# Geometry-Based Manipulation through Robotic Caging

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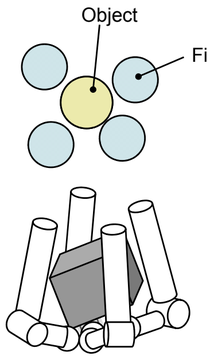
Caging is a method to confine object configurations by a closed region made by robot bodies. It can be used as a substitute for or a complement to conventional grasping in robotic manipulation. Because caging is a geometrical concept, manipulation via caging falls into a class of “geometry-based manipulation.” Geometry-based manipulation can be performed by position-controlled robots according to only geometrical information, which is a merit for the present level of robot technology. In this paper, we discuss three forms of geometry-based manipulation via caging: caging manipulation by robots and walls, in-hand caging manipulation, and caging-based grasping by robot fingers with soft skins. We present basic ideas and some experimental results of them.

## Introduction

Caging: Geometry-based manipulation
- No need for force sensing/control
- Only geometrical information is necessary

→ Useful for manipulation tasks



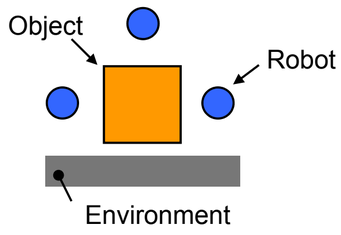

There exist many studies on conventional robotic caging

Objective: Exploring new forms of geometry-based manipulation via caging

Those may not be humanlike, but can be suitable to today’s robots

## Caging by Robots and Walls

- Caging by not only robots, but also walls




- Caging with smaller number of robots
- Caging in narrow passages
- Sensorless manipulation
- Manipulability is not trivial

Manipulability

- Robot-only caging: objects can be manipulated with fixed robot formations
- Caging by robots and walls: changeability of the closed caging region can be formulated as manipulability in a broad sense

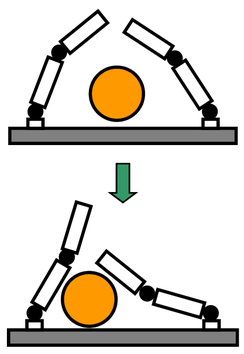
The closed caging region should not shrink discontinuously or divide

Manipulation by three circular robots with an RRT-based planner

Manipulation by two circular robots with an RRT-based planner

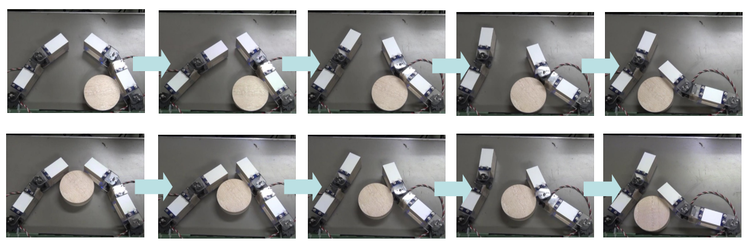
## In-Hand Caging Manipulation

- In-hand manipulation with objects caged

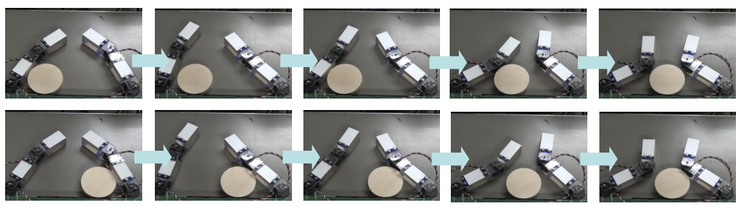


- Position-control-based in-hand manipulation
- Sensorless manipulation
- Manipulability is not trivial

Manipulation with an RRT-based planner (to left corner)

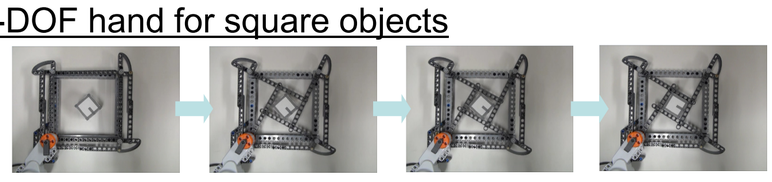


Manipulation with an RRT-based planner (to center)

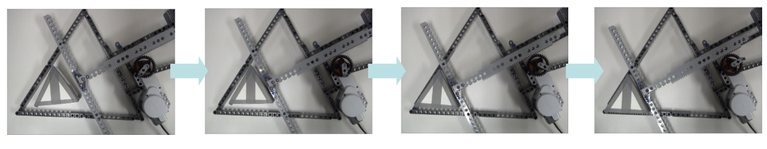


Minimalistic examples

1-DOF hand for square objects

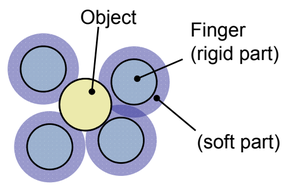


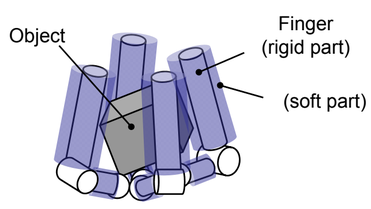
1-DOF hand for triangular objects



## Caging-based Grasping by Rigid Fingers with Soft Skins

- An object is caged by rigid parts and simultaneously grasped by soft parts



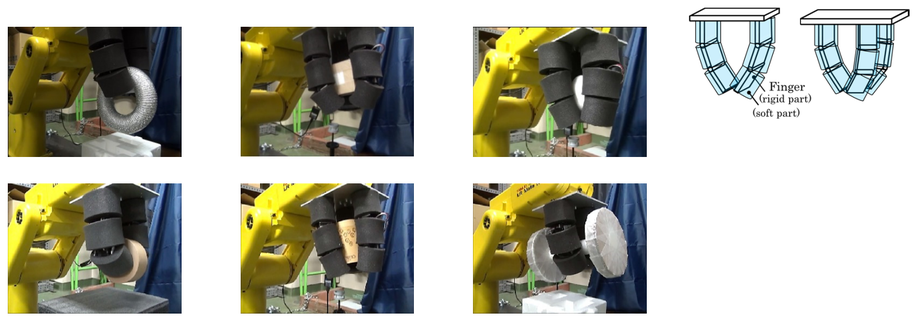

- Position-control-based grasping with geometrical information
- Very robust
- Grasping with partial object information

Requirements

- *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 become rigid, the closed region for caging becomes empty.

→ Both can be tested geometrically and explicit mechanical analysis is not necessary

Grasping by two- or three-fingered articulated hands




Grasping by two- or four-jaw grippers