Caging in the context of Robotic Manipulation

Alberto Rodriguez Garcia
Human Sensing Lab
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Goal of the Talk

- Give an overview of what I am interested in and an example of the kind of results I work on.

- Try to convince you that it is worth working on it.
“The process of using one's hand to rearrange one's environment”

- Manipulation is an art, an engineering discipline and a science.
- Refers to physical changes like moving an object, joining two or more objects or reshaping one.
Grasping

- Grasping is the process of placing the fingers of a hand around an object in order to hold it.

- Allow robots to manipulate objects. By first immobilizing them with respect to their hands, any kind of uncertainty on the object's location is eliminated.
Problem with Grasping

Assumptions:

- *(perfect)* Geometrical model of the object.
- *(perfect)* Ability to locate the object in the workspace.
- *(perfect)* Ability to place fingers in a specific location in synchronicity.
- *(perfect)* Physical model of contact and friction.

What is the problem with grasping? ...
Let's get rid of all sensor information, and only perform tasks whose output invariant with respect to assumptions.

Then obviously, the system does not get corrupted by noisy sensor information.

Example: Just a geometrical model of the object and try to manipulate the object without knowing its location.
Sensorless Manipulation: Extreme

Introduction

Grasping

Sensorless Manipulation

Caging

Conclusions
Key idea: Instead of grasping the object, just trap it.

Once you have trapped the object you do not know exactly where the object is, the only thing you know is that:

- It is between your fingers.
- It cannot escape.
Why is caging useful?

- Caging regions have positive measure while grasping ones have measure zero.
- We no longer depend on unrealistic assumptions. We can consider uncertainty in object geometry, object and finger location ...
- Knowing the accuracy of object location, object geometry and finger placement, we can say if our system can manipulate it or not.
Is caging the solution?

- We know that trapping an object is an achievable task. Is that enough?
  - Some cases yes: For moving an object you do not really need to immobilize it first.
  - Some case no: What if we need to orient an object? What if we need to eliminate the uncertainty in its location?

  **It is much more simple to grasp an object once you know that is trapped.**

- There is a nice relationship between the space of cages and the space of grasps.
Definitions:

- **Squeezing caging**: the fingers trap the object even if they move closer.
- **Stretching caging**: the fingers trap the object even if they separate.
**Theorem:** Given a compact body in an euclidean space $\mathbb{E}^n$ any two finger caging configuration is either squeezing, stretching or both.

**Key implications:**

- Simplifies the algorithmic search for cages.
- It tells us that from any cage there is a *blind* policy in order to reach grasp. Either separate the fingers or close them. There is zero uncertainty that you will grasp the object.
Caging with n fingers

- **Squeezing and Stretching**: characterization of the relationship between cages and grasps for two fingers. Can we extend it to n fingers?
  - The straightforward answer is **NO**.
  - With more than two fingers there are placements of the hand where you cannot blindly increase or decrease the distance between the fingers without breaking the cage.
No direct generalization, but:

- We know how to formalize the problem.
- We know what we are looking for.
- We have gone from a broad description of what we were interested:
  - Grasp an object with uncertainty in object geometry and location.
  - To something specific that can be computed and searched in an algorithmic way:
    - Search for good caging configurations: Those that have a path in Shape space that end up in an isolated configuration (allow us to grasp the object blindly).
Manipulation is essential to allow robots to interact with the world.

Grasping is a difficult task that might be eased by the use and study of caging.