

Caging-Based Grasping by a Robot Hand with Rigid and Soft Parts



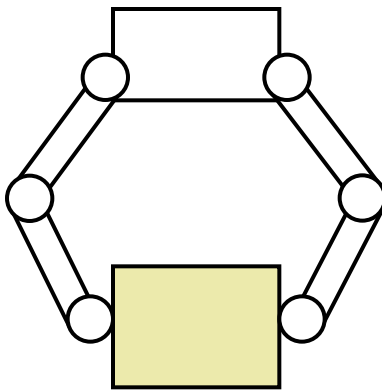
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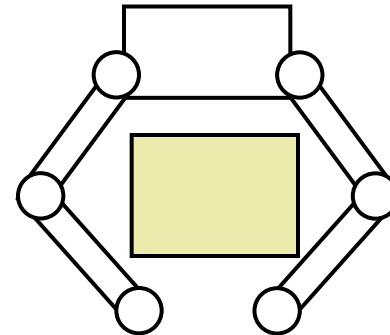
Background: Grasping vs. Caging

■ Grasping



- Object is localized
- Need for force control

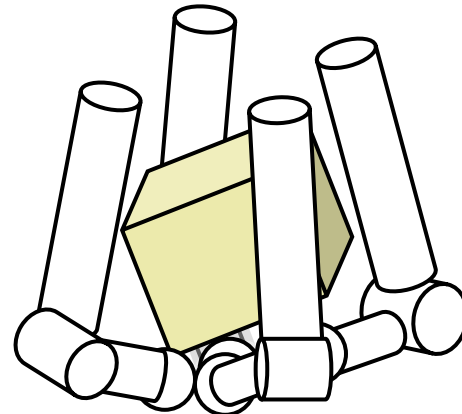
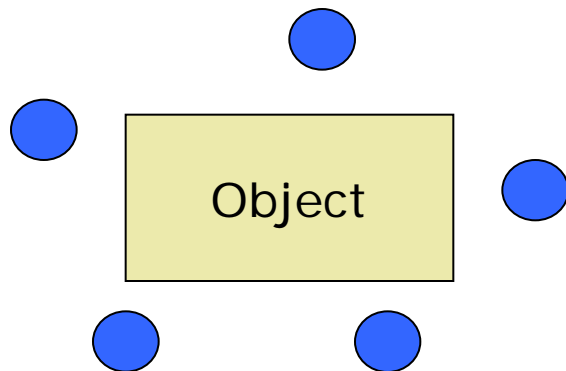
■ Caging [Rimon 99]



- Object is movable
- No need for force control

Caging

- Easily executed by today's robots
- Object movement is not allowed in some applications
 - Possible inaccurate object placement
 - Possible collisions



Motivation

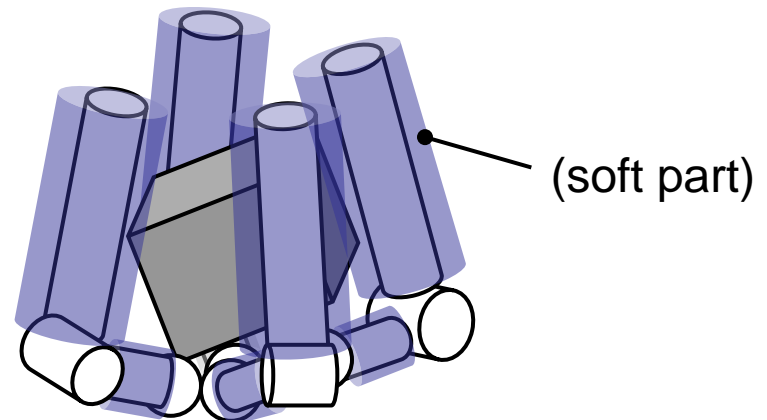
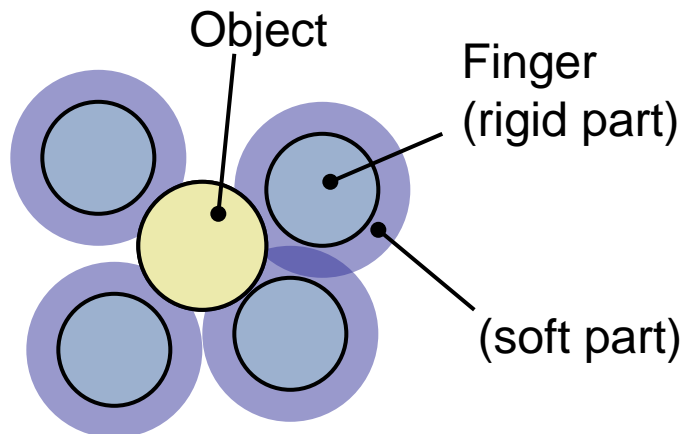
- To propose a new approach to grasping with the merit of caging:

“Caging-based grasping”



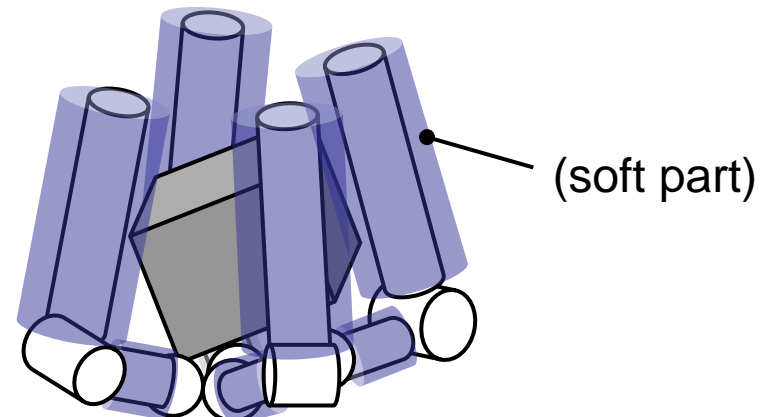
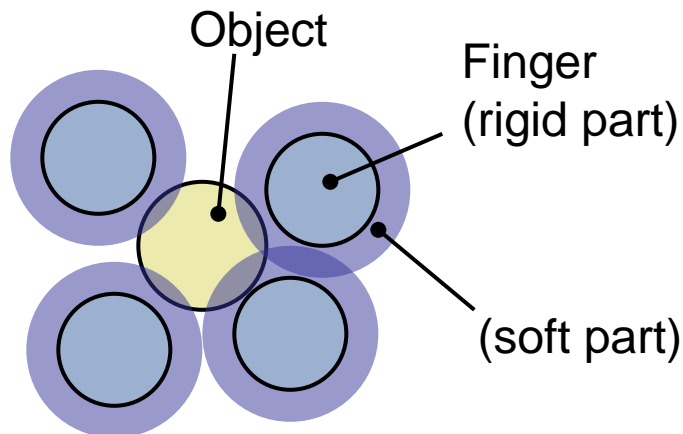
What is caging-based grasping?

- A robot hand with rigid and soft parts is used
 - Rigid parts cage the object
 - Soft parts achieve a complete grasp by their deformation



Merit of caging-based grasping

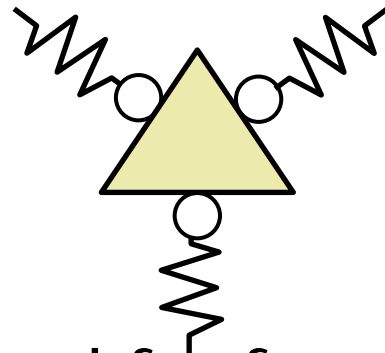
- Grasping by position-controlled hands
 - No need for force sensing/control
 - Only **geometrical analysis** is necessary to achieve grasping



Previous studies on position-controlled hands

- Compliant grasps

(e.g., [Cutkosky and Kao 89] [Inoue and Hirai 08])

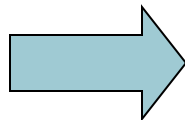


- No need for force sensing or explicit force control
- **Mechanical analysis** on grasp stability is necessary to achieve grasping

Definition of caging-based grasping

- Rigid-part caging condition:
 - The object is caged in a closed region formed by the rigid parts of the robot hand.
- Soft-part deformation condition:
 - Assuming that the soft parts of the robot hand are rigid, the closed region for caging becomes empty.

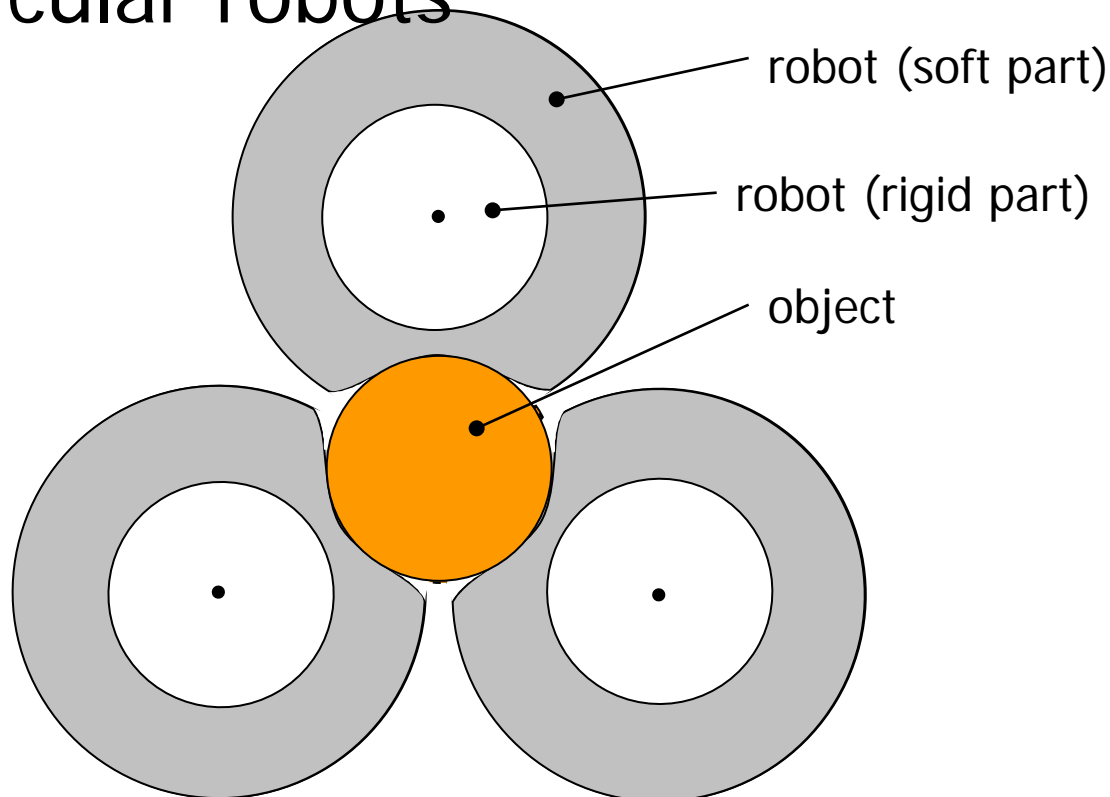
Both of the above geometrical conditions hold



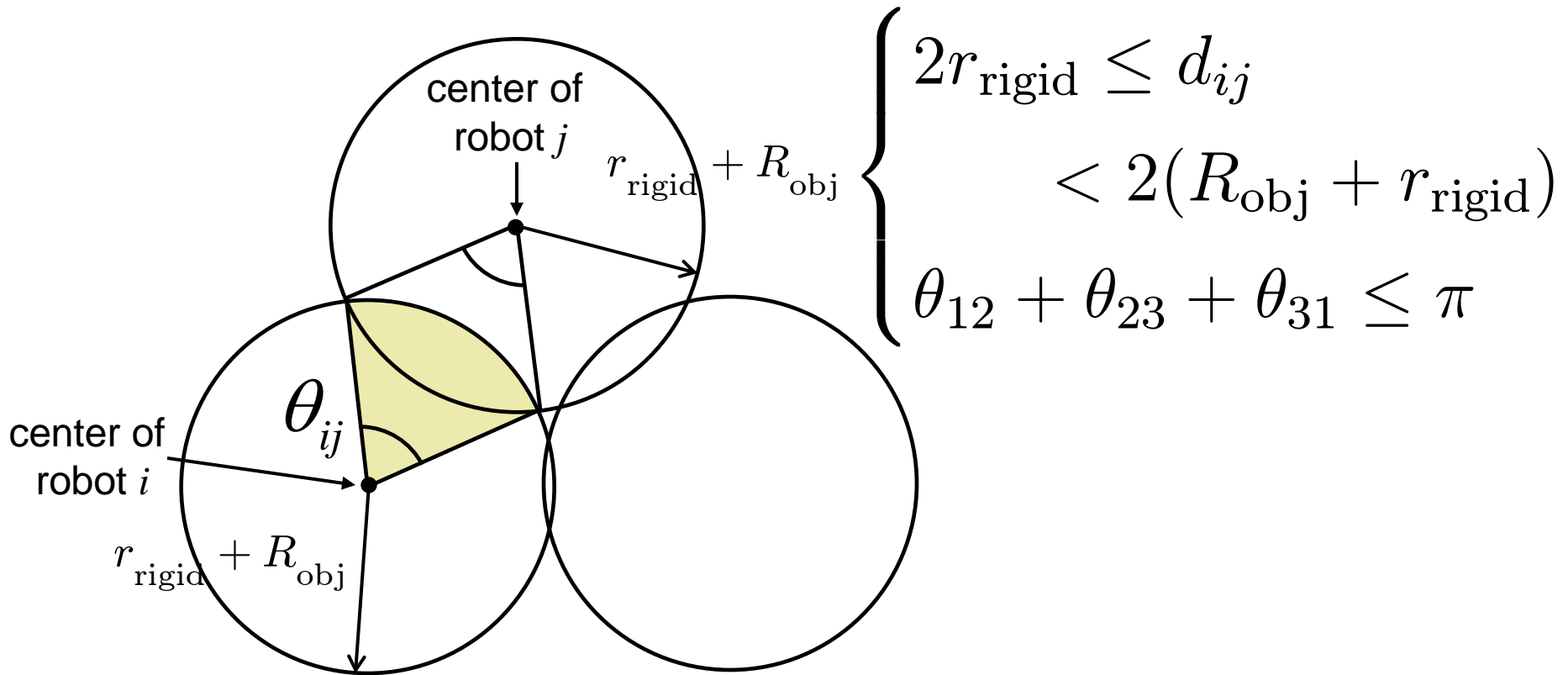
Grasping is achieved

An example of 2D caging-based grasping

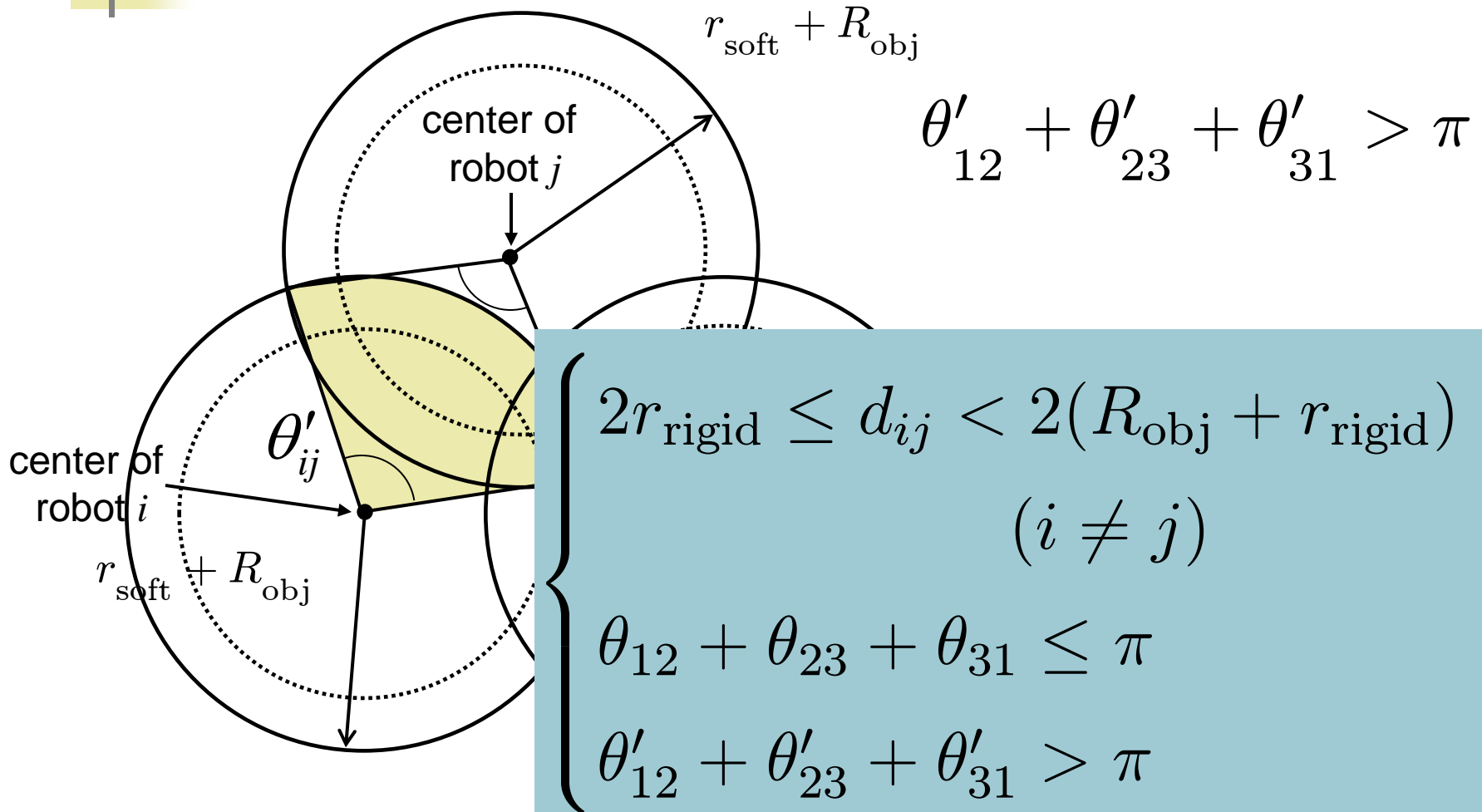
- Grasping a circular object by three circular robots



Rigid-part caging condition



Soft-part deformation condition



2D caging-based grasping: Experiments



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Caging

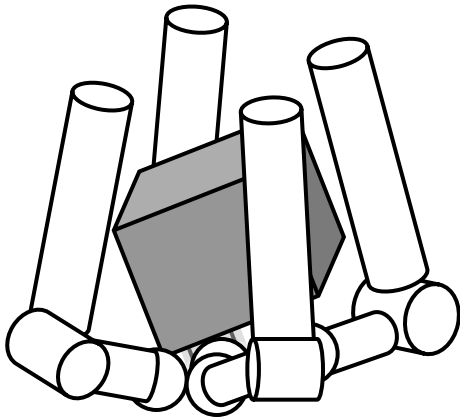


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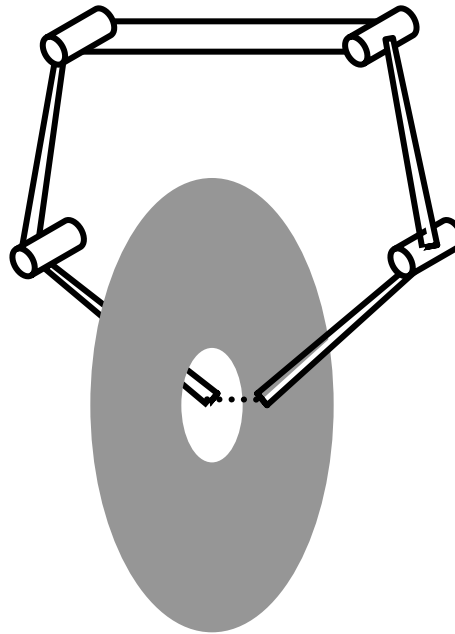
Caging-based grasping

Mobile robots: iRobot Create
Object: styrene foam (used as a pallet)
Soft parts: Urethane foam

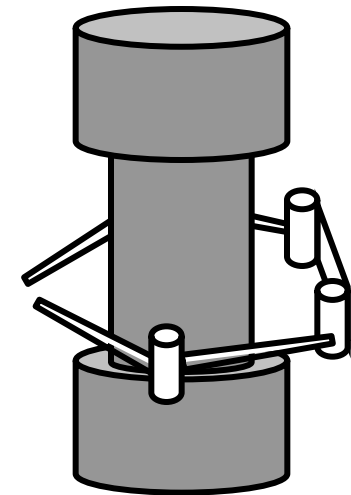
Typical types of 3D multifingered caging [Makita et al. 10]



Envelope-type Caging

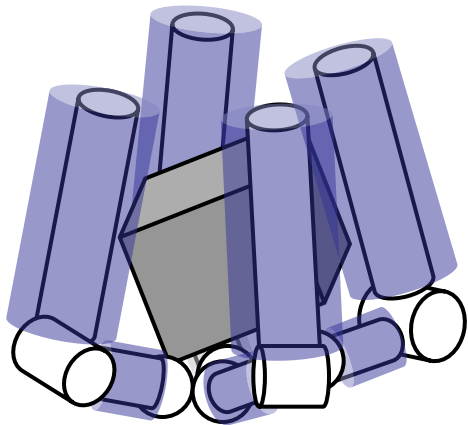


Ring-type Caging

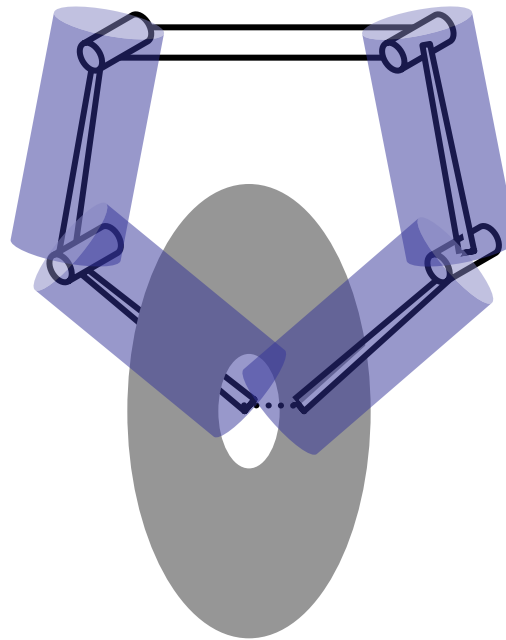


Waist-type Caging

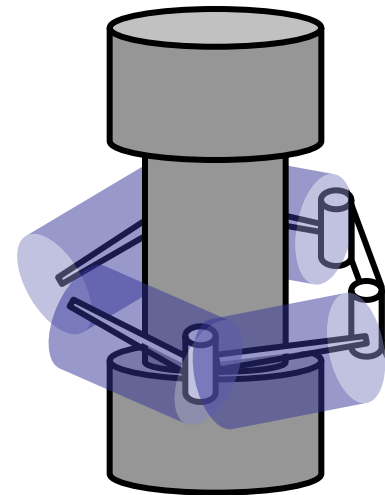
Typical types of 3D caging-based grasping



Envelope-type
caging-based grasping



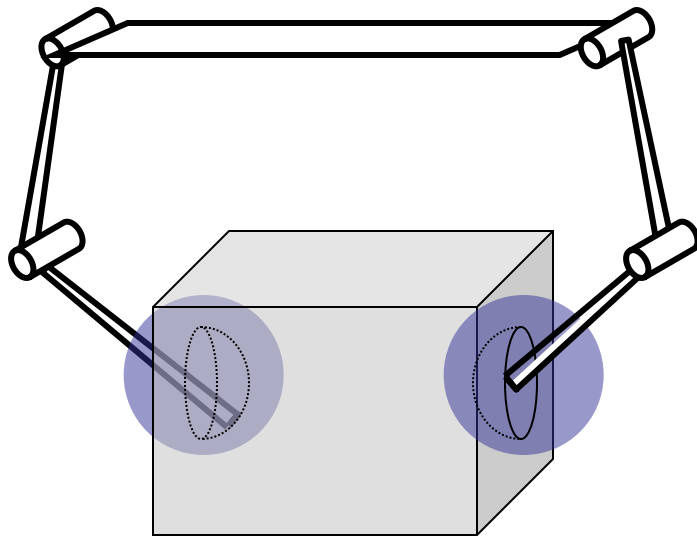
Ring-type
caging-based grasping



Waist-type
caging-based grasping

Caging-based grasping using local geometric features

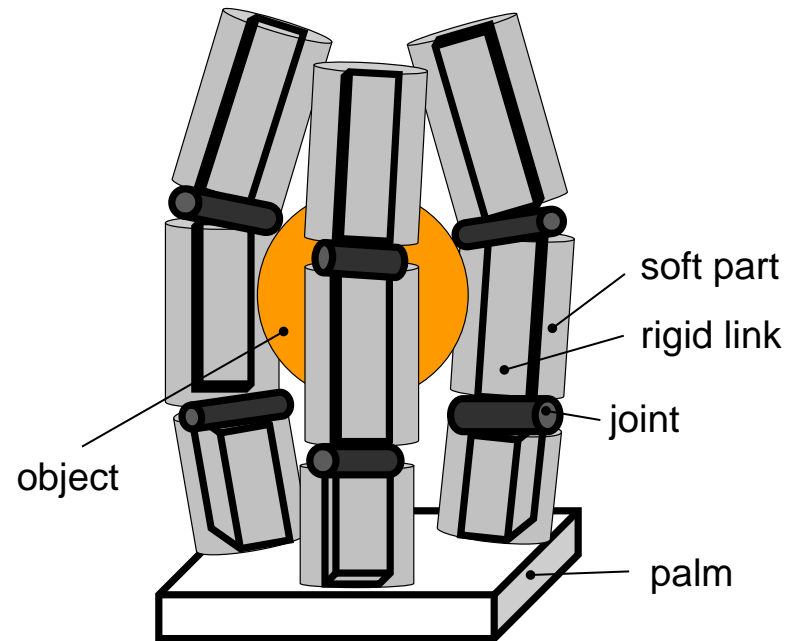
- Example: local hollows on the object enable caging-based grasping



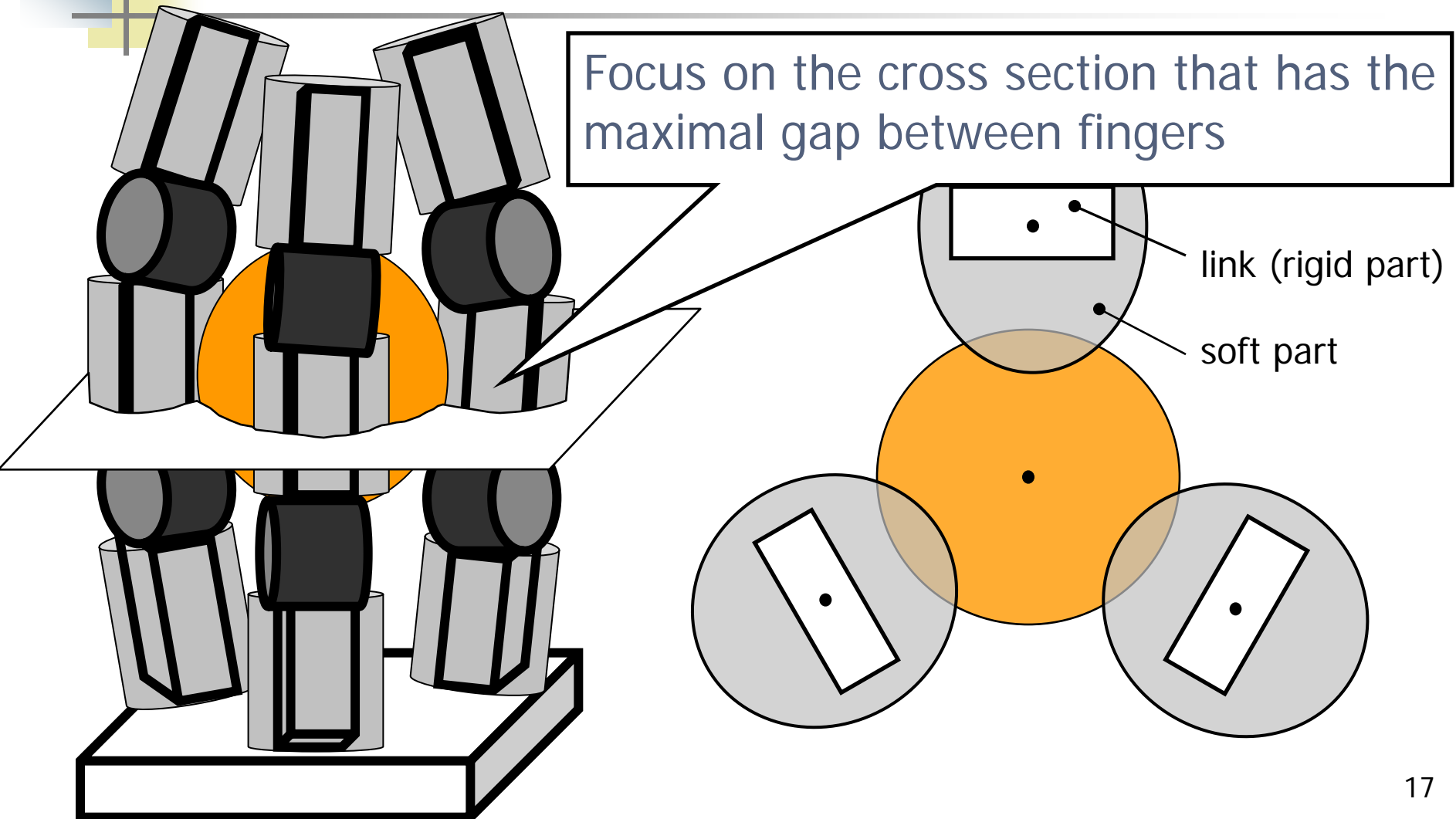
Ring-type caging
caging-based grasping

An example of 3D caging-based grasping

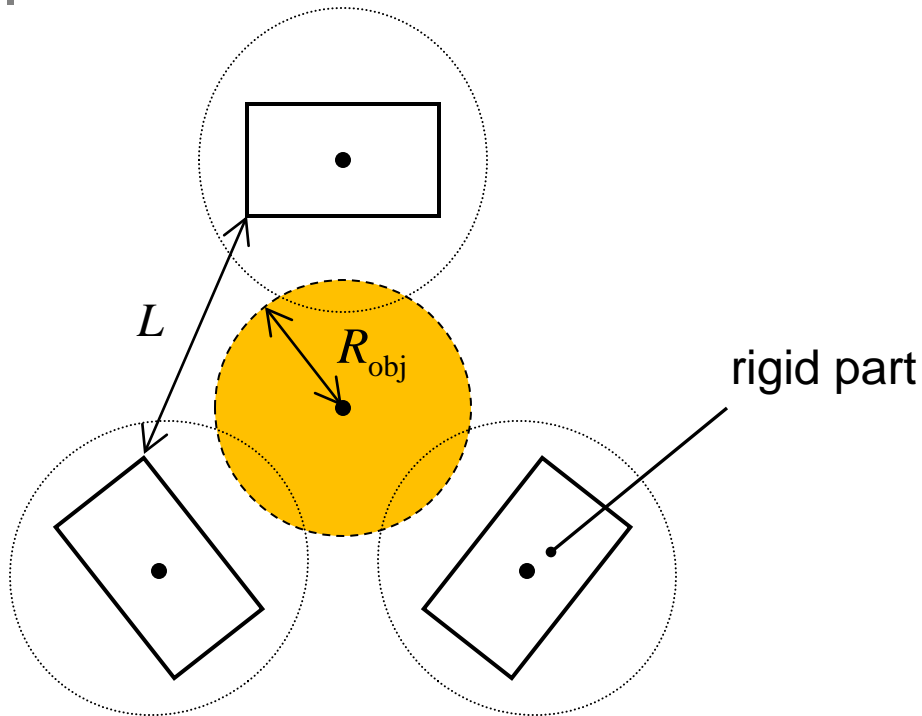
- Grasping a sphere by a symmetric hand
 - Rigid parts: cuboid links
 - Soft parts: cylindrical skins



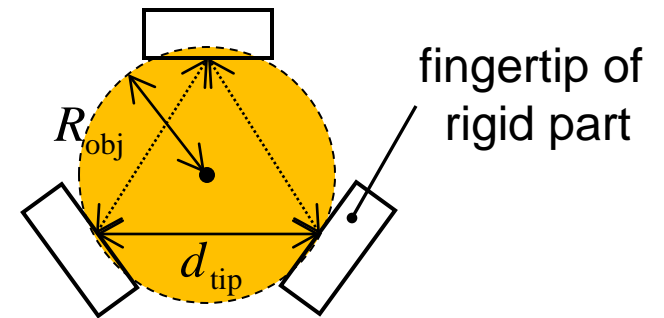
Derivation of sufficient condition for caging-based grasping



A sufficient condition for rigid-part caging

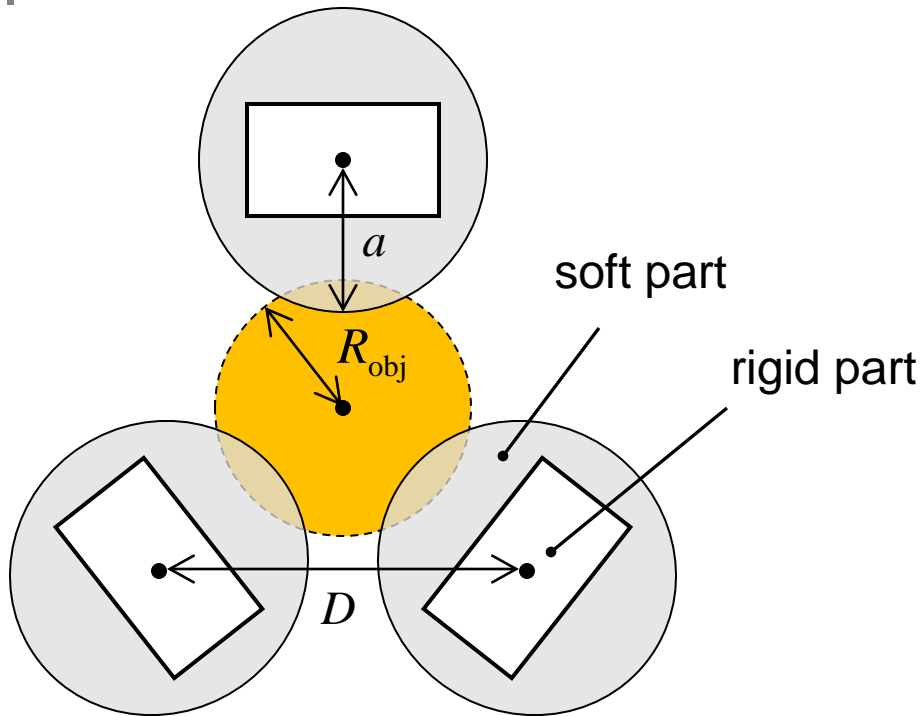


$$L < 2R_{obj}$$



$$d_{tip} < \sqrt{3}R_{obj}$$

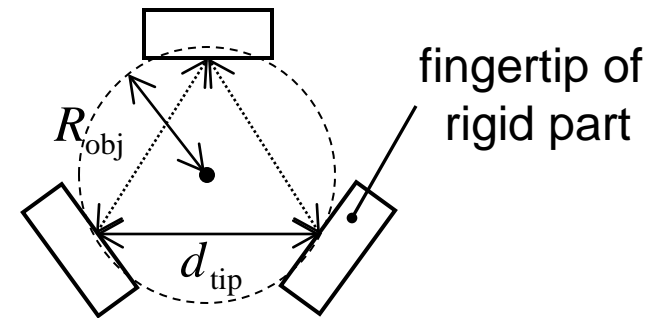
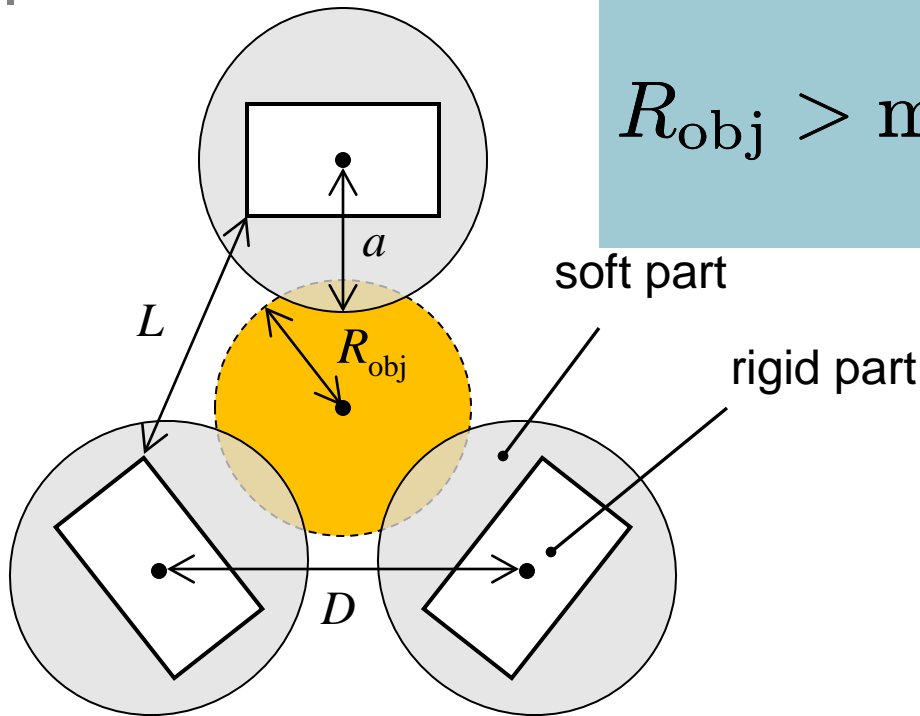
A sufficient condition for soft-part deformation



$$\sqrt{3}(a + R_{obj}) > D$$

A sufficient condition for caging-based grasping

$$R_{\text{obj}} > \max \left(\frac{d_{\text{tip}}}{\sqrt{3}}, \frac{L}{2}, \frac{D}{\sqrt{3}} - a \right)$$



$$L < 2R_{\text{obj}}$$

$$\sqrt{3}(a + R_{\text{obj}}) > D$$

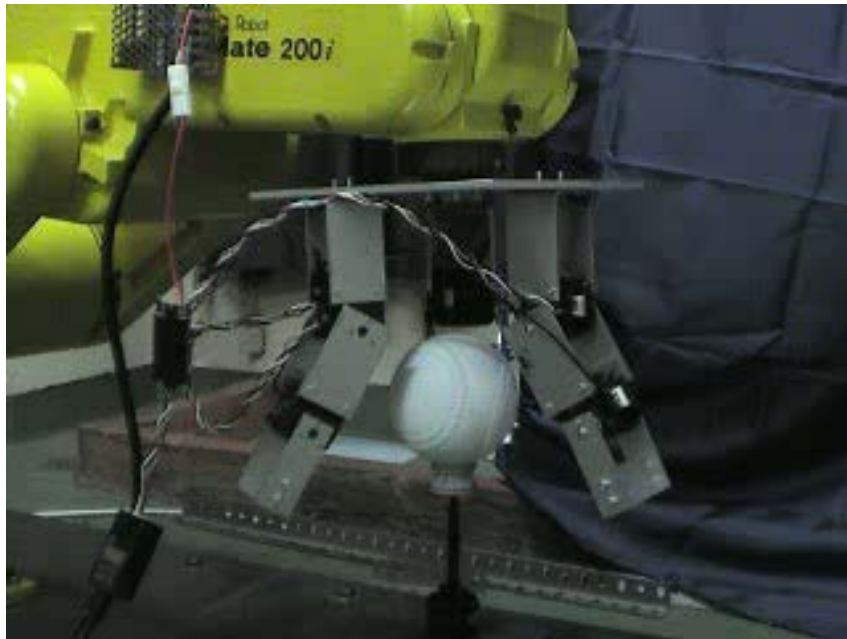
$$d_{\text{tip}} < \sqrt{3}R_{\text{obj}}$$

3D caging-based grasping: Experiments

- Three-fingered hand with semicylindrical soft parts

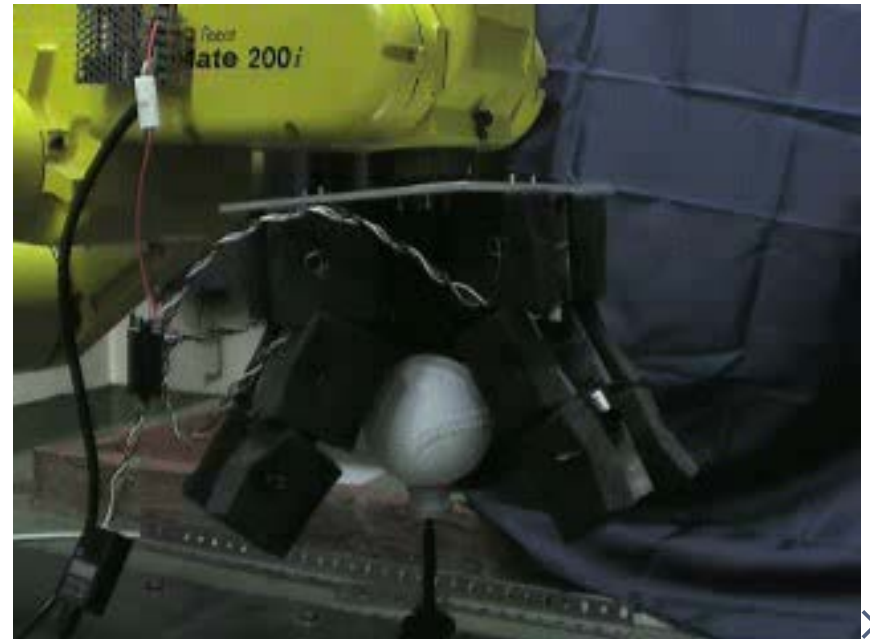


Pick-and-place demonstration



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Caging



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Caging-based grasping

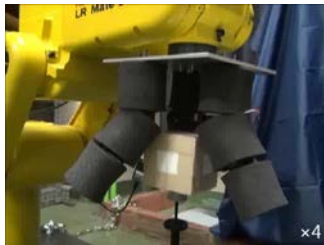
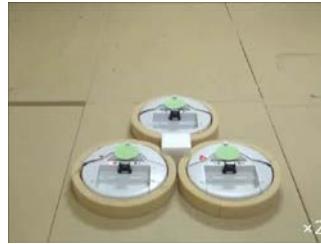
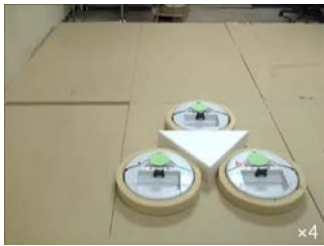


Summary

- A new and simple approach to grasping by position-controlled robot hands: “caging-based grasping” was proposed.
 - Conditions for 2D and 3D caging-based grasping were derived.
 - Experimental validation of caging-based grasping was performed for a 2D case (with mobile robots) and a 3D case (with a multifingered hand).

Future work

- Application to objects in various shapes



- Application to various robot hands