From Caging to Grasping

ICRA 2011
Workshop on Uncertainty in Automation

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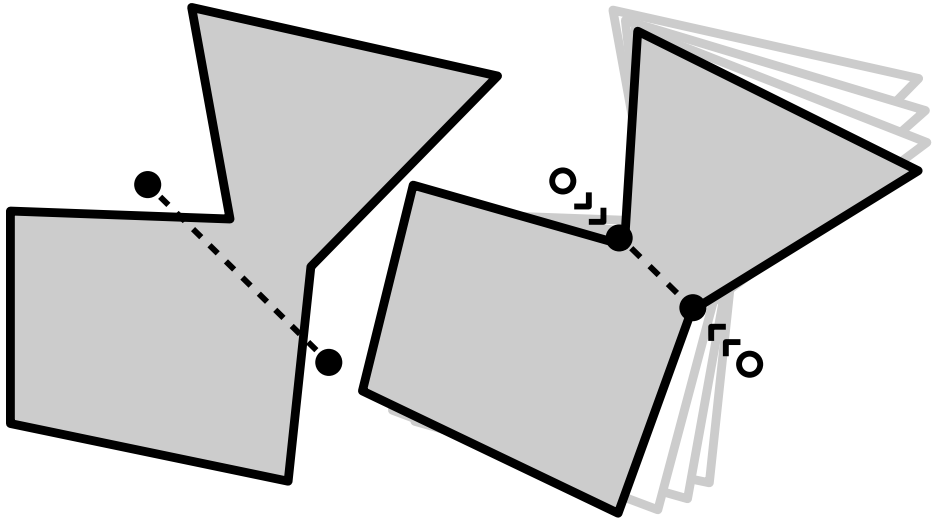
Caging

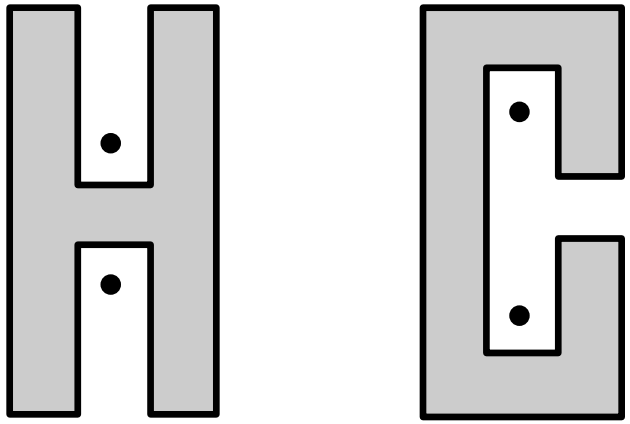


I. Non-prehensile manipulation.

II. Waypoint to a grasp.

From Caging to Grasping

- Two-fingered manipulators:
  - ✓ Squeezing and Stretching conditions.



  - ✓ Infallible strategy to reach a grasp.
  - ✓ All two-finger cages: pregrasping cages.

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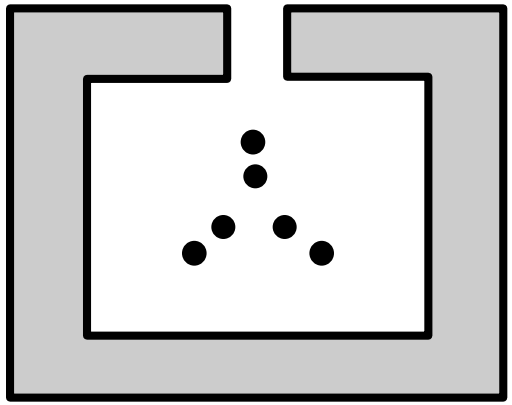
- N-fingered manipulators:
  - ✓ Can we always infallibly grasp an object beginning from a cage?



  - ✓ Not all cages are pregrasping cages.

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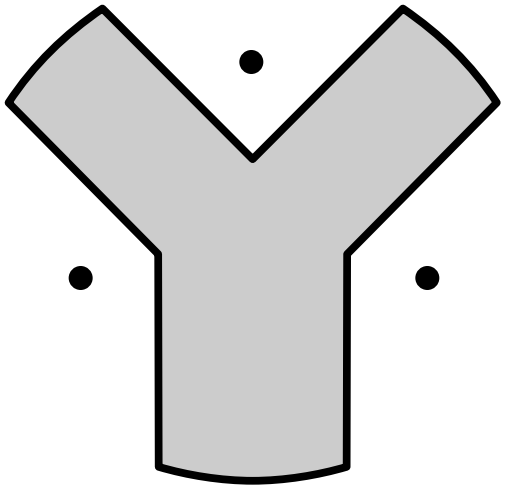
From Caging to Grasping

- N-fingered manipulators:



✓ Extend the squeezing/stretching characterization.

✓ Naturally gives pregrasping cages.

Related Work

- Caging for grasping:
  - ✓ Davidson and Blake (1998).
  - ✓ Sudsang, Ponce and Srinivasa (1999).
  - ✓ Gopalakrishnan and Goldberg (2002).
- Caging with N-fingers:
  - ✓ Rimon and Blake (1999).
  - ✓ Pereira, Campos and Kumar (2004).
  - ✓ Pipattanasomporn, Vogmasa and Sudsang (2008).

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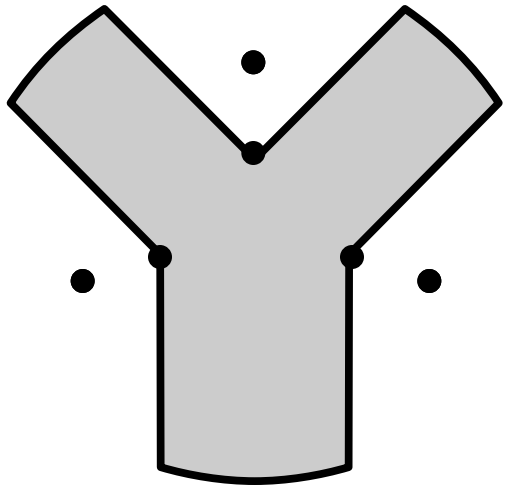
Definitions

- Cage
  - ✓ No manipulator escaping path while moving as a rigid object.
- Grasping cage
  - ✓ Cage for which a subset of the fingers holds an equilibrium grasp.
- Pregrasping cage
  - ✓ Exists a caging path to a grasping cage.



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2-Finger Caging

- Distance between the fingers $D : \mathcal{M}_2 \longrightarrow \mathbb{R}$
- Consider level sets $D^{-1}(d_0)$
- Caged $\Leftrightarrow$ No escape path while $D = d_0$
- Squeezing/Stretching caged $\Leftrightarrow$ No escape path while $D \leq / \geq d_0$

All caging configurations are either squeezing, stretching, or both

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N-Finger Caging

2-fingers

N-fingers

$$\mathcal{D} :: \mathcal{M}_{\mathbb{R}^2} \longrightarrow \mathbb{R}$$

$$\mathcal{D}^{-1}\left(\not{0}_{\mathbf{0}}\right)$$

$\Leftrightarrow$ No escape path while $\mathcal{D} = \not{0}_{\mathbf{0}}$

$\Leftrightarrow$ No escape path while $\mathcal{D} \leq I \geq \not{0}_{\mathbf{0}}$

Note: Equivalent if $n = 2$ and $F = D$.

N-Finger Caging

Equivalent Theorem

All F-caging configurations are either F-squeezing, F-stretching, or both

Corollarium

All F-cages are pregrasping cages.
(certain conditions on F)

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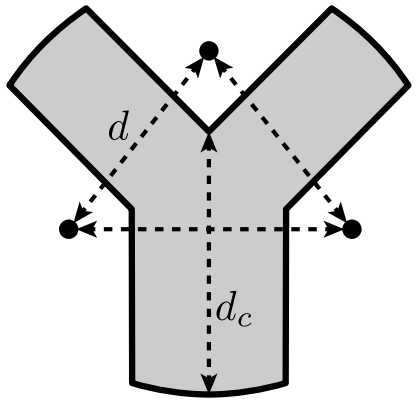
Example 1

- Energy of the finger formation:

$$F = \frac{1}{2} \sum_{\substack{i,j \in 1 \ldots n \\ i \neq j}} d^2 \left(p_i, p_j \right)$$



if initially:

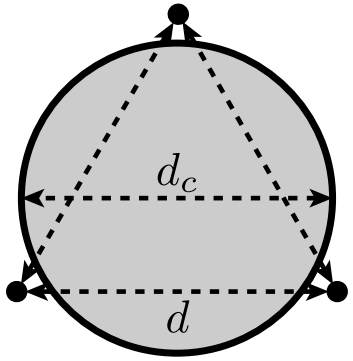
$$F < 2d_c^2$$

F-squeezing cage

Example II

- Maximum finger-finger distance:

$$F_{max} = \max_{i,j \in 1 \ldots n} d\left(p_i, p_j\right)$$



if initially:

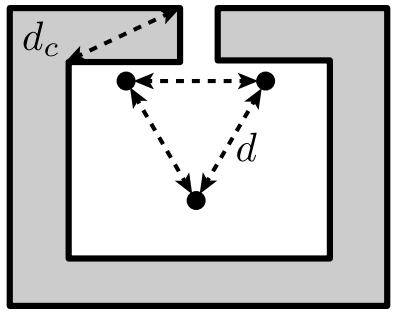
$$F_{max} < d_c$$

F_{max}-squeezing cage

Example III

- Minimum finger-finger distance:

$$F_{min} = \min_{i,j \in 1 \ldots n} d\left(p_i, p_j\right)$$



if initially:

$$F_{min} > d_c$$

F_{min}-stretching cage

Summary

- Pregrasping cages:
  - ✓ Some cages better than others.
- Given F defined on finger formation, F-cages:
  - ✓ Object will never escape while maintaining the value of F.
  - ✓ Grasp the object by increasing/decreasing F.

F-cages $\subsetneq$ Pregrasping cages $\subsetneq$ Caging