Imitation du geste naturel de préhension

JOURNÉE GT1/GT3/GDR STIC SANTÉ
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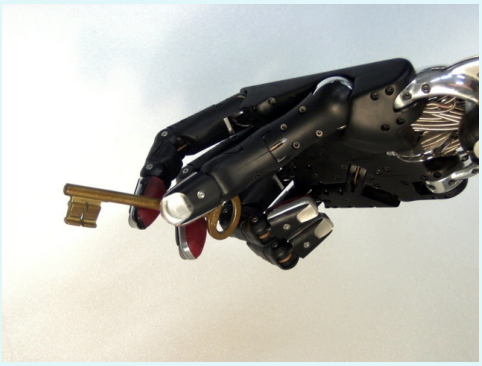
Objectives

- Strategy for grasping unknown objects
- Planning the in-hand manipulation



Grasping unknown objects

Find the grasp configuration

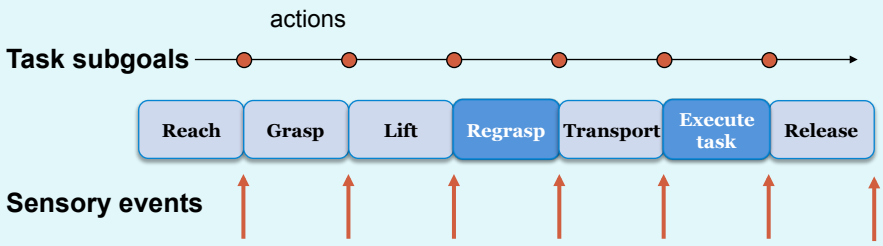
- That is find
  - Coordinates of the contact points on the object surface
  - Finger joint configurations with respect to the palm
- With different grasp types
  - Precision grasp: contacts with fingertips or last phalanxes
  - Intermediate grasp: contacts with internal phalanxes
  - Power grasp: contacts with internal phalanxes and palm
- To handle
  - All sorts of objects
  - Not known in advance

- According to
  - Object position/orientation
  - Object shape
  - Real-world context (accessibility)
- Promoting
  - Further use
  - Or Regrasping

In-hand manipulation

In-hand manipulation

- Part of the whole manipulation task for
  - Task execution
  - Regrasping



- In-hand manipulation capacity reflects dexterity

Task	Object part	Grasp type	Action
Hand it to somebody	Shank	Power	Move to person
Insert in storage	Handle	Precision	Drop in hole
Fasten screw	Handle	Power or precision (depending on the size)	Contact screw and rotate

Regrasping

- Situation : the object is not initially grasped with the grasp configuration due to
  - Wrong initial pose
  - Accessibility
- The grasp configuration needs to be changed
  - By successively lifting fingers (finger gaiting)
  - By rolling the object in hand (Precision grasp ←→Power grasp)

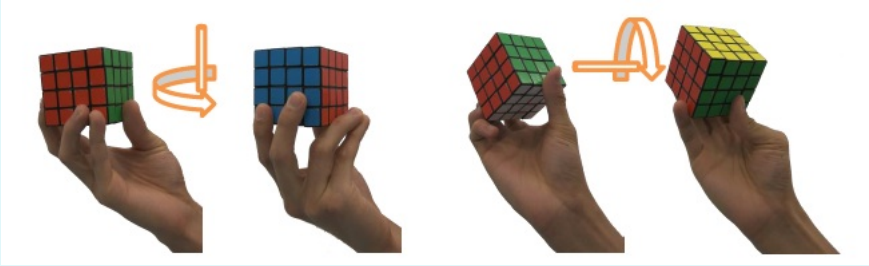
Task execution

- Without in-hand action
  - Through the arm or the wrist
  - Out of the subject, The object moves but the grasp configuration doesn't change
- With in-hand action
  - Fine rotations and translations of objects in hand (Example tasks: Press button, Unlock key, Unscrew head screw, Open bottle)
  - Internal movements of articulated objects (Example objects: scissors, wire cutters, tweezers, chopsticks, pipette)
  - Internal movements of soft objects (Example objects: sponge, clothes)

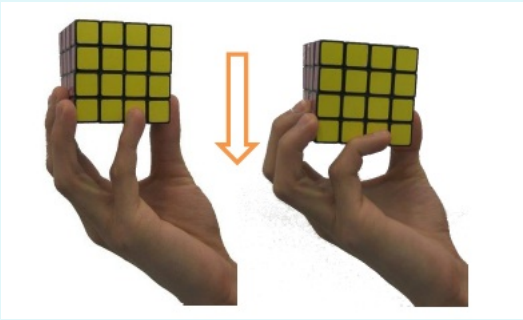
Object movements

In-hand possible movements

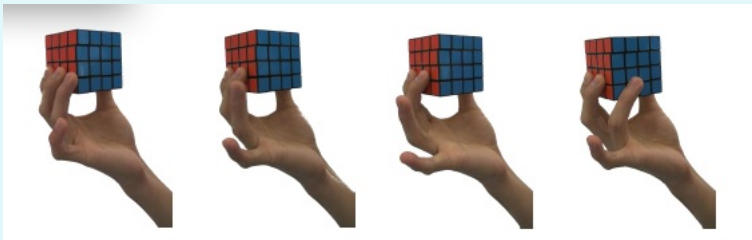
- Rolling fingertips (object rotation)



- Changing joint configurations (opening, closing, etc) for object translation



- Finger gaiting



Constraints

- Collision avoidance (between fingers, with object, with external environment)
- Finger kinematics
- Contact maintenance
- Equilibrium

Grasping

State-of-the-art

Previous works

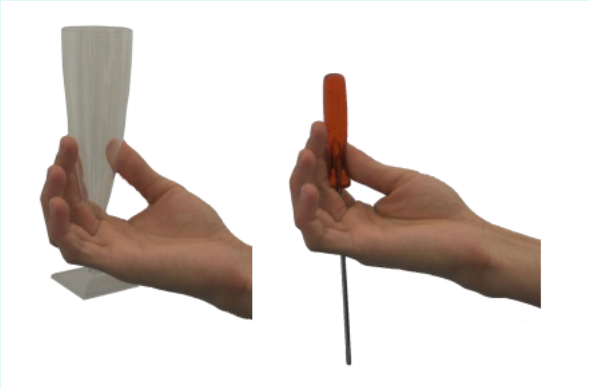
- Different approaches
- But all mainly
  - Determine the contact points on the known object surface
  - Taking into account some criteria such as grasp quality

- The grasp configuration is conditioned by the object envelop
- But there are uncertainties at execution level
  - Hand pose
  - Contact forces
  - Contact locations
  - Object shape

➔ Difficult to position fingertips at predetermined positions on the surface surface

- Often missing
  - The hand !
  - The context (accessibility)
  - The human-like nature
  - The future object use

- Consequences on the grasp configuration
  - Unnatural



- Useless

- Non accessible

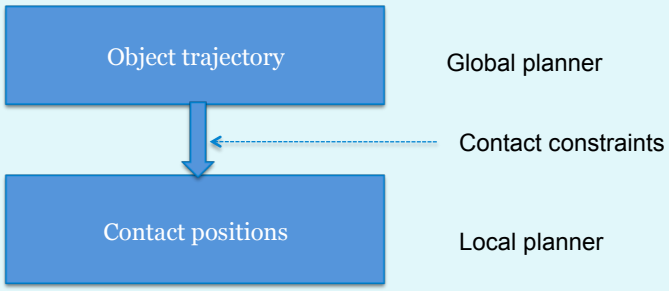
In-hand manipulation

State-of-the-art

- Find the trajectory between initial grasp and final grasp
- Challenges
  - **Reactive time**
  - Very large number of degrees-of-freedom
  - Several closed kinematic loops
  - Blend of continuous (finger and object motions) and discrete events (breaking of some contacts)

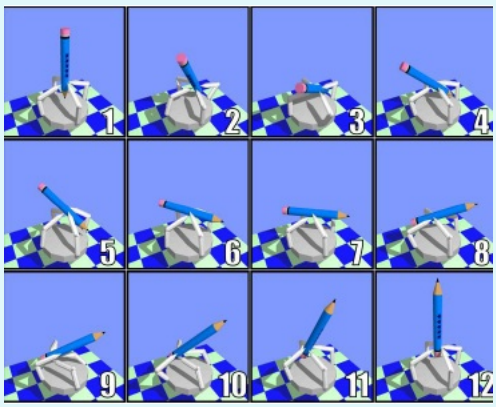
In-hand manipulation

- Previous methods
  - Adaptation of existing path planning methods for the hand considered as a whole
  - Conditioned by the object trajectory



- Feasibility with the hand tested via kinematic constraints only
- Object (and finger) surface needs to be known accurately (parameterization)
- Initial grasp configuration is known by geometric considerations
- Fingertip position needs to be controlled accurately

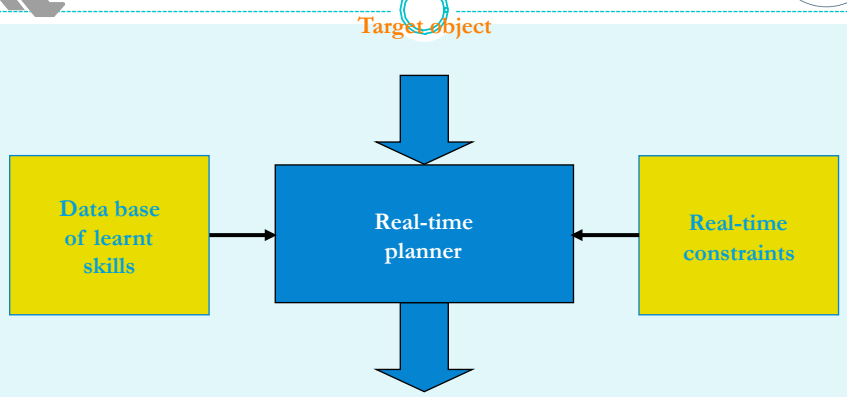
- Consequences
  - Unnatural movements



The in-hand manipulation planning

THE CORE IDEA AND DEVELOPED APPROACH

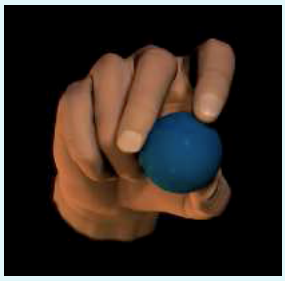
HANDLE methodology



to achieve the dexterous manipulation task
responding intelligently and effectively
to all kind of situations

From human recording

- Recorded movements annotated with grasp classes



Tripod

Writing tripod

- Each grasp class gives the following information
  - Grasp number
  - Grasp name
  - Type
    - Precision, intermediate, power
  - Opposition type
    - Palm, Side, Pad
  - Thumb position
    - Abducted, Adducted
  - Virtual finger

From learning

- Each grasp class is associated with
  - The object
    - Handled part
    - Relative hand-object position/orientation
  - The further movement
- The further movement is described by
  - Start and end grasp classes
  - Start and end object position/orientation
  - Object motion
    - Desired trajectory
    - Or desired movement (rotation, translation)

Open

Pour

Transport

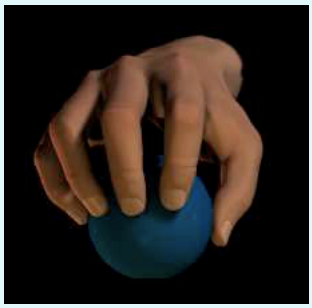
??

In-hand planning objectives

- To adapt the hand to the real object (shape, position, etc) and current conditions (accessibility) according to the desired grasp class
- To define the transitions between grasp classes according to the desired movement

Grasping strategy

- Grasping strategy is then choice of a grasp class
  - Using knowledge in the learnt data base
    - According to object shape
    - According to object use



Precision sphere

Planning

- Planning is then generation of a desired hand+object movement with successive grasp classes

Prismatic 4 finger

Adding intermediate grasp classes when necessary (e.g. Prismatic 3 finger)

Prismatic 2 finger

- If start and end grasp classes are identical
  - Fine movement is a relative movement of the object in the hand without changing the grasp configuration (e.g. rolling)
- If not
  - If the transition between both grasp classes is physically feasible, plan the movement of the fingers accordingly.
  - If the transition is not feasible, determine additional intermediate grasp classes until transitions between grasp classes are all feasible.

- If the initial grasp class is not feasible (e.g. for accessibility reasons)
  - Plan a regrasping sequence, possibly with several intermediate grasp classes) to attain the desired initial grasp class

Methodology

1. Plan the desired grasp class sequence
2. Test the feasibility of the grasp classes vs object and environment
3. Complete the sequence by initial regrasping if necessary
4. Adapt the grasp classes to the object
5. Plan the transitions between 2 grasp classes (same or not)
   - Computation of the in-hand motion
   - Or adaptation of learnt primitives

Observation 1

- There is a variety of possible motions for object transport in free space. A precise object trajectory would rarely be imposed.
  - The movement is described by
    - A desired final object position/orientation
    - A desired object orientation (sometimes) during movement (e.g. transport of a container with liquid inside)
  - The only case where the trajectory may be imposed is movement in contact with an external environment (e.g. using a tool)

Solution

- Gross motion is performed through the relative hand-object position/orientation
- Fine motion is small adjustment of the gross motion performed by fingertip motions
- Uncertainties will be compensated by force control

Final object position/orientation

Desired palm position/orientation

Desired fingertip trajectories relatively to the hand

A rough approximation of the object size only is necessary

The precise shape of the object enters late in the computation

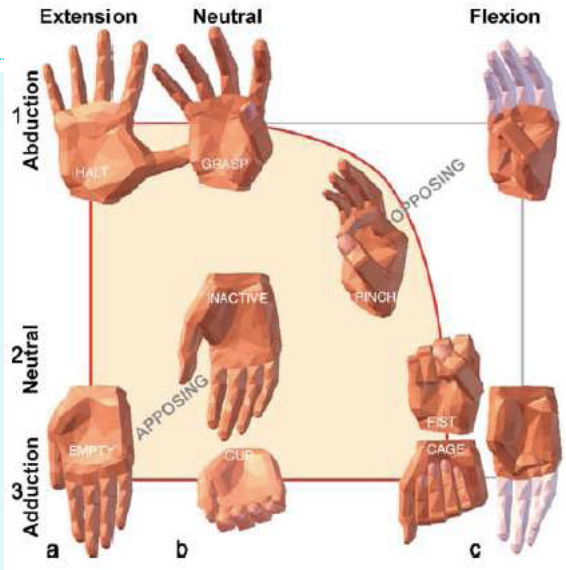
Observation 2

- There are many similarities between grasp classes
  - Same shapes are used for different types (Precision, Intermediate, Power)

  - Same shape is used for different object sizes

Solution

- A limited number of generic grasp classes will be considered.
- The hand will gradually mould to the shape of the object.
- The generic grasp classes will be adapted with
  - The distance of the object to the palm
  - The finger adduction/abduction and flexion/extension



Observation 3

- Even if they are independent mechanisms, fingers do not really move independently.
- If so, the movement does not look natural.

Solution

- The hand is considered as a whole
- Each grasp class is seen as a fingertip distribution wrt a Natural Grasping Axis
- We use internal hand synergies to shape the hand around the NGA and consequently determine the fingertip positions

Observation 4

- The hand + arm system is redundant.
- For a given object part and the corresponding chosen grasp class, there are several possible grasp configurations (distribution of fingertip contact positions on the object).
- For a given grasp configuration, there are many possible wrist and arm configurations.
- Some of them are far from being natural.

Solution

- Imitate the Tenodesis effect which links finger configurations (joint angles) with wrist configuration.
- Chose the palm position/orientation accordingly