Generality and Simple Hands

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Joint work with
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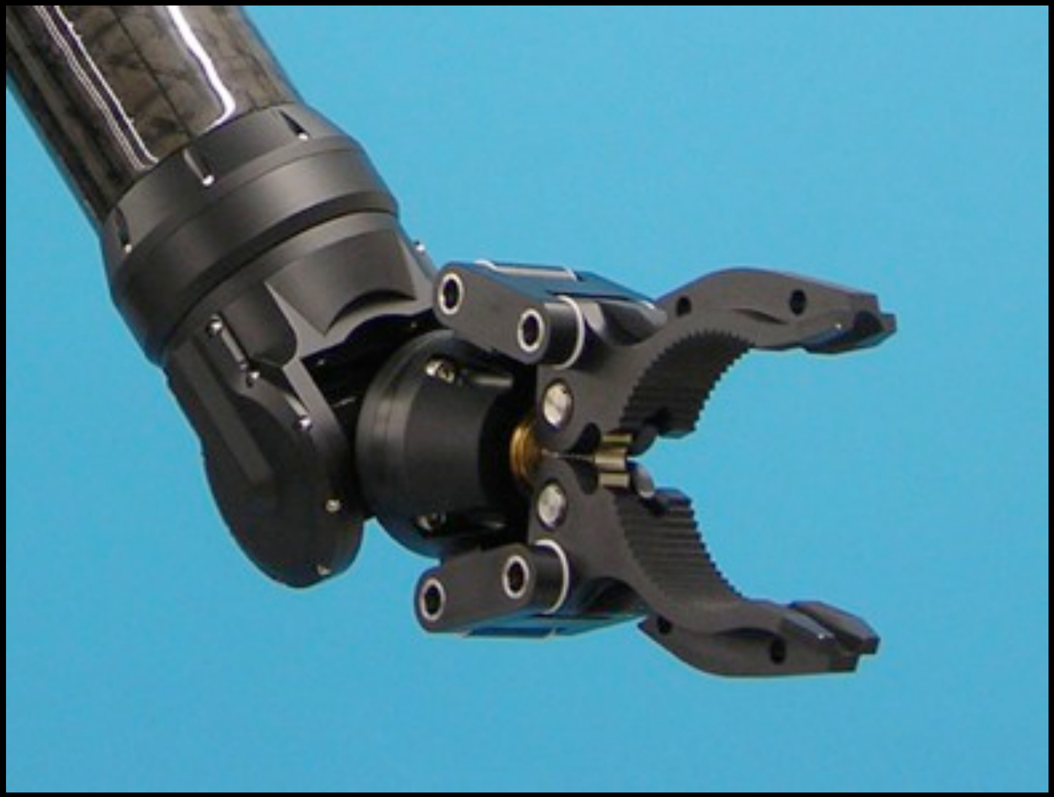
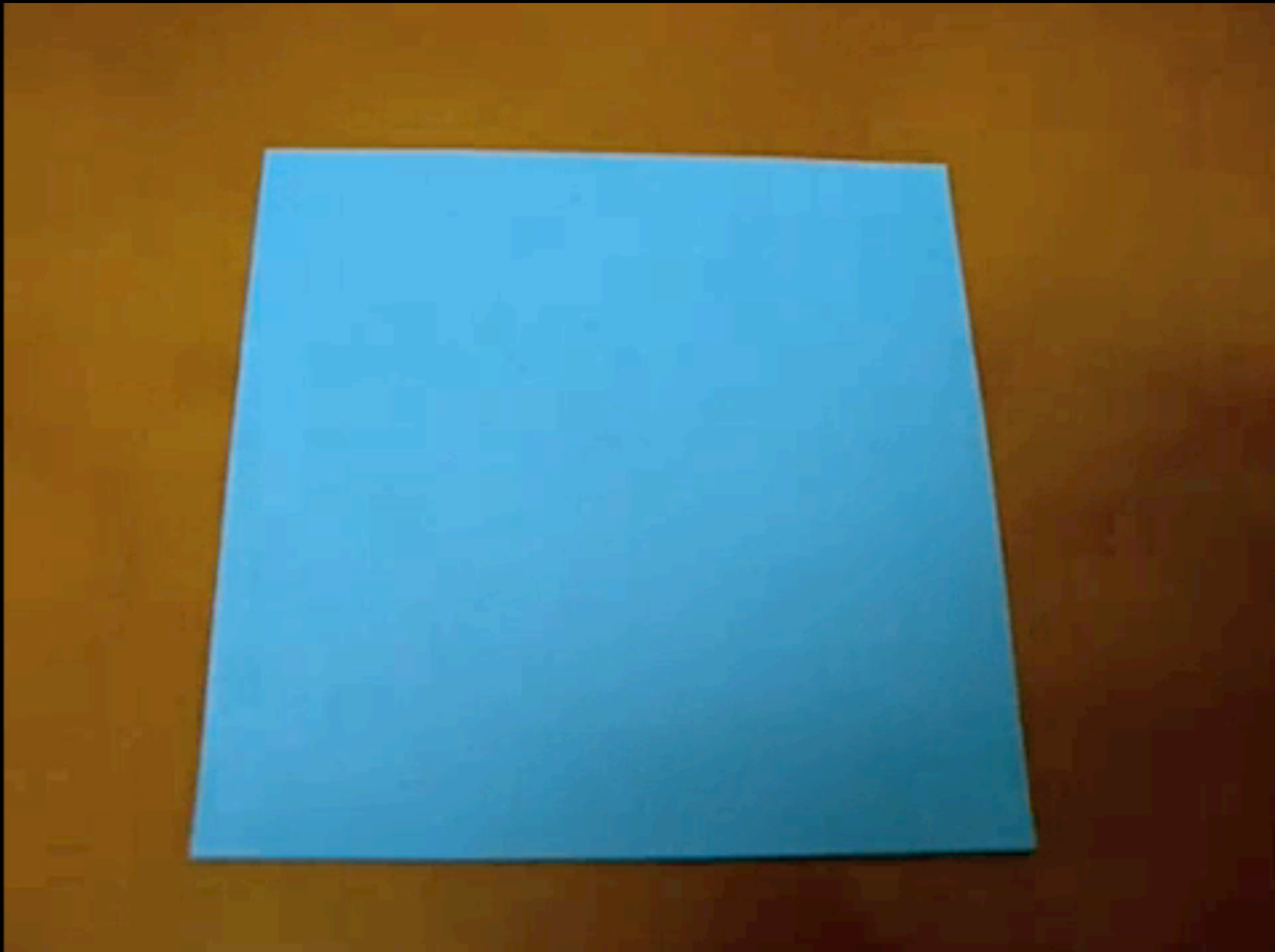
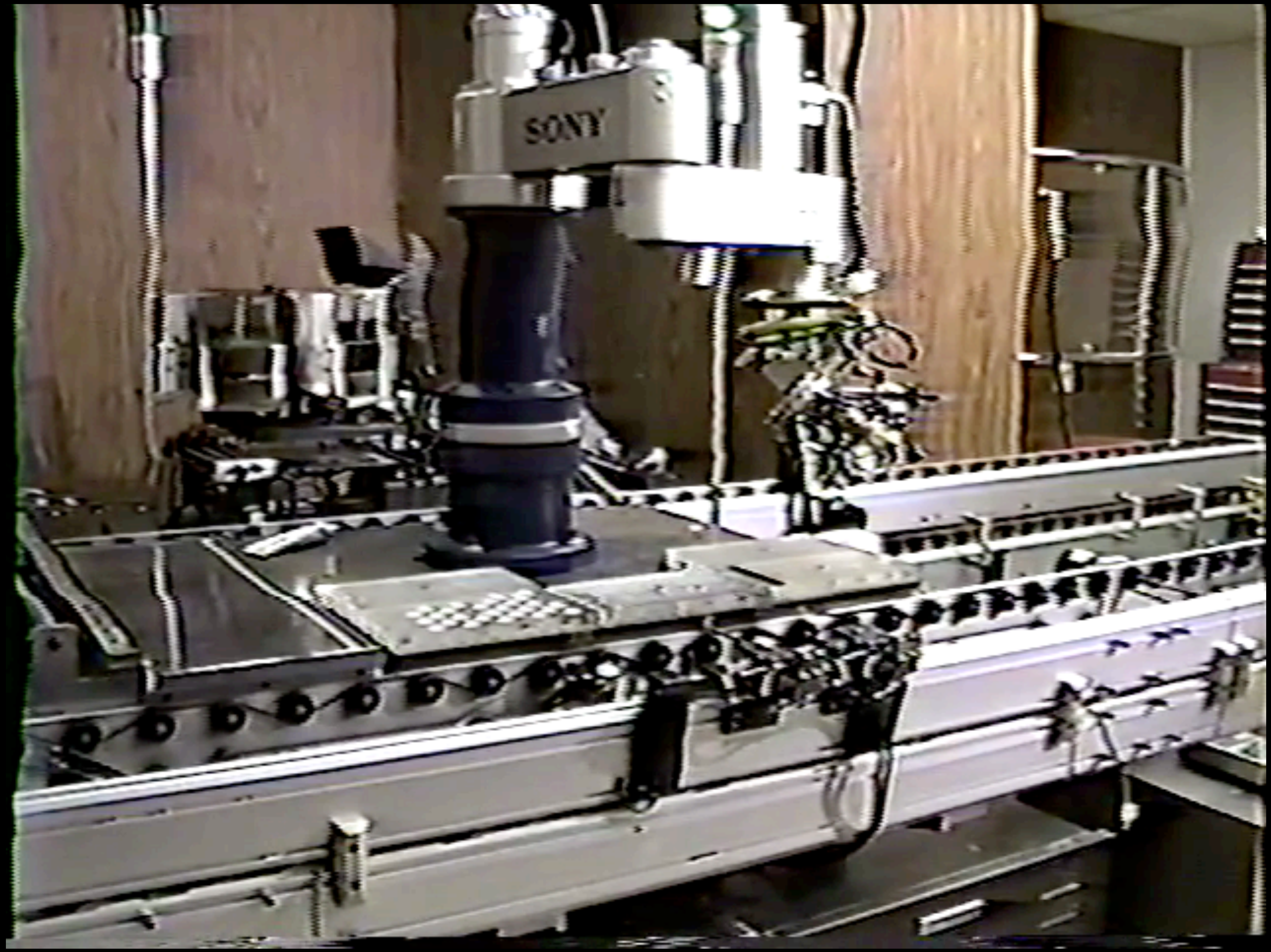
Can a robot hand be both simple and general?

- Assume:
  - Few actuators, e.g. one;
  - Few sensors;
  - Simple mechanisms;
  - Small, light, inexpensive.
- Could it ...
  - Pick parts from a bin?
  - Operate scissors?
  - Open a door?
  - Fold origami?



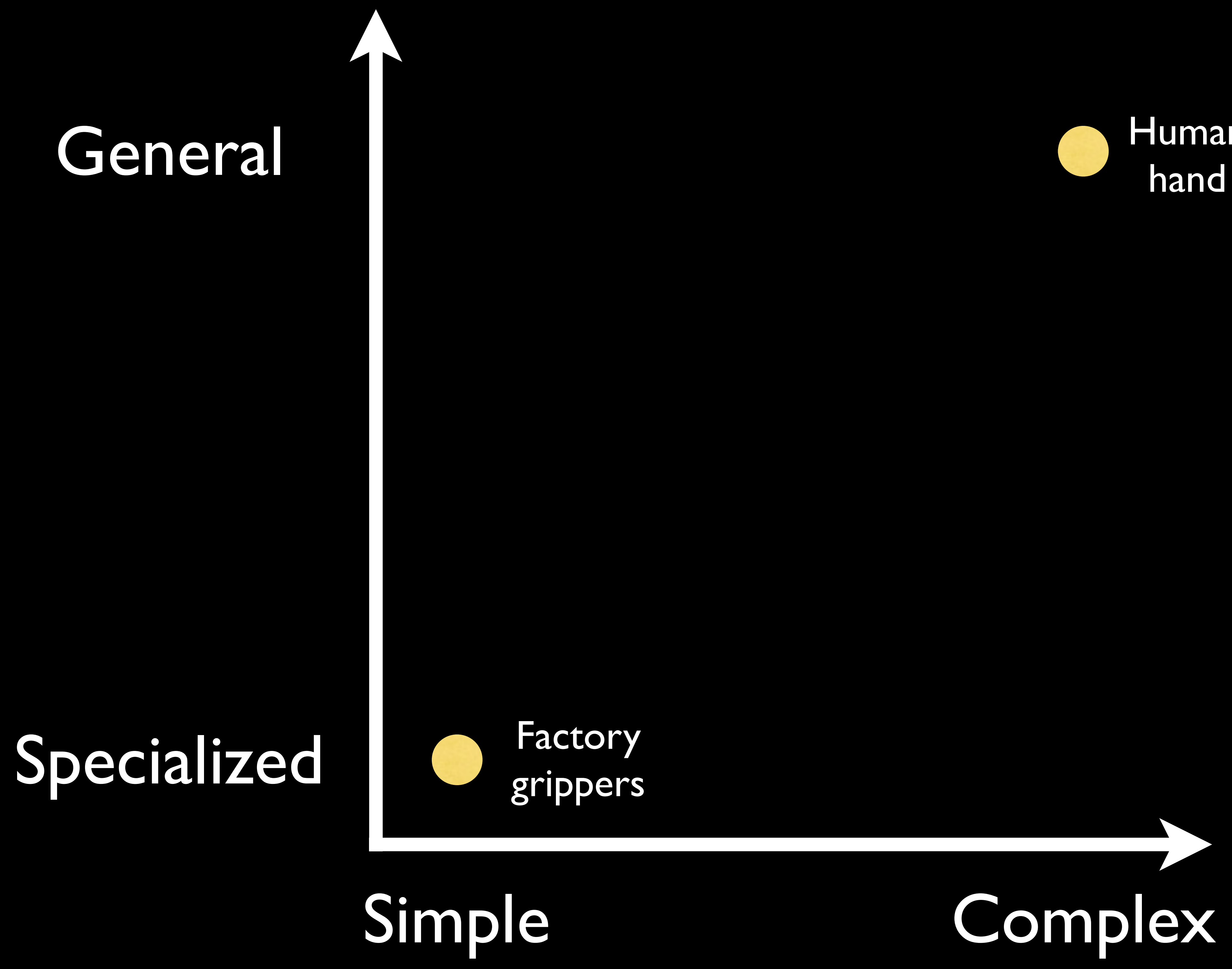
The Kraft Viper





Six simple but
not general hands.

Sony SMART Cell


General
Specialized
Simple
Complex
Human
hand
Factory
grippers

The case for complexity.

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- In examples, complexity correlates with generality.

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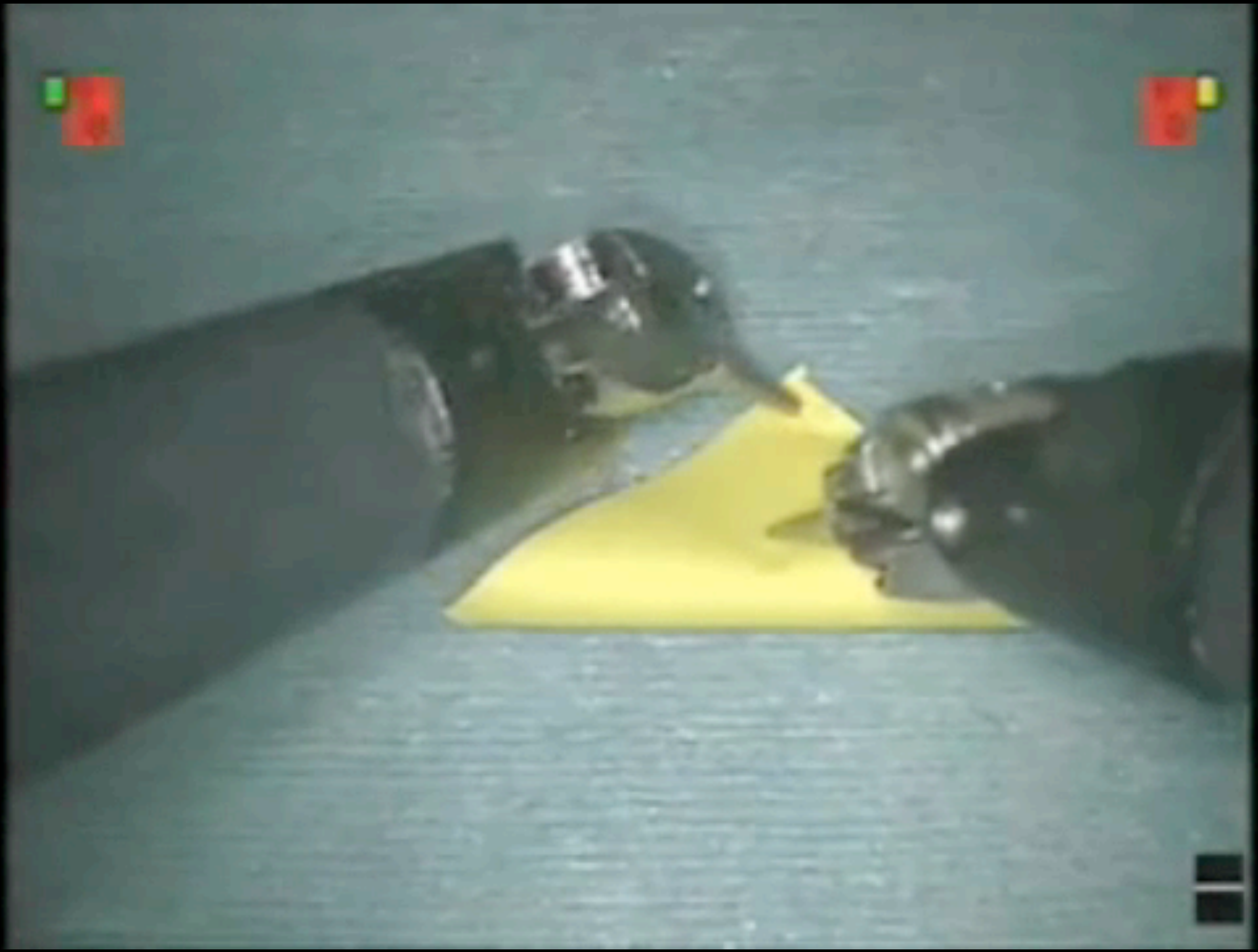
- Grasping involves conforming hand shape to given object shape. More freedoms implies greater variety of shapes.
- In-hand manipulation of a rigid body the straightforward way requires nine actuators.
- For haptic shape sensing, more sensors and more freedoms implies more data.
- Design constraints have consequences.

Second, the case for simple hands ...



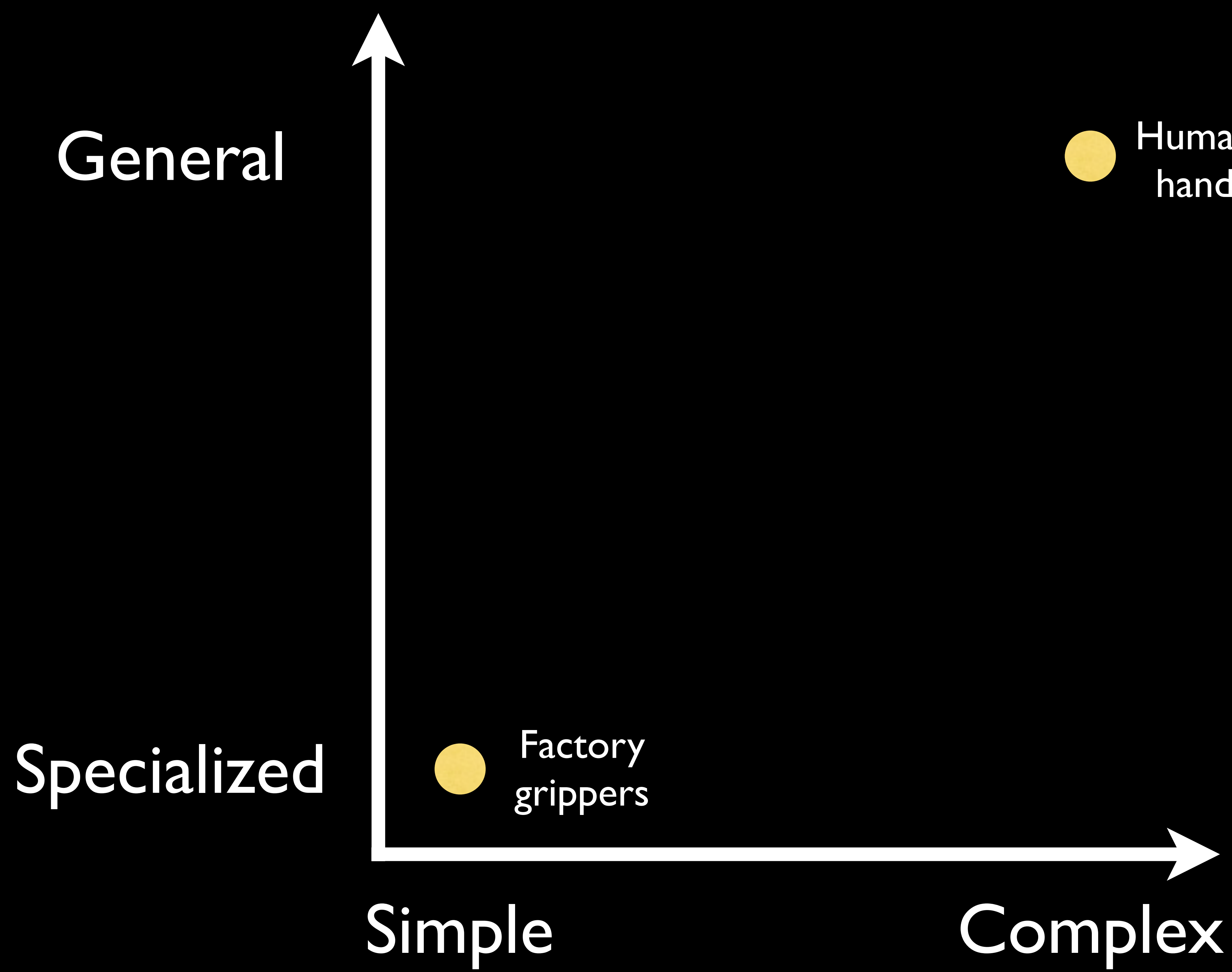
da Vinci Surgical System
Kanazawa University

Some simple but general hands.

- da Vinci surgery (and origami)
- human with prosthetic hook
- hardware pickup tool
- chopsticks
- roulette croupier
- underwater teleoperated grippers

Summarizing the case for simplicity.

- Humans, animals, teleoperators can do a lot with simple hands;
- Practical issues – robustness, cost, weight, ...
- Scientific benefits.
- The gold standard for generality is a human *with tools*. Humans are adept with anthropomorphic *and* simple effectors.


General
Specialized
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Human hand
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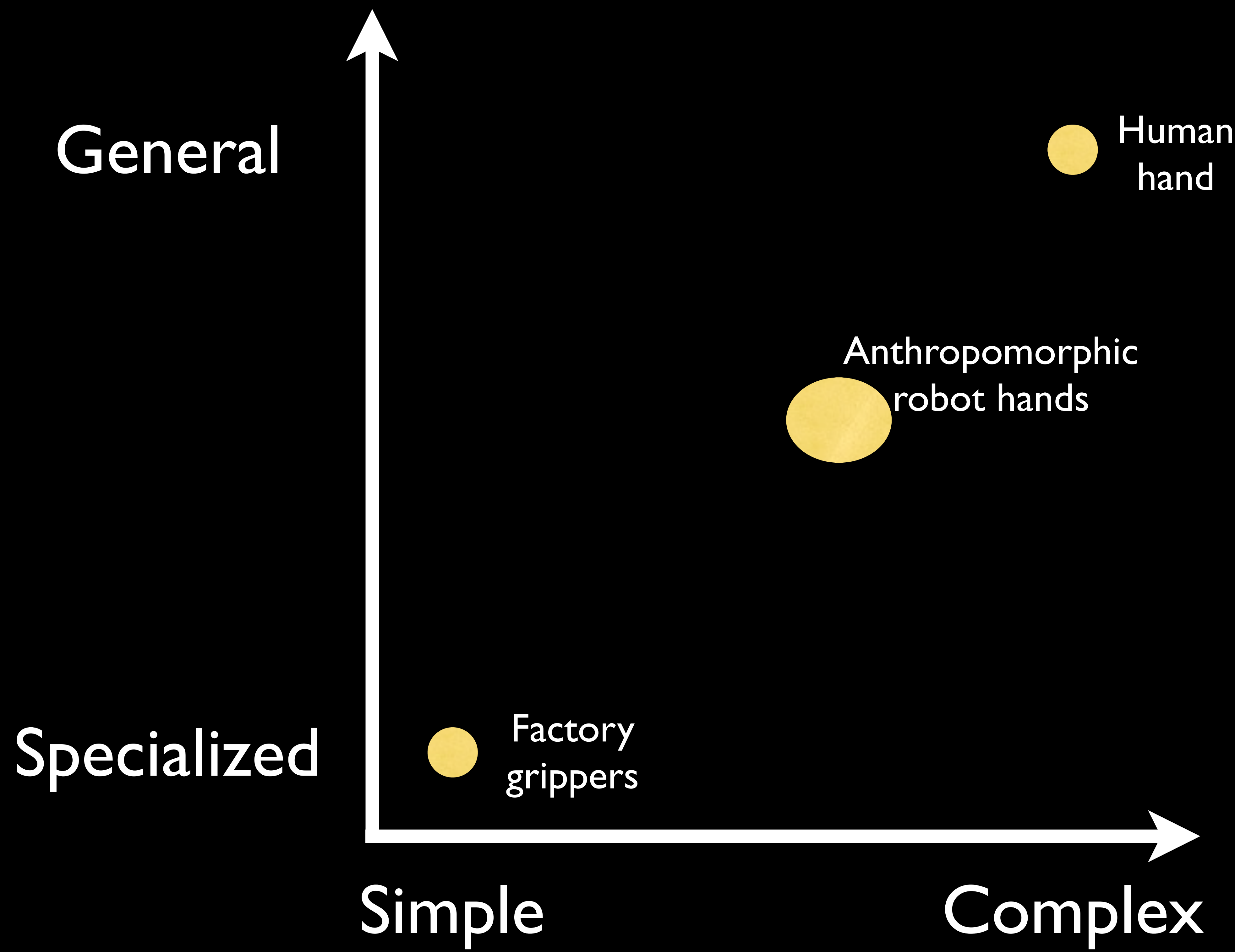
General
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Human hand
Anthropomorphic robot hands
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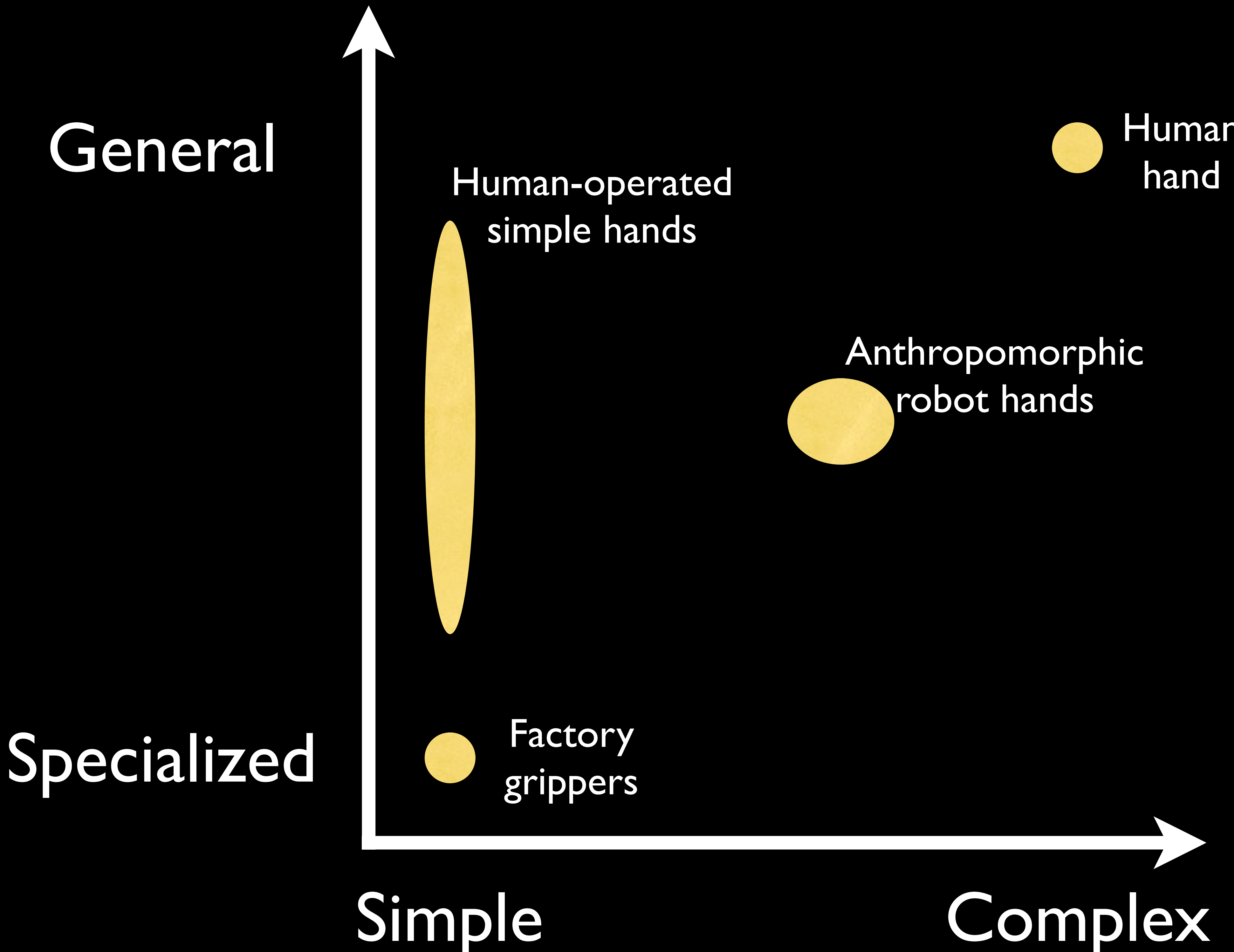
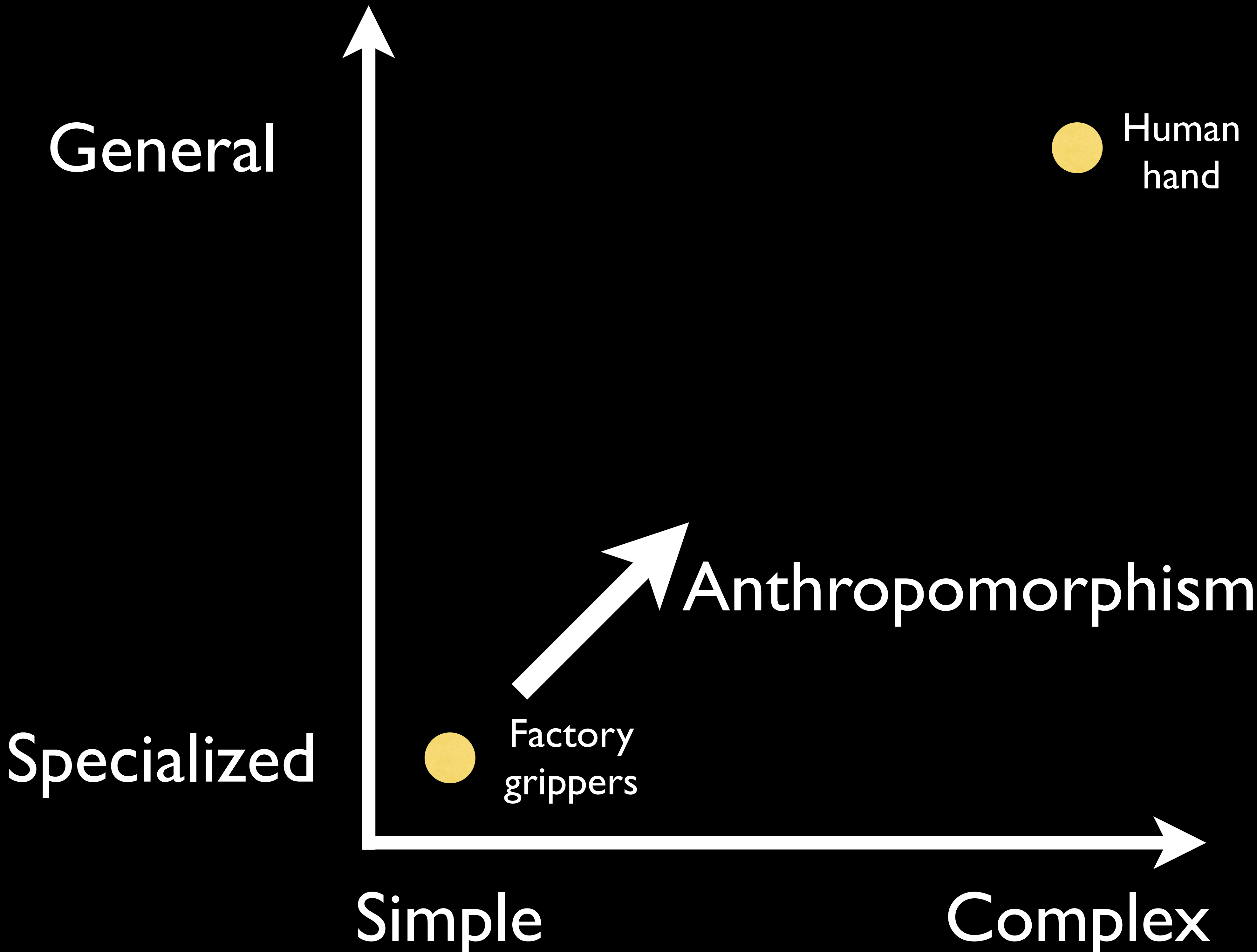

General
Specialized
Simple
Complex
Human-operated simple hands
Factory grippers
Anthropomorphic robot hands
Human hand


General
Specialized
Human
hand
Anthropomorphism
Factory
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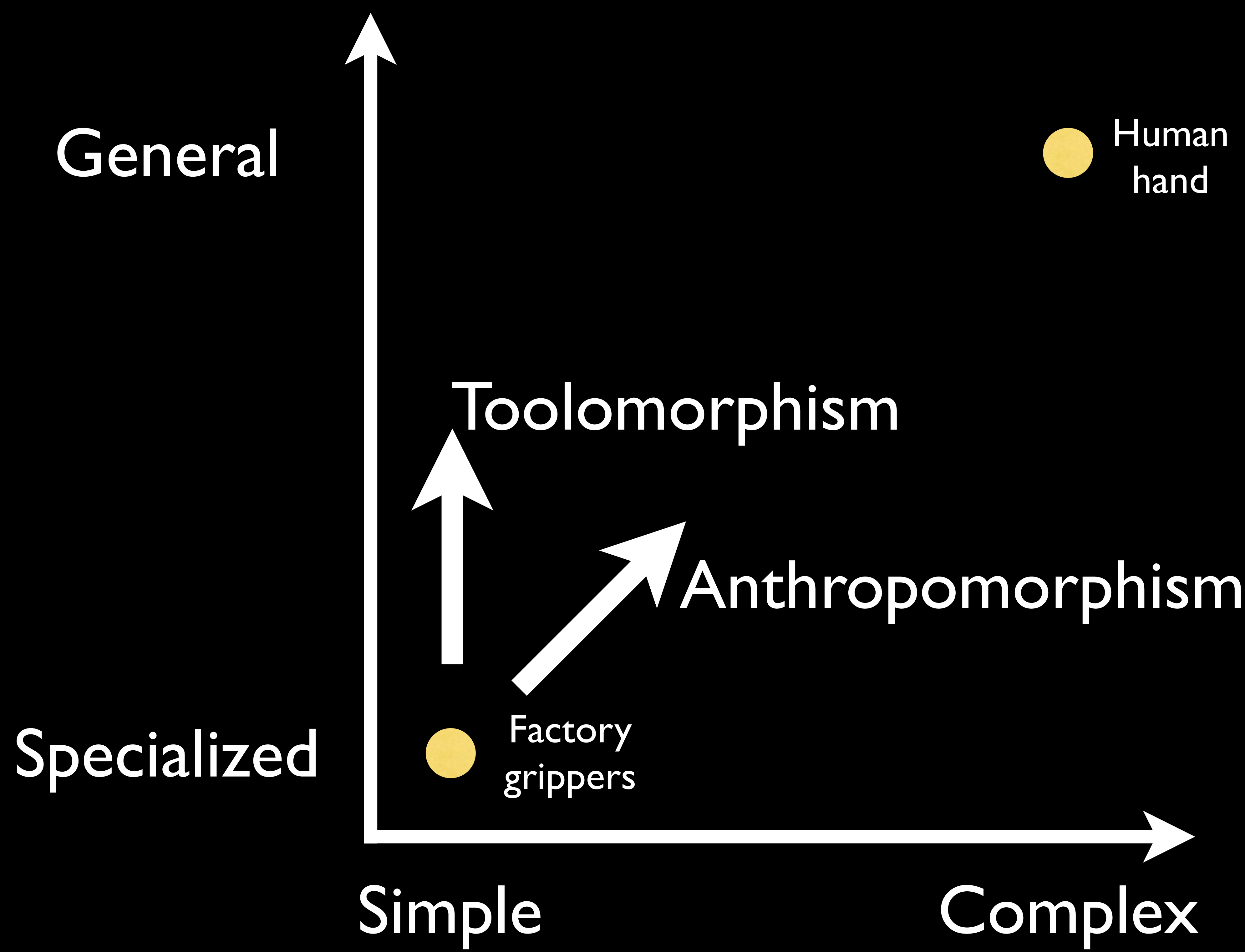
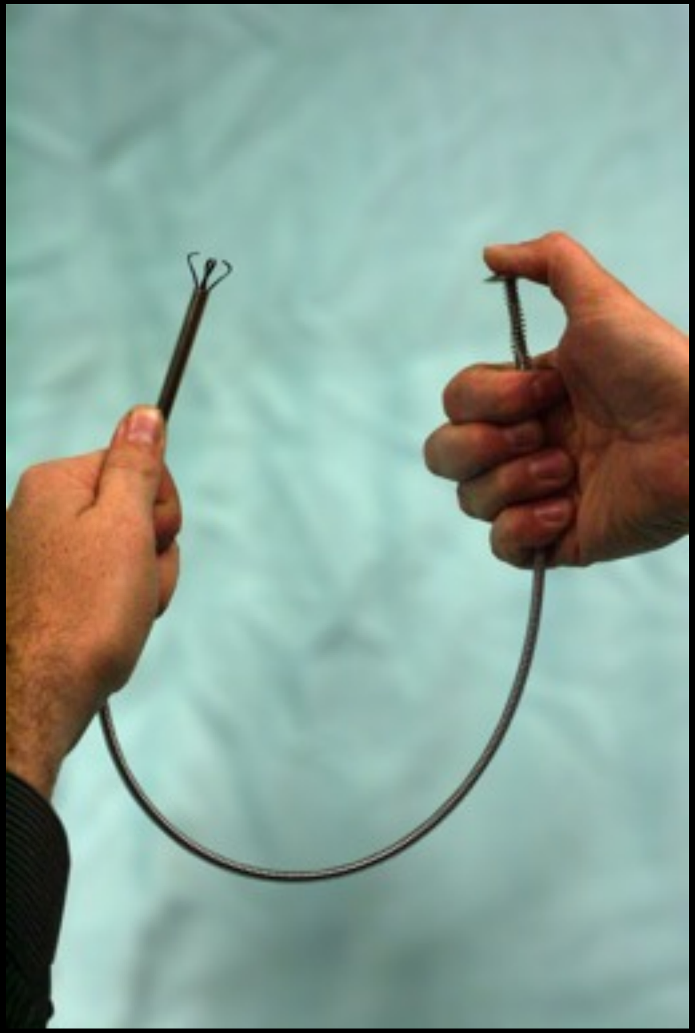
Simple
Complex


General
Human hand
Toolomorphism
Anthropomorphism
Specialized
Factory grippers
Simple
Complex

Part II
A toolomorphic manipulator

Part II
A toolomorphic manipulator

Our inspiration:
the pickup tool.



Pickup tool philosophy

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- ***Let the fingers fall where they may.***
    - Instead of "put the fingers in the right place".

Pickup tool philosophy

- ***Let the fingers fall where they may.***
  - Instead of "put the fingers in the right place".
- ***Grasp first, ask questions later.***
  - Instead of knowing pose in advance, and avoiding object motion during grasp.

Preview

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- Task: bin picking
  - High uncertainty; High clutter
  - Target rich environment

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- Let the fingers fall where they may
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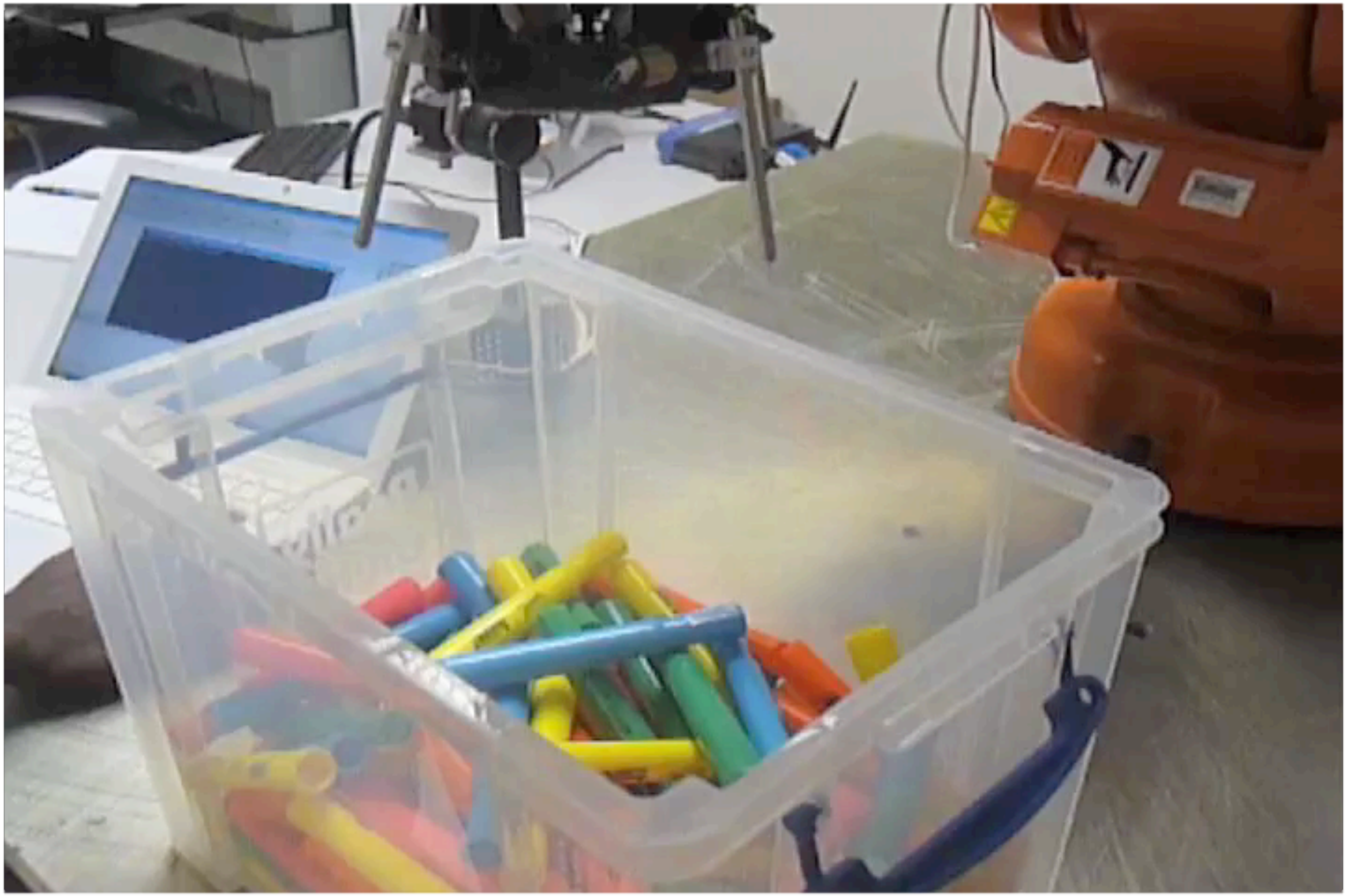
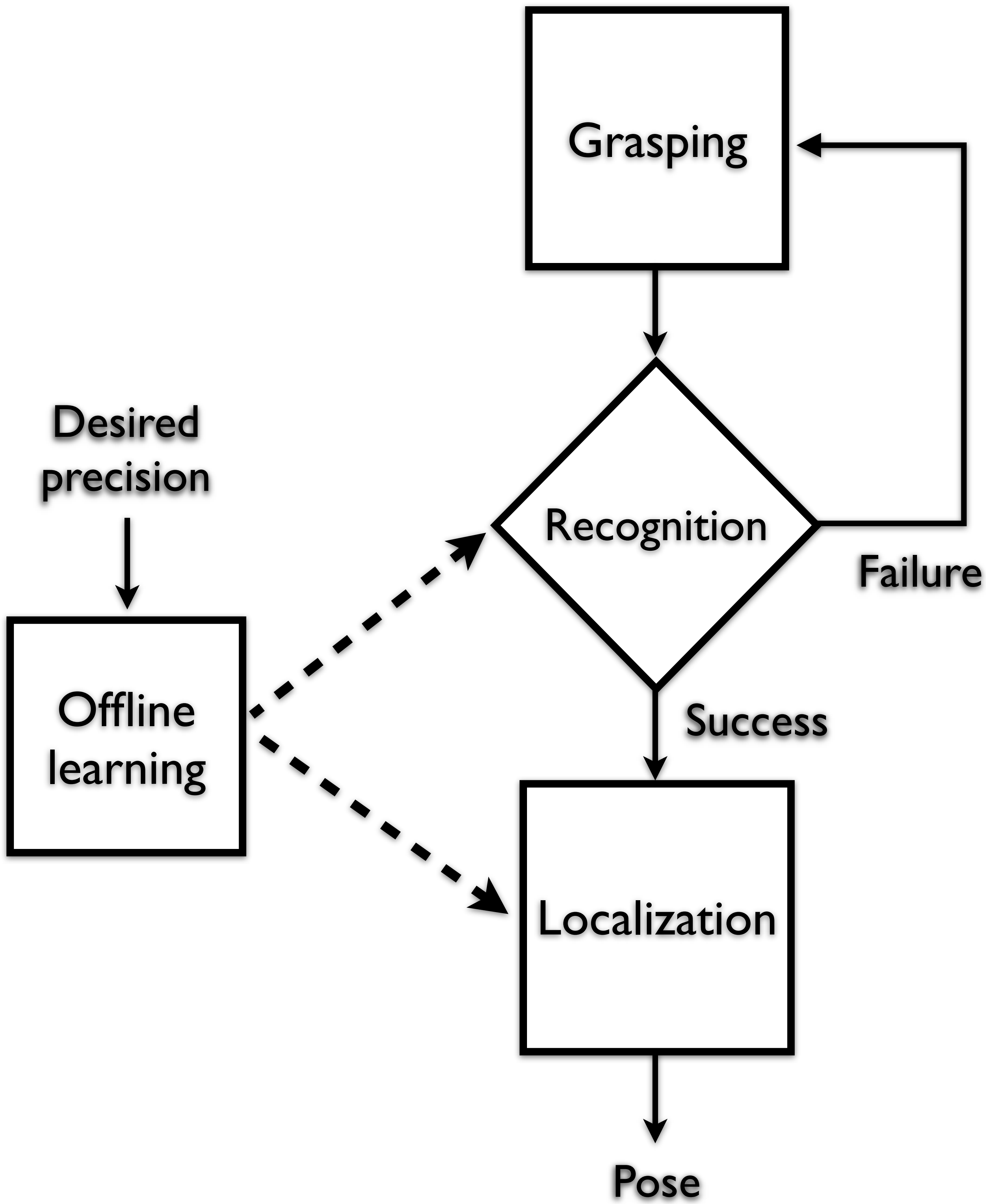
Preview

- Task: bin picking
  - High uncertainty; High clutter
  - Target rich environment
- Let the fingers fall where they may
  - Simple hand; Blind grasp
- Grasp first, ask questions later
  - Hope that object falls into stable pose
  - Simple recognition and localization
  - Offline learning of perception




Grasping
Desired precision
Recognition
Failure
Offline learning
Success
Localization
Pose

Hand concept

Planar palm
Linear fingers
Single actuator
Compliant coupling
Joint angle encoders

Hard and slippery!

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Linear fingers
Single actuator
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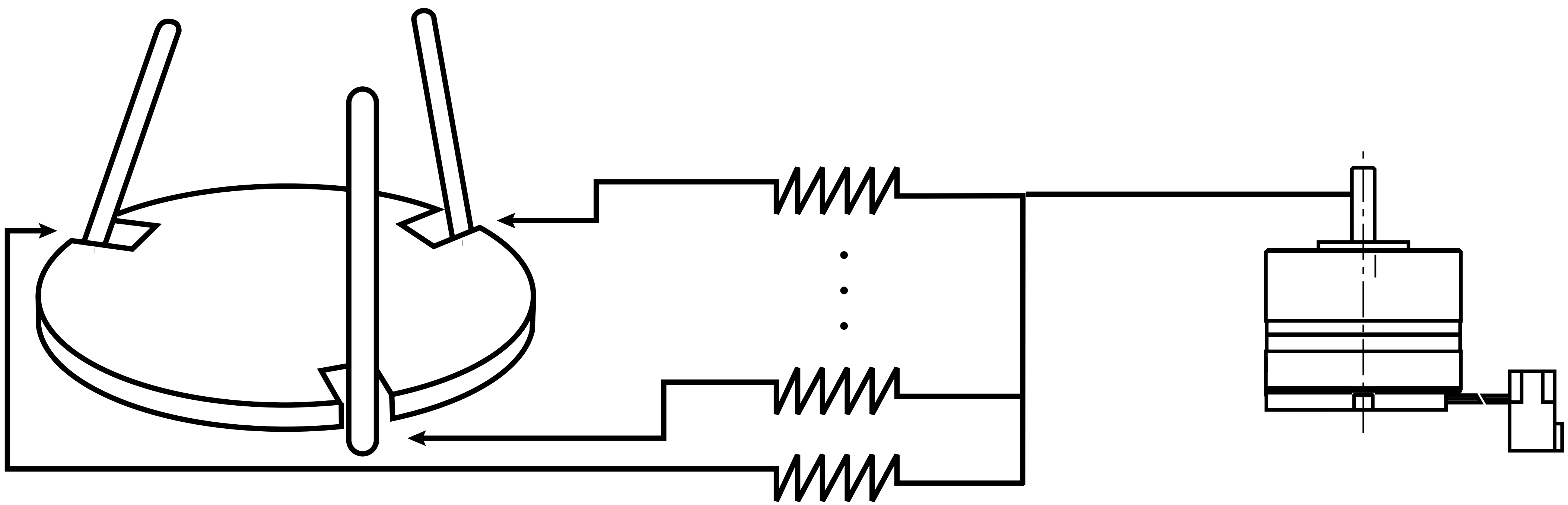
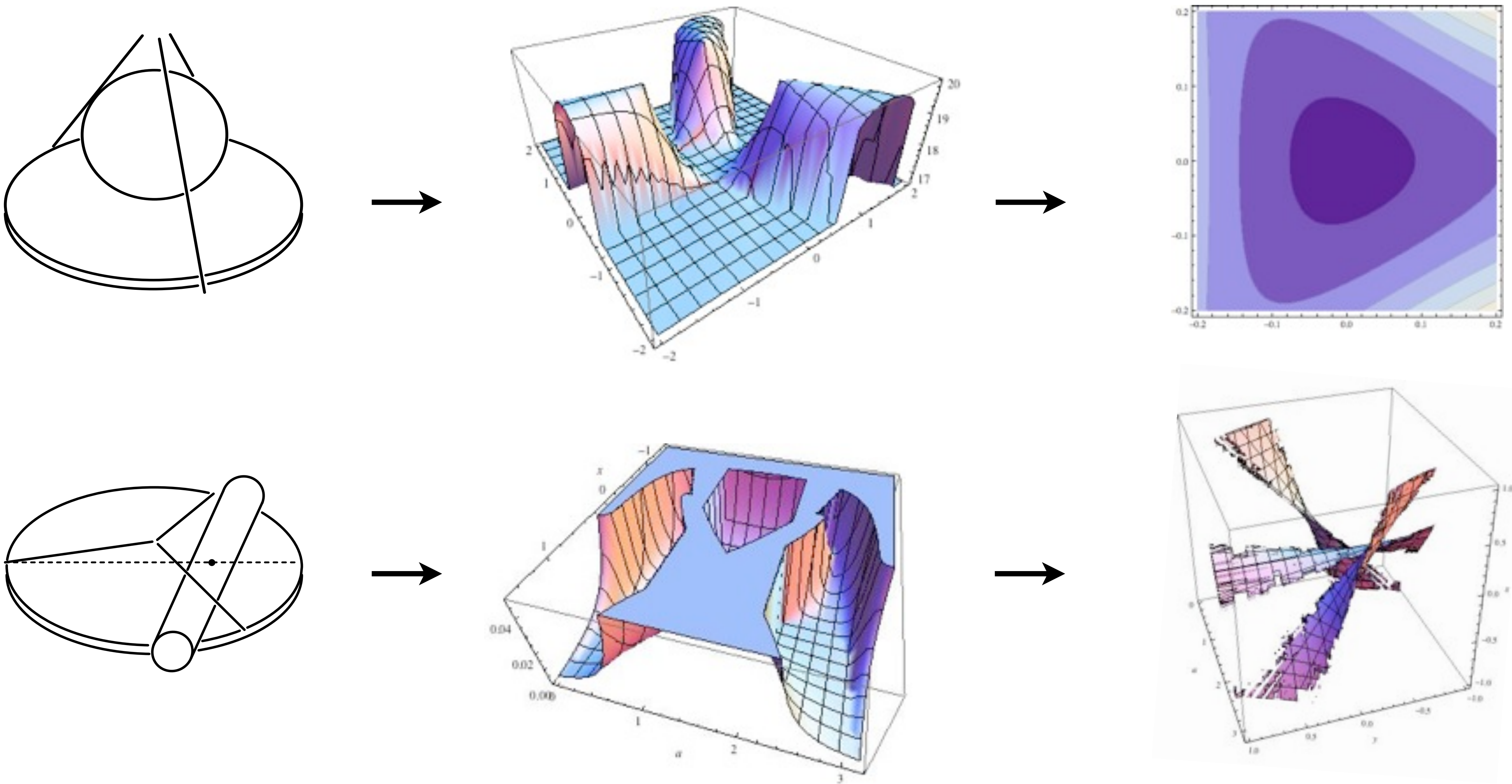
Joint angle encoders



Hard and slippery!

Hard and slippery for perception and learning



Perception uses finger and motor encoders

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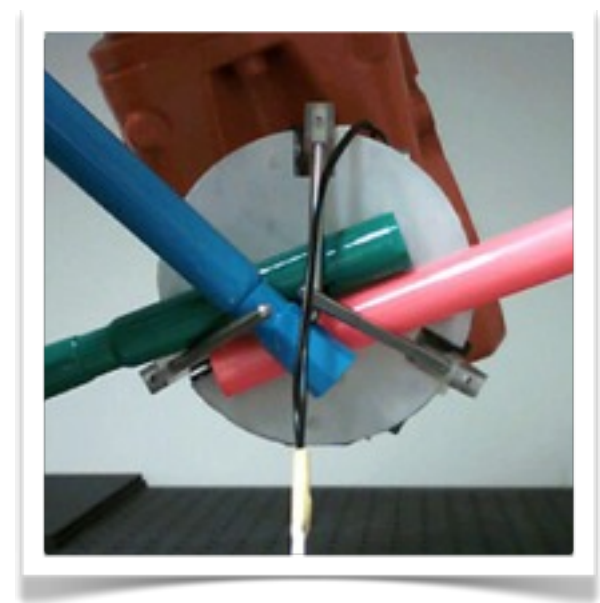
- Grasp Classification



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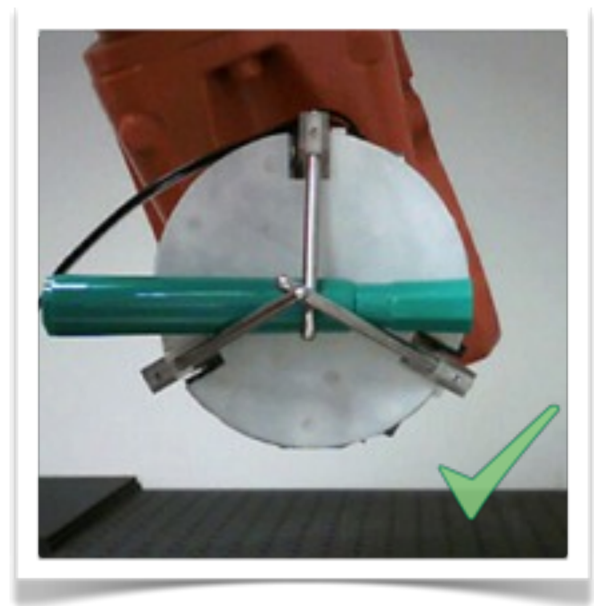

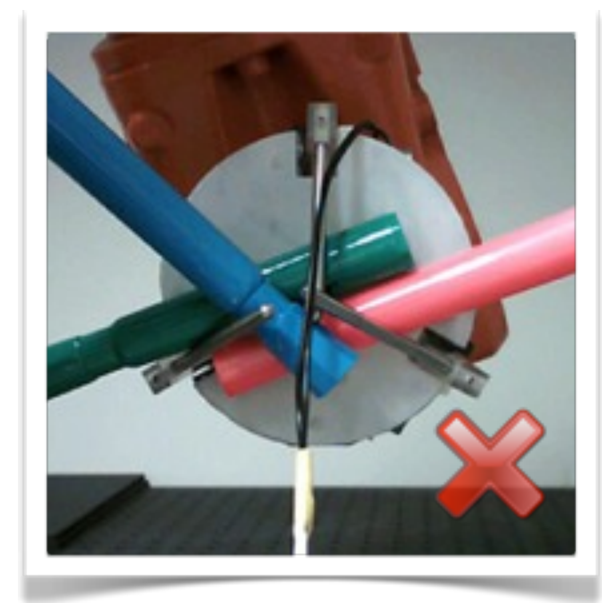

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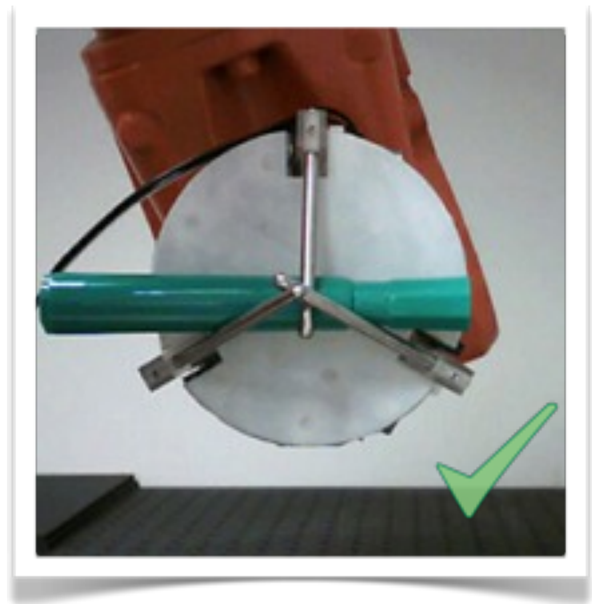
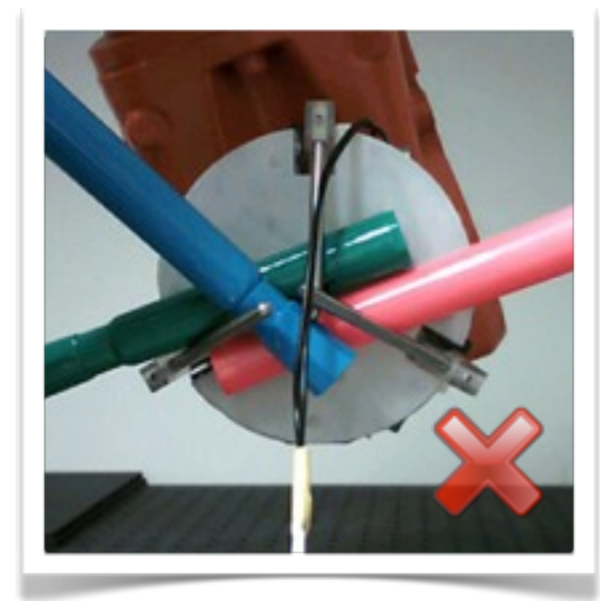
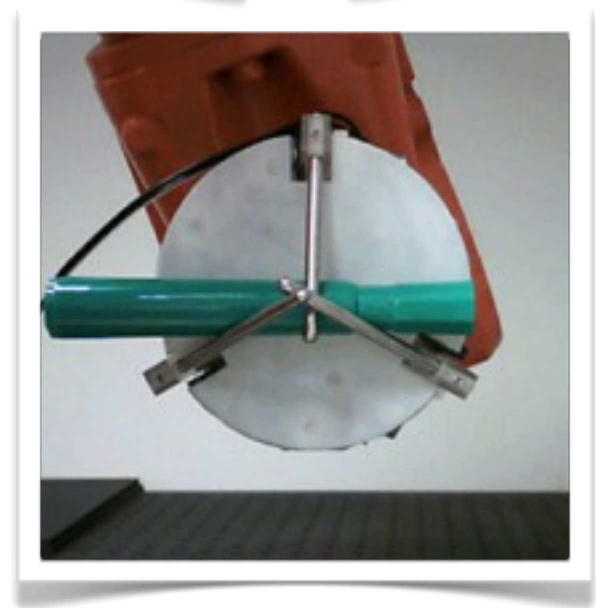




- In-hand Localization



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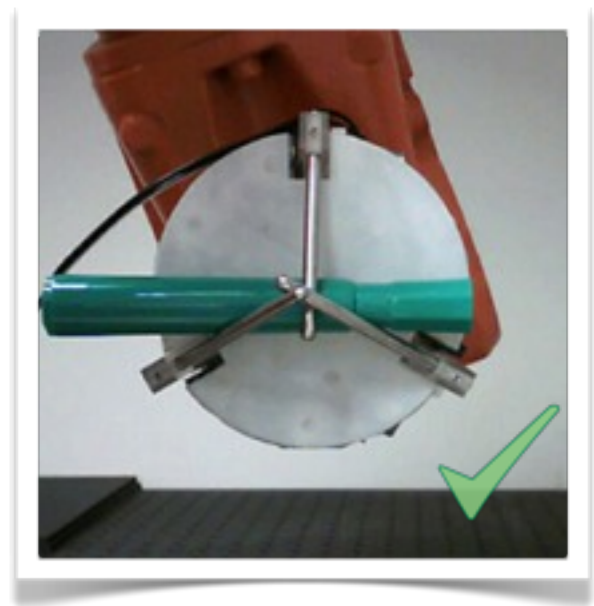
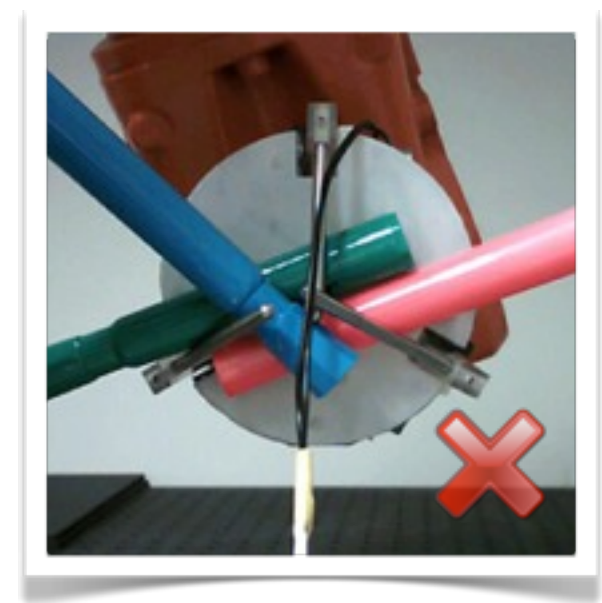


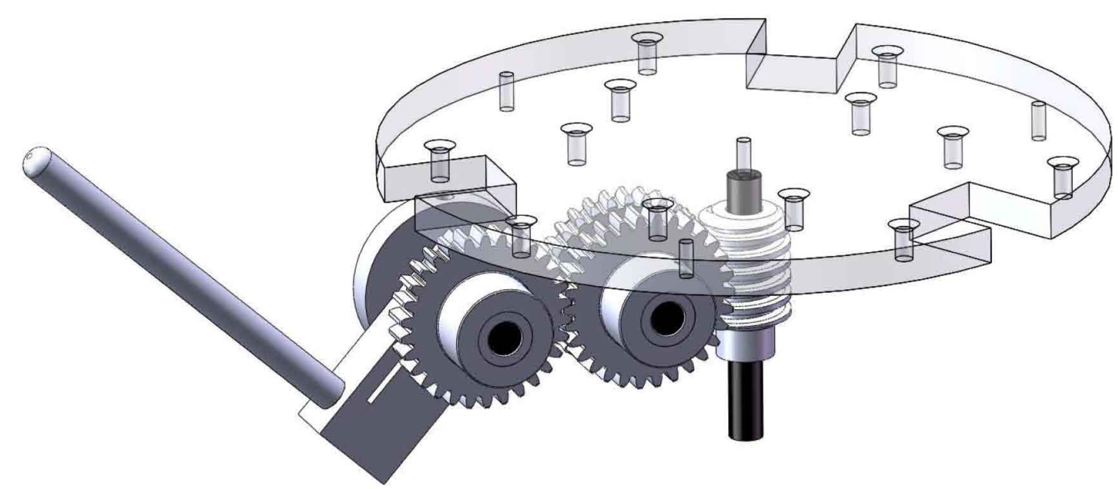


- In-hand Localization

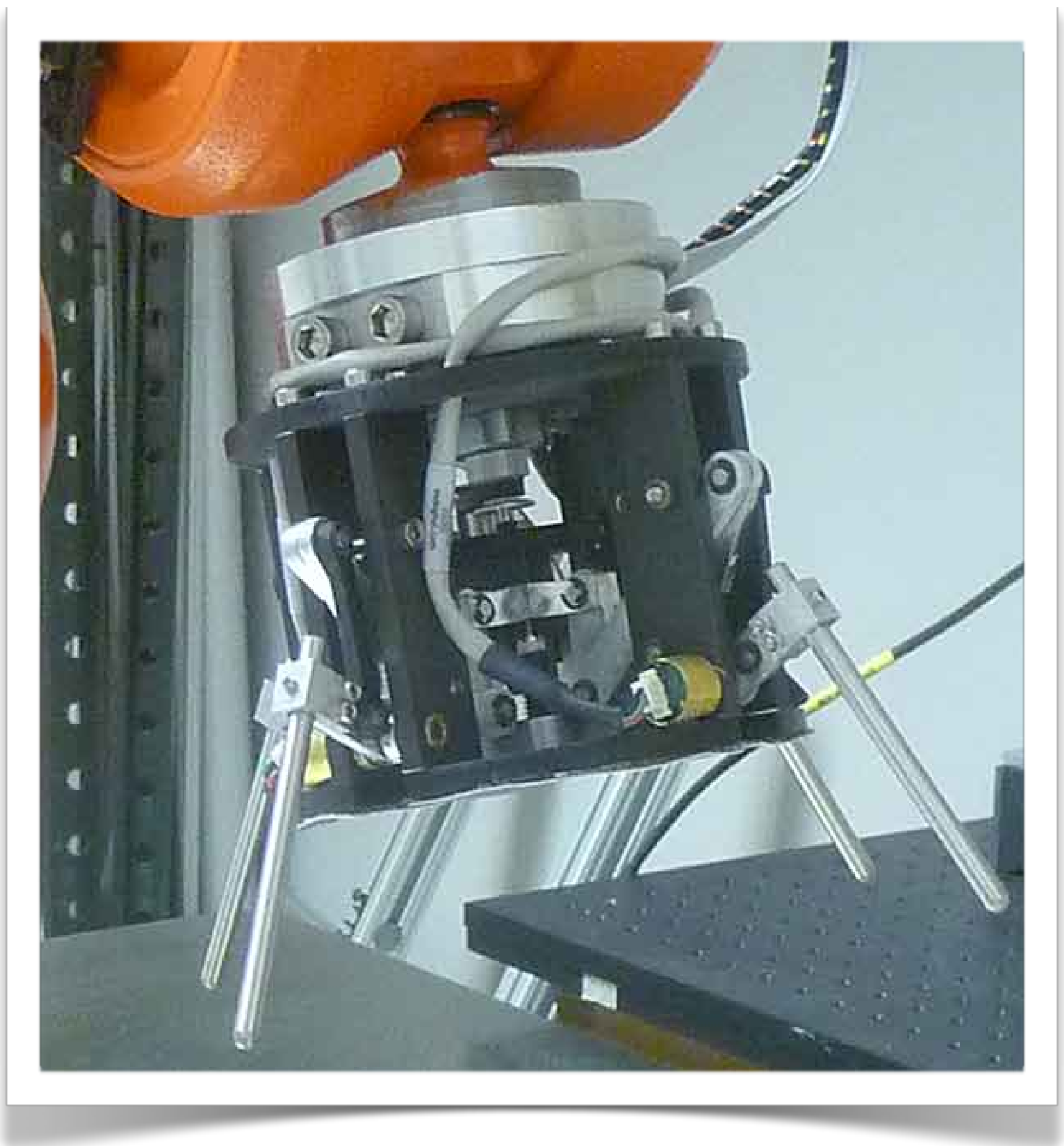
The Implementation

Prototype 1

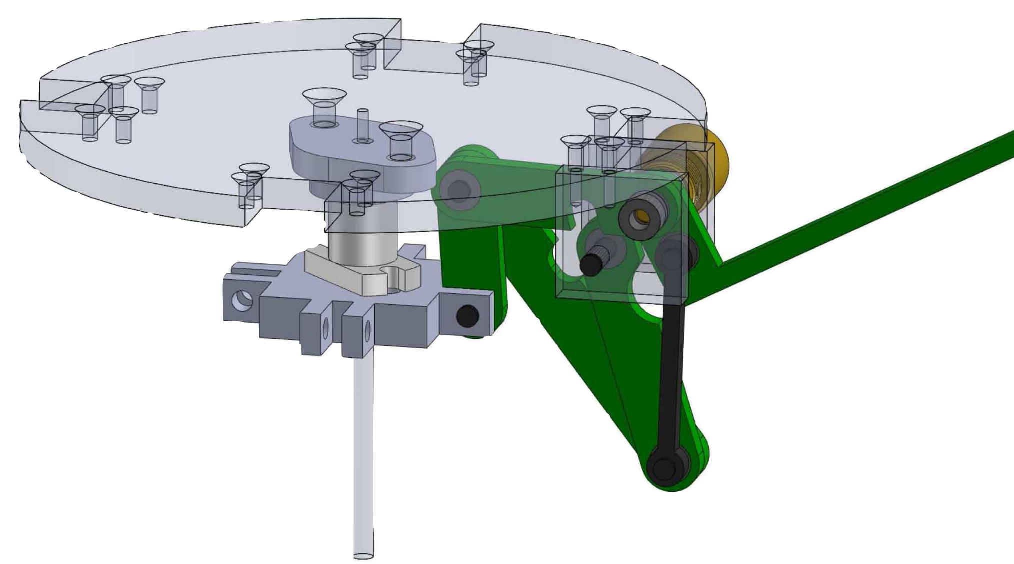
- 3 fingers.
- Gear transmission.
- Torsional springs.



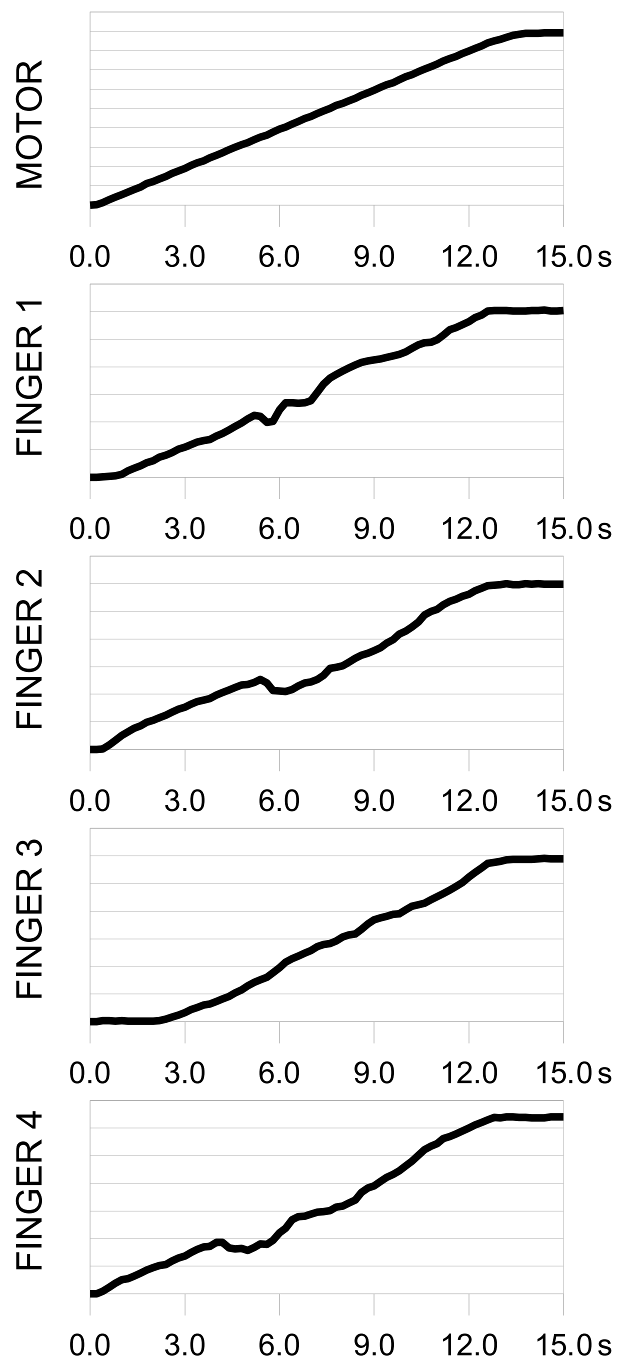
Prototype II



- 4 fingers.
- Linkage transmission.
- Elastic link in the linkage.
- Fully observable.



Grasp Signature



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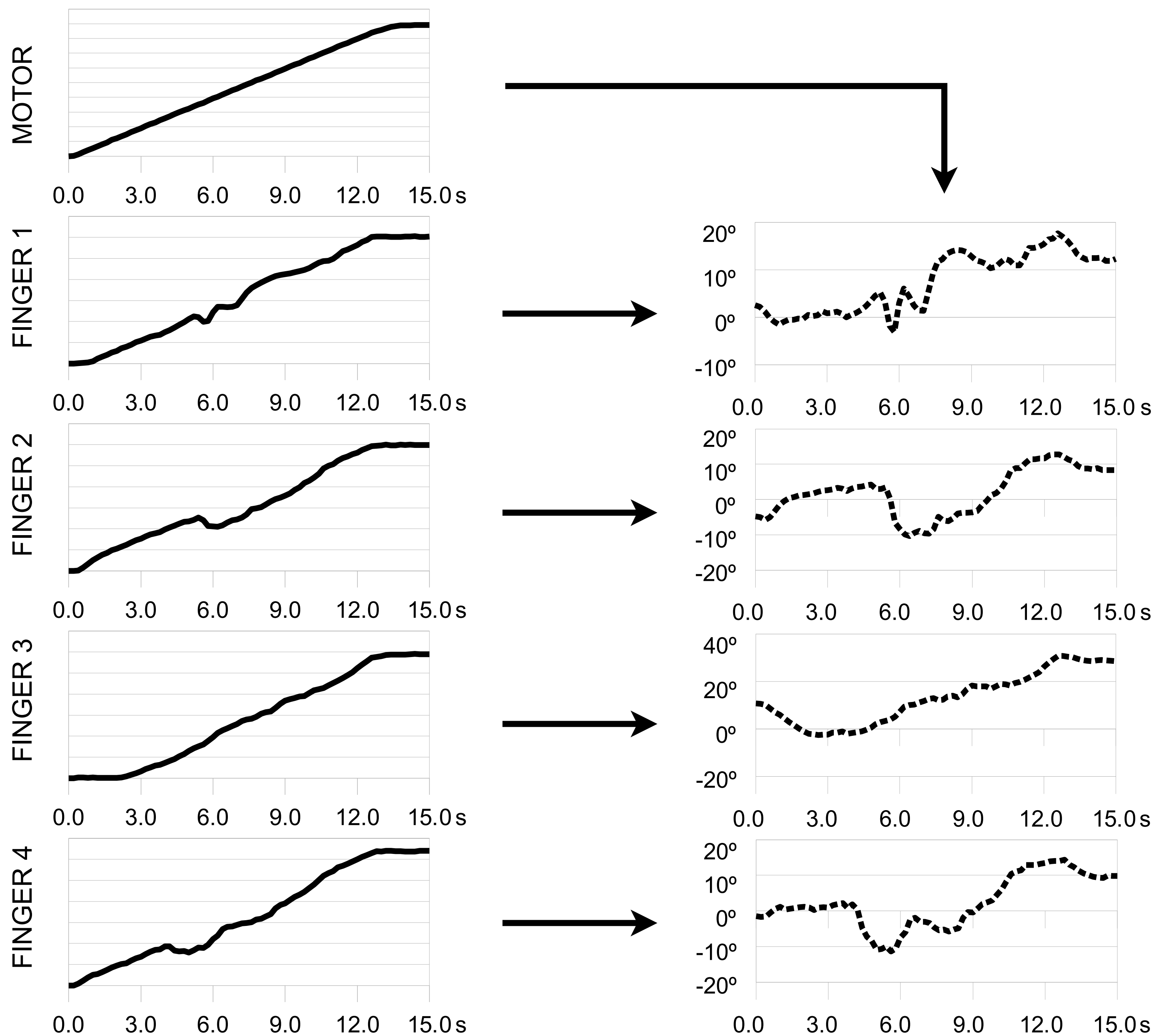


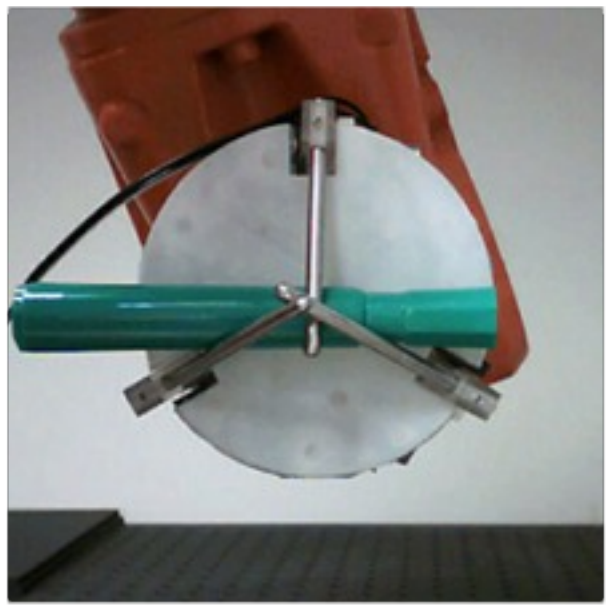
Experimental Setting

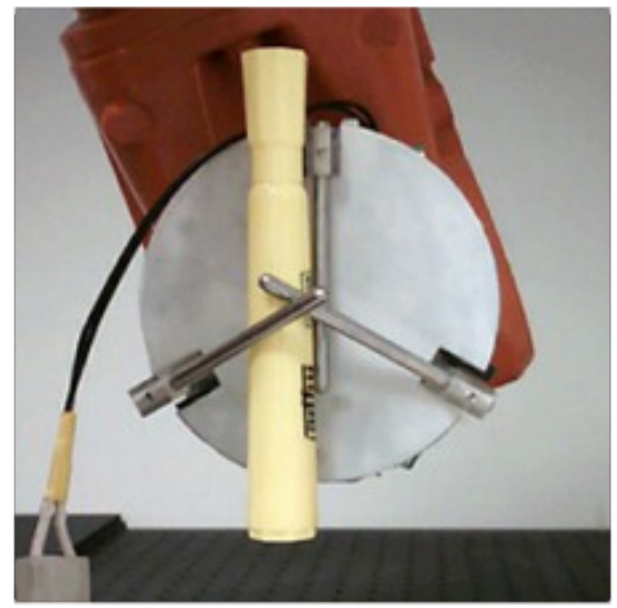
- Industrial manipulator.
- Preprogrammed grasp motion.
- State machine commands:
  - Robot
  - Gripper
  - Vision system
  - Logger
- 200 trials with each gripper.

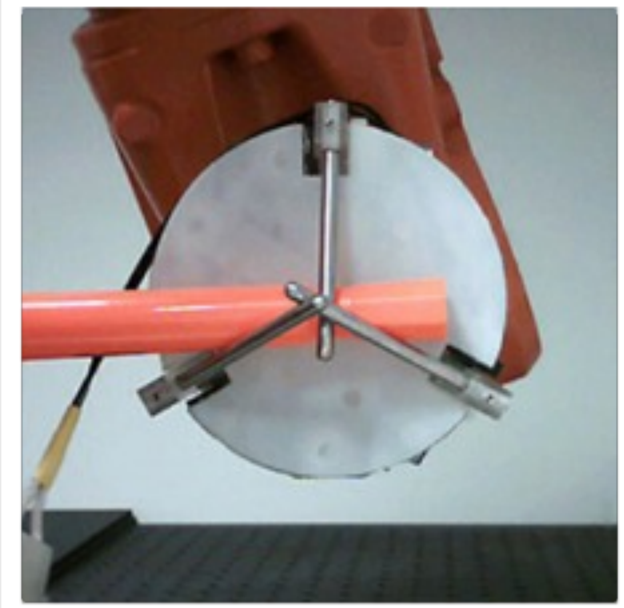
Blind grasp statistics

# markers grasped	0	1	2	3	4
P1	57 (28.5 %)	83 (41.5 %)	43 (21.5 %)	17 (8.5 %)	0 (0 %)
P2	37 (18.5 %)	84 (42.0 %)	49 (24.5 %)	27 (13.5 %)	3 (1.5 %)

Typical "successful" blind grasps







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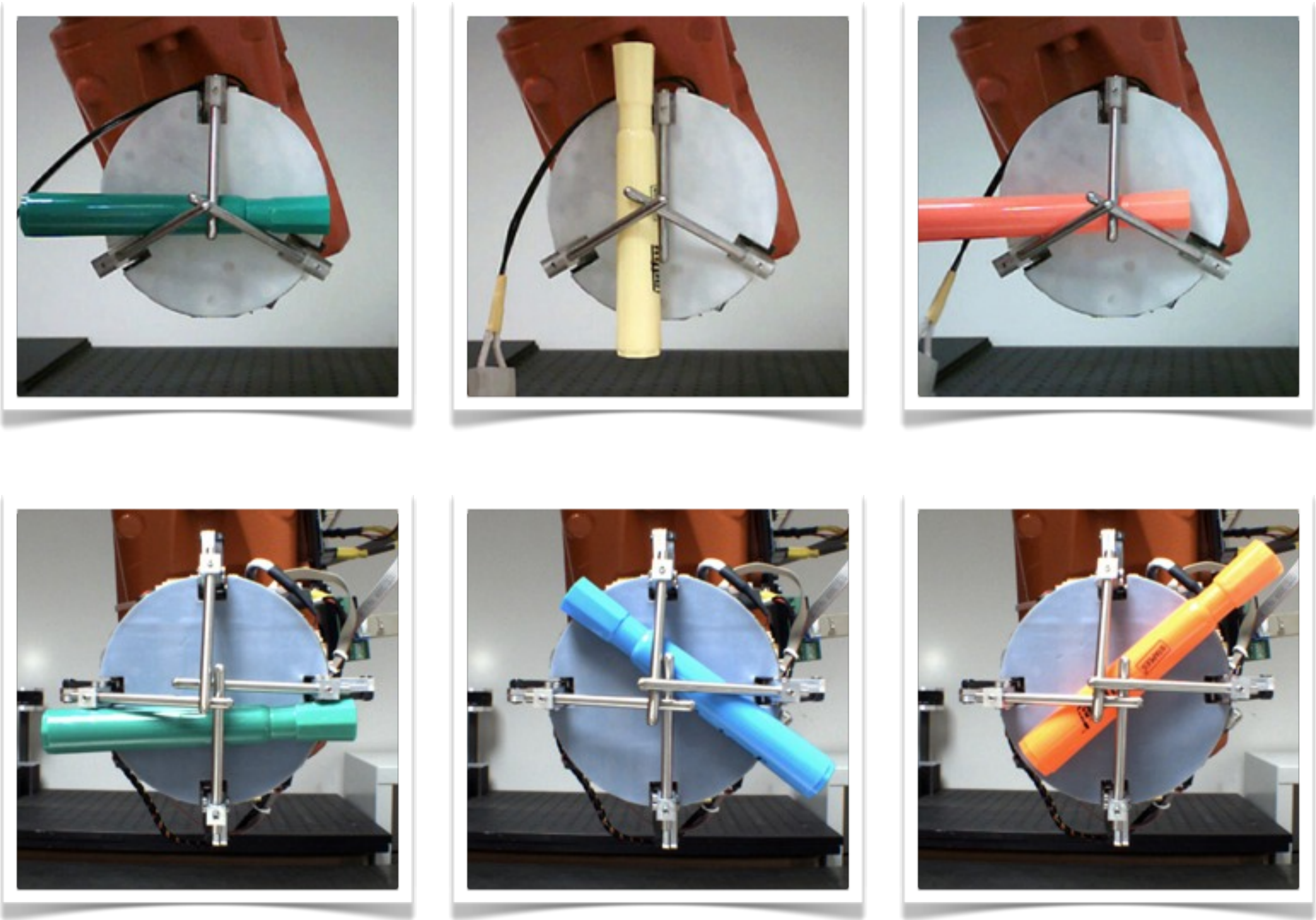

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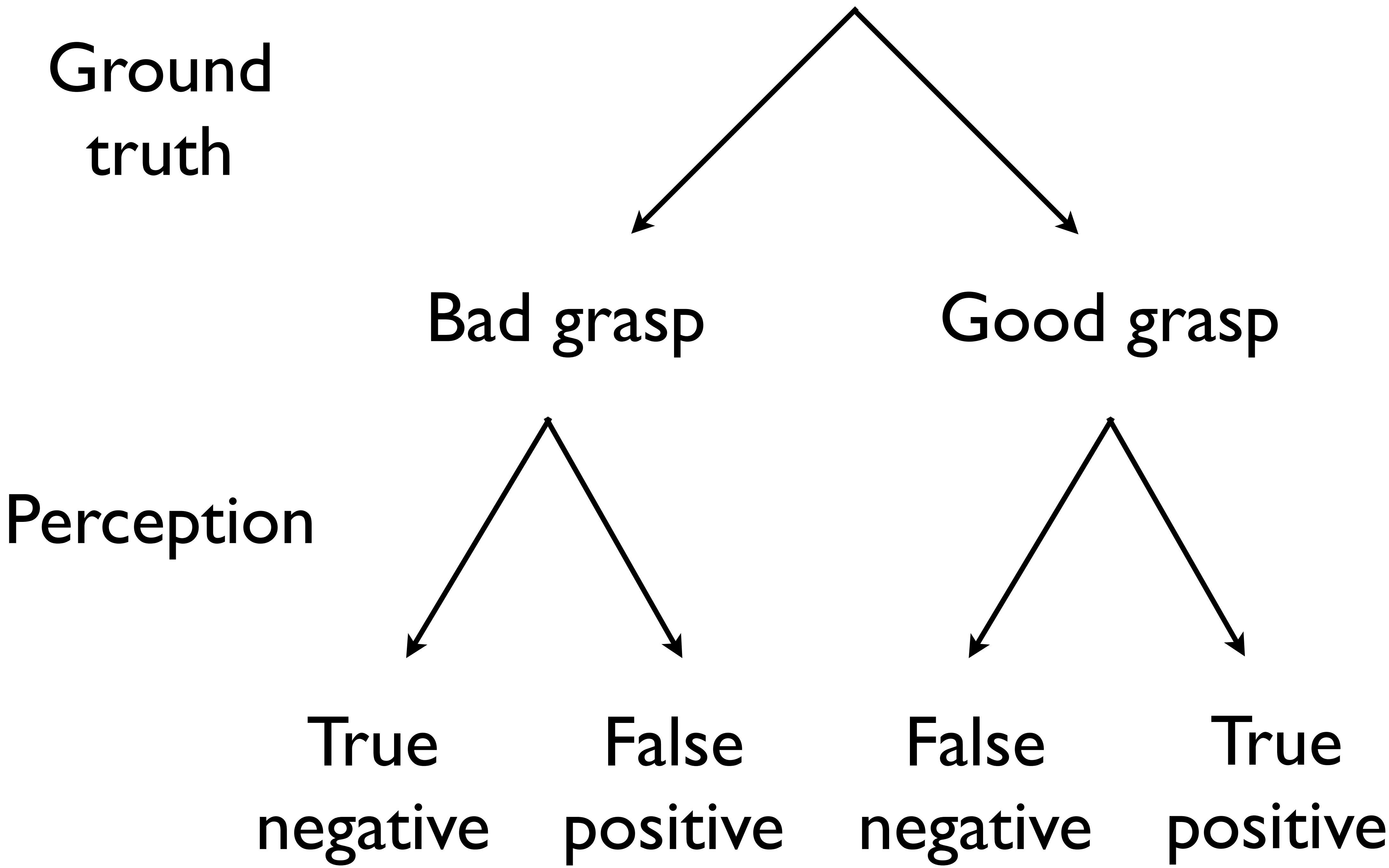
Results


Ground truth
Bad grasp
Good grasp
Perception
True negative
False positive
False negative
True positive

Classifier statistics

- Accuracy: True / True + False
- Precision: True positives / Positives
- Recall: True positives / Good grasps

Accuracy

- Principle Component Analysis compression.
- Support Vector Machine classifier.

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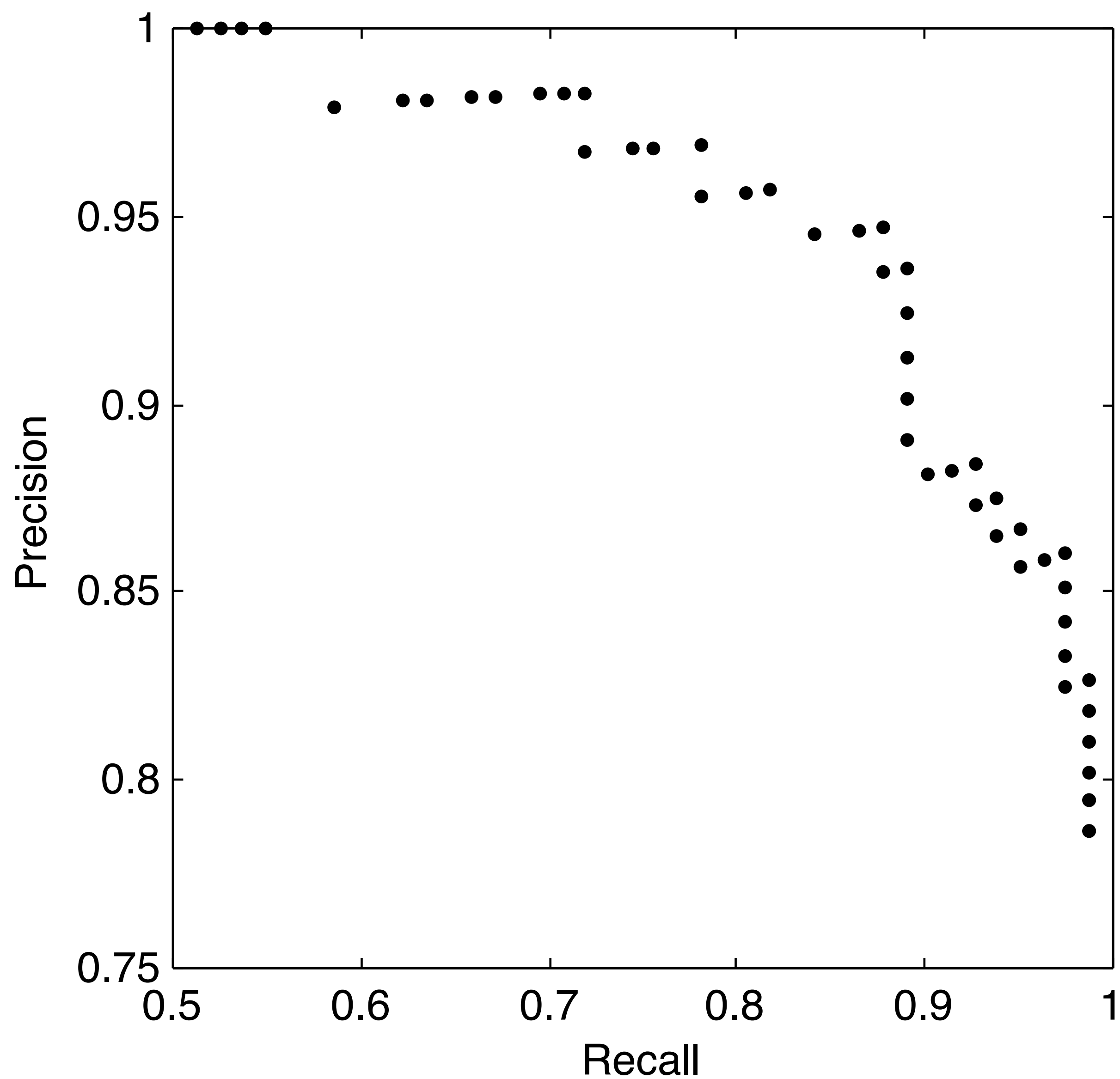
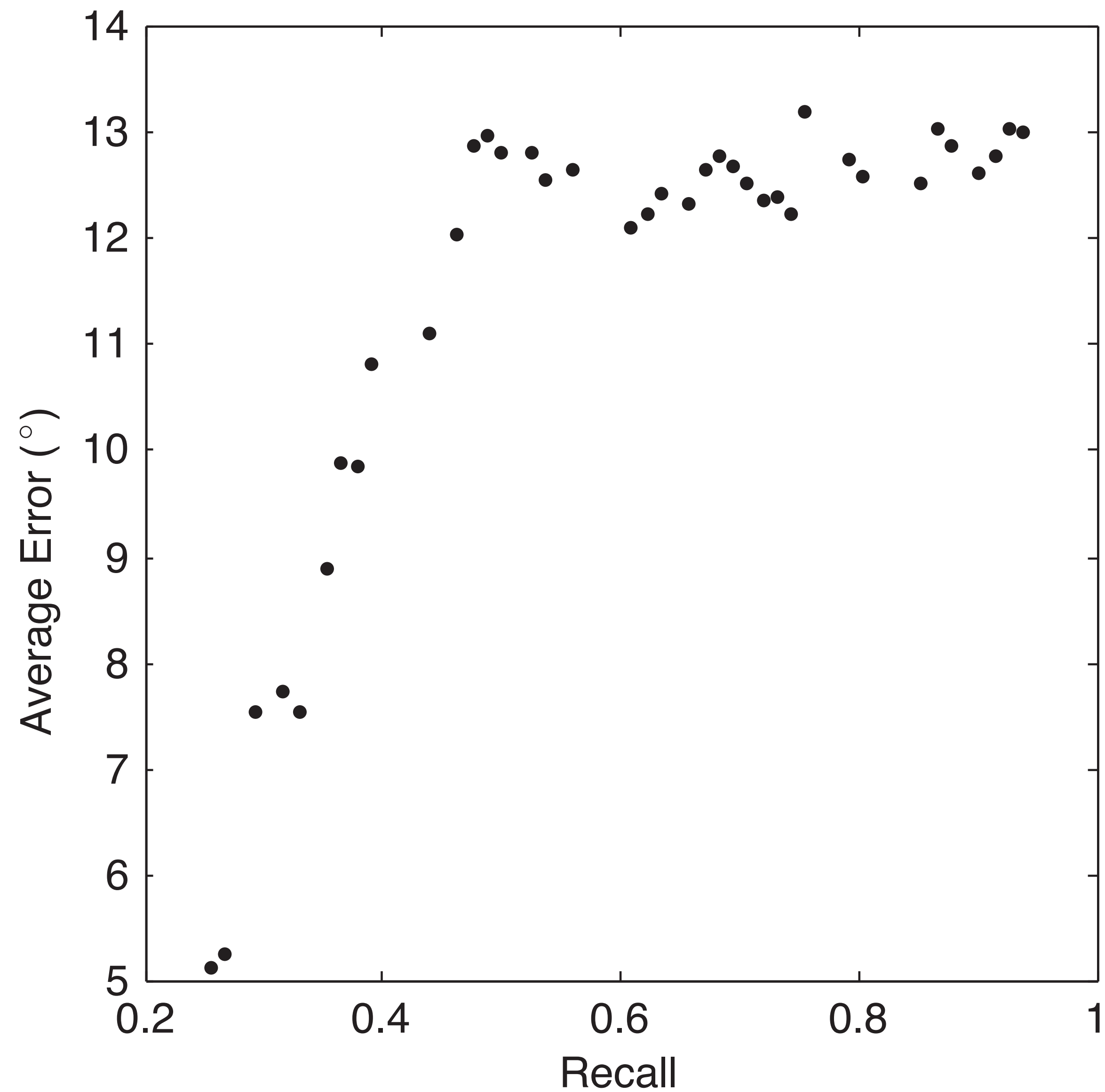
Grasp Recognition



Virtually eliminate false positives,
while missing half of the good grasps.

In-Hand Localization



Reduce mean error to 8 degrees,
but miss 2/3 of the good grasps.

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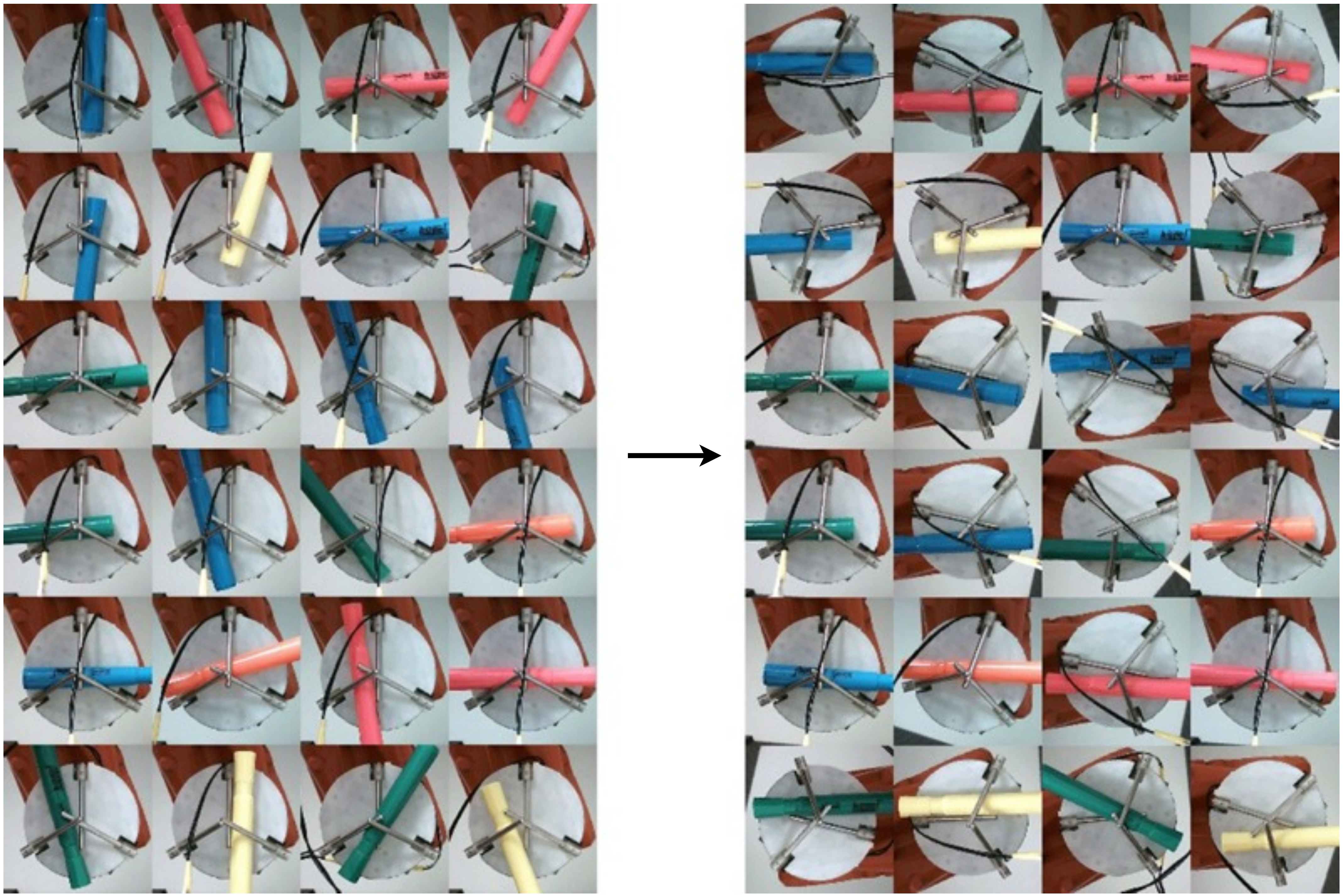
In-Hand Localization

In-Hand Localization



Discussion

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- Design hand for perception. Design for learning.

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- You could say, it's not very good.
    - It fumbles.
    - But, so do humans.
    - Real problem: it fumbles slowly.

Future Work

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- Better hand:
  - Non-interfering fingers.
  - Palm and finger shape: V-shape potential fields.
  - Variable stiffness.

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Future Work

- Better hand:
  - Non-interfering fingers.
  - Palm and finger shape: V-shape potential fields.
  - Variable stiffness.
- Better control:
  - Faster fumbling (Alberto's talk)
  - Learn policy

Thanks!!