

Position and Orientation Control of Polygonal Objects by Sensorless In-hand Caging Manipulation



Background

INTELLIGENT B/NOUSTRIPL ROBOTICS

- Robotic in-hand manipulation
 - Most studies: Pursuit of dexterity like humans
 - Rich sensors
 - Force control
 - Another direction: Sensorless approach
 - Without object sensing
 - Position control



- Limited dexterity
- Easy implementation
- Potential applications such as versatile part feeders

Related studies



- Caging-based in-hand manipulation [Ma+ 2017] [Bircher+ 2019]
 - Robust manipulation insensitive to contact models
 - A camera is used to localize the object
- Sensorless in-hand manipulation [Tahara+ 2010] [Ospina+ 2020]
 - Sensorless control of object pose
 - Relative to its initial pose

Sensorless control of "absolute" position/orientation is not studied

Sensorless in-hand caging manipulation [Maeda+ 2017]





Our previous studies on sensorless manipulation



In-hand caging manipulation of circular objects [Maeda+ 2017] Application to various objects [Maeda+ 2014]





 Orientation control is not considered A dedicated hand for each object to manipulate only to a specific goal pose





Sensorless in-hand caging manipulation for position and orientation control

Geometry-based manipulation planning algorithm
Implementation with actual position-controlled robot hands



Objects and Hands



Objects				Hands
Triangle			4-DOF Hand	
Square	Rectangle	Cross	L-shape	6-DOF hand

Overview of the proposed method



Manipulation planning: C-spaces





Manipulation planning: feasibility check



■Caging manipulability ■Caging A connected configuration free space for A separate object configuration free space possible object poses is uniquely identified is found NG NG OK ()K Object 0 -20 -40 -40 -60 -60 -80 500 400 400 300 300 -200 200 -200 200 100 -400 -400Single connected Configuration free space connected to Multiple connected Separate configuration configuration free space configuration free free space outer region spaces

Manipulation planning: heuristics for jamming avoidance





Manipulation planning: termination condition



 Configuration free space of the object is included in a specified goal region



Execution of planned manipulation (convex objects)





Manipulation to the goal is achieved regardless of initial object poses by the same hand motions without object sensing

Execution of planned manipulation (concave objects)



Manipulation to the goal is achieved regardless of initial object poses by the same hand motions without object sensing





Discussion

1. Jamming



Jamming is found near the palm

Error in goal pose

2. Positioning accuracy





 More efficient manipulation planner that can deal with high-resolution C-space discretization



Summary



Conclusion

- A geometry-based planner for in-hand caging manipulation with position and orientation control was proposed
- In-hand caging manipulation to goal position/orientation was successfully demonstrated for various objects
 - same hand motion regardless of initial object pose
 - Sensorless: without object sensing

Future work

- Improvement of manipulation planner
- Application to versatile part feeders

