.$$

This maps the contact basis to a wrench in the world frame.

Combining multiple fingers

The net force on the object is:

$$F_o = G_1 f_{c_1} + \cdots + G_k f_{c_k} = \begin{bmatrix} G_1 & \cdots & G_k \end{bmatrix} \begin{bmatrix} f_{c_1} \\ \vdots \\ f_{c_k} \end{bmatrix}$$

We can redefine the array $\begin{bmatrix} G_1 & \cdots & G_k \end{bmatrix}$ as a new mapping:

$$G = \begin{bmatrix} \mathrm{Ad}^T_{g^{-1}_{oc_1}} B_{c_1} & \cdots & \mathrm{Ad}^T_{g^{-1}_{oc_k}} B_{c_k} \end{bmatrix} \qquad F_o = G f_c \qquad f_c \in FC;$$

This is the grasp map, which maps an entire hand to a wrench in the world frame.

Force Closure

Proposition 5.3. Convexity conditions for force-closure grasps *Consider a fixed contact grasp which contains only frictionless point contacts. Let* $G \in \mathbb{R}^{p \times m}$ *be the associated grasp matrix and let* $\{G_i\}$ *denote the columns of* G. *The following statements are equivalent:*

1. *The grasp is force-closure.*
2. *The columns of* G *positively span* $\mathbb{R}^p$.
3. *The convex hull of* $\{G_i\}$ *contains a neighborhood of the origin.*
4. *There does not exist a vector* $v \in \mathbb{R}^p$, $v \neq 0$, *such that for* $i = 1, \ldots, m$, $v \cdot G_i \geq 0$.

Force Closure Alternate Definition

Line between contacts is within both friction cones.

Why? This is in the next HW.

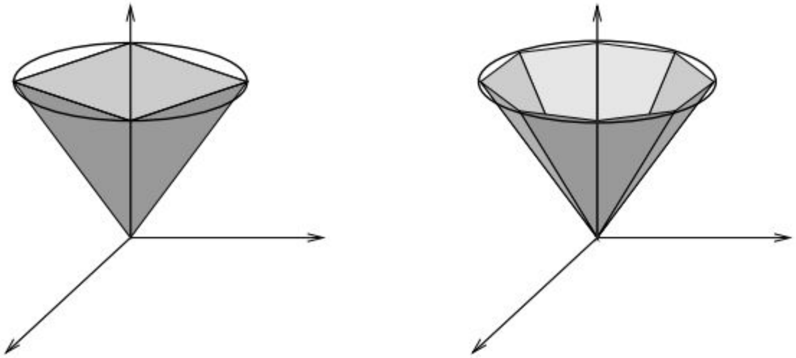
Limitations of Force Closure

- Assumes you can move fingers in any direction
- Assumes you can exert as much as infinite force
- Sometimes it’s better to execute suboptimal grasps

Approximating the Friction Cone

Why would you do this?

$$f_i = \begin{bmatrix} \mu \cos \frac{2\pi i}{n} \\ \mu \sin \frac{2\pi i}{n} \\ 1 \end{bmatrix}$$



Approximating the Friction Cone

Why would you do this?

You can simplify the constraints to a **Positive** linear combination of facet vectors

$$f_i = \begin{bmatrix} \mu \cos \frac{2\pi i}{n} \\ \mu \sin \frac{2\pi i}{n} \\ 1 \end{bmatrix}$$