Sensor and Touch-Based Reflex Grasping Methods

Paulo Camasmie

16848 Design and Control for Dexterous Manipulation | Spring 2020

Professor Nancy Pollard

Enhancing Adaptive Grasping Through a Simple Sensor-Based Reflex Mechanism

Emanuele Luberto[1], Yier Wu[1], Gaspare Santaera[2], Marco Gabiccini[1], and Antonio Bicchi[1,2]

[1]Universita di Pisa
[2]Instituto Italiano di Tecnologia

Method

- Preliminary grasp planned based on rough estimates
- Hand positioned and shaped to pre-grasp position
- Adaptive Sensor based algorithm
  - Wrist pose
  - Hand closure
- Object uniformly approached by all fingers

Pisa/IIT Softhand with IR Sensors

Cost Function

- All sensor measurements collected

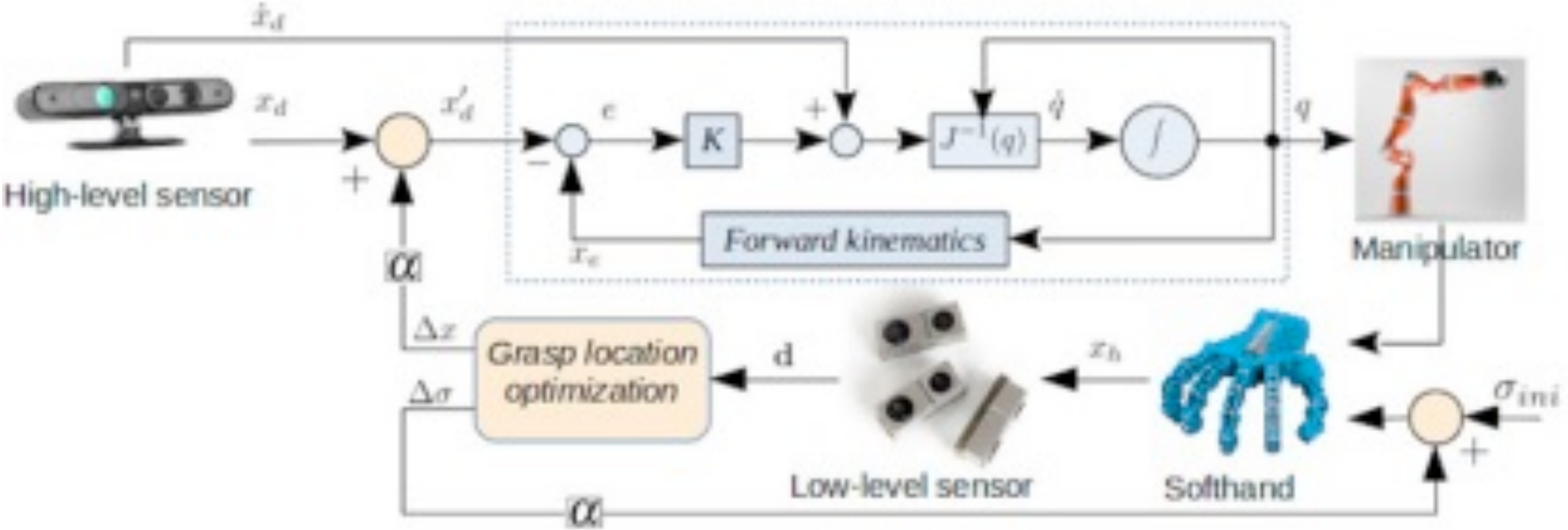
$$\mathbf{d} = [d_1, d_2, \ldots, d_n]^T$$

- Minimize Residual at every time step

$$\min_{\underline{\mathbf{x}}} f(\underline{\mathbf{x}}), \quad \text{where} \quad f(\underline{\mathbf{x}}) = \frac{1}{2}\underline{\mathbf{r}}(\underline{\mathbf{x}})^T \underline{\mathbf{r}}(\underline{\mathbf{x}})$$

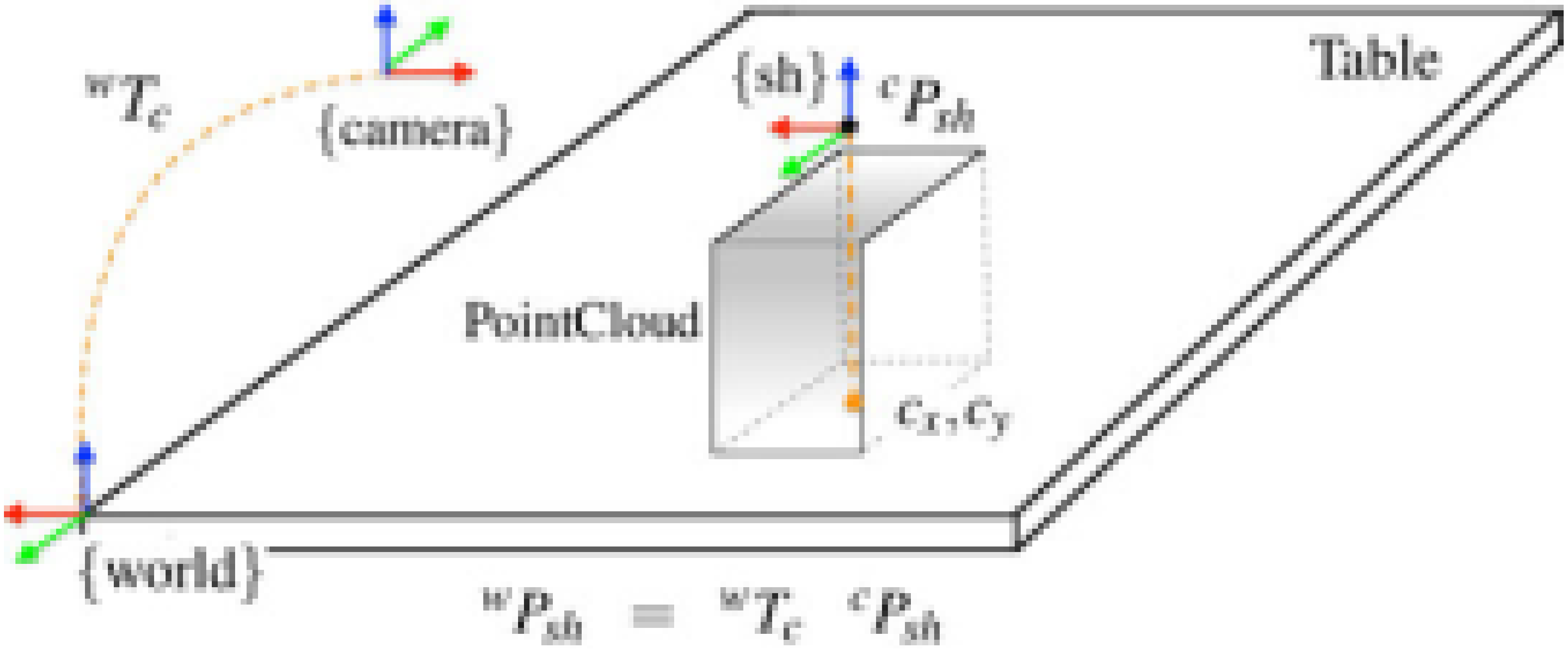
$$\underline{\mathbf{x}} = [p_x, p_y, p_z; r_x, r_y, r_z; \sigma]^T$$

Control

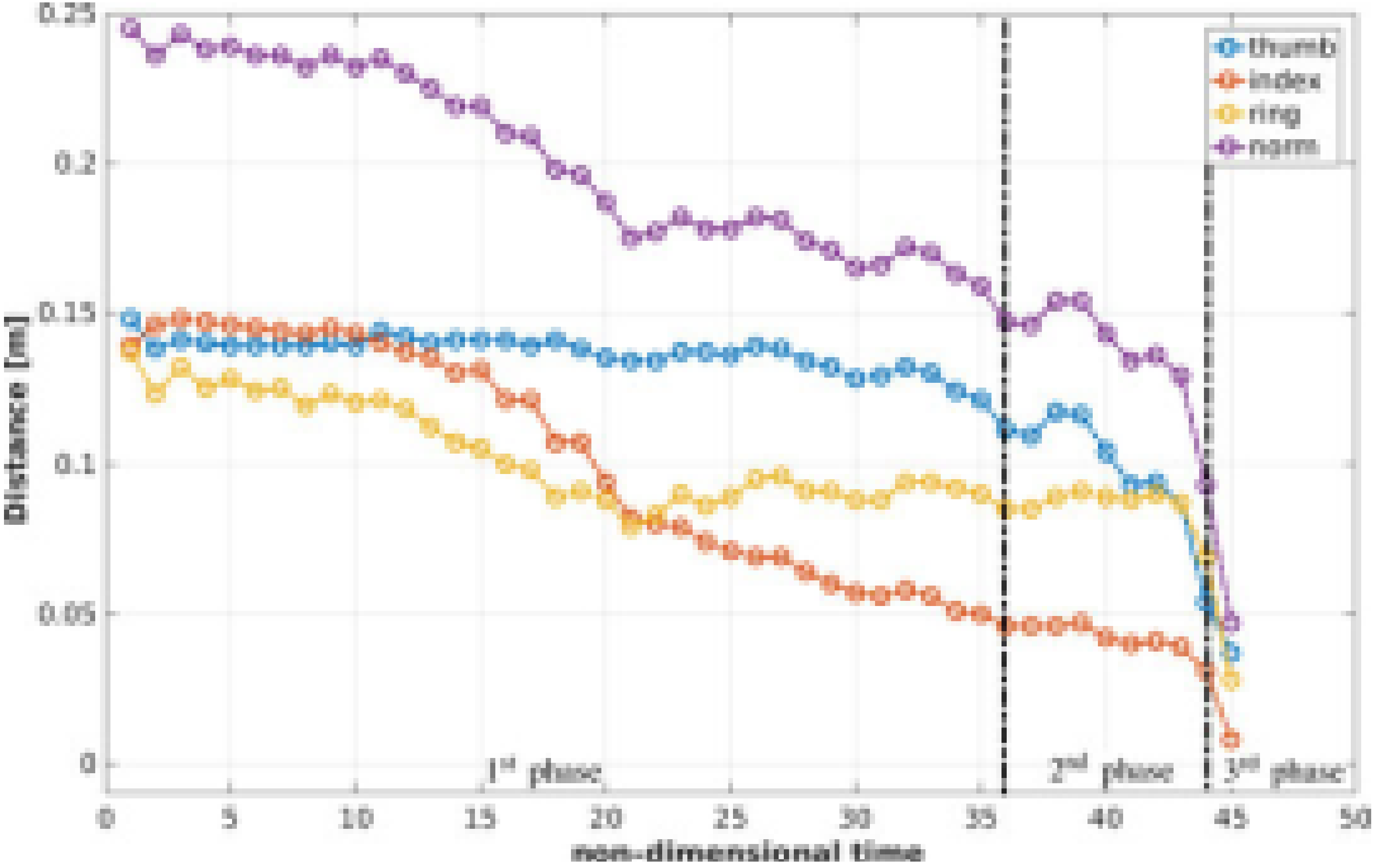


High-level sensor
Manipulator
Forward kinematics
Grasp location optimization
Low-level sensor
Softhand

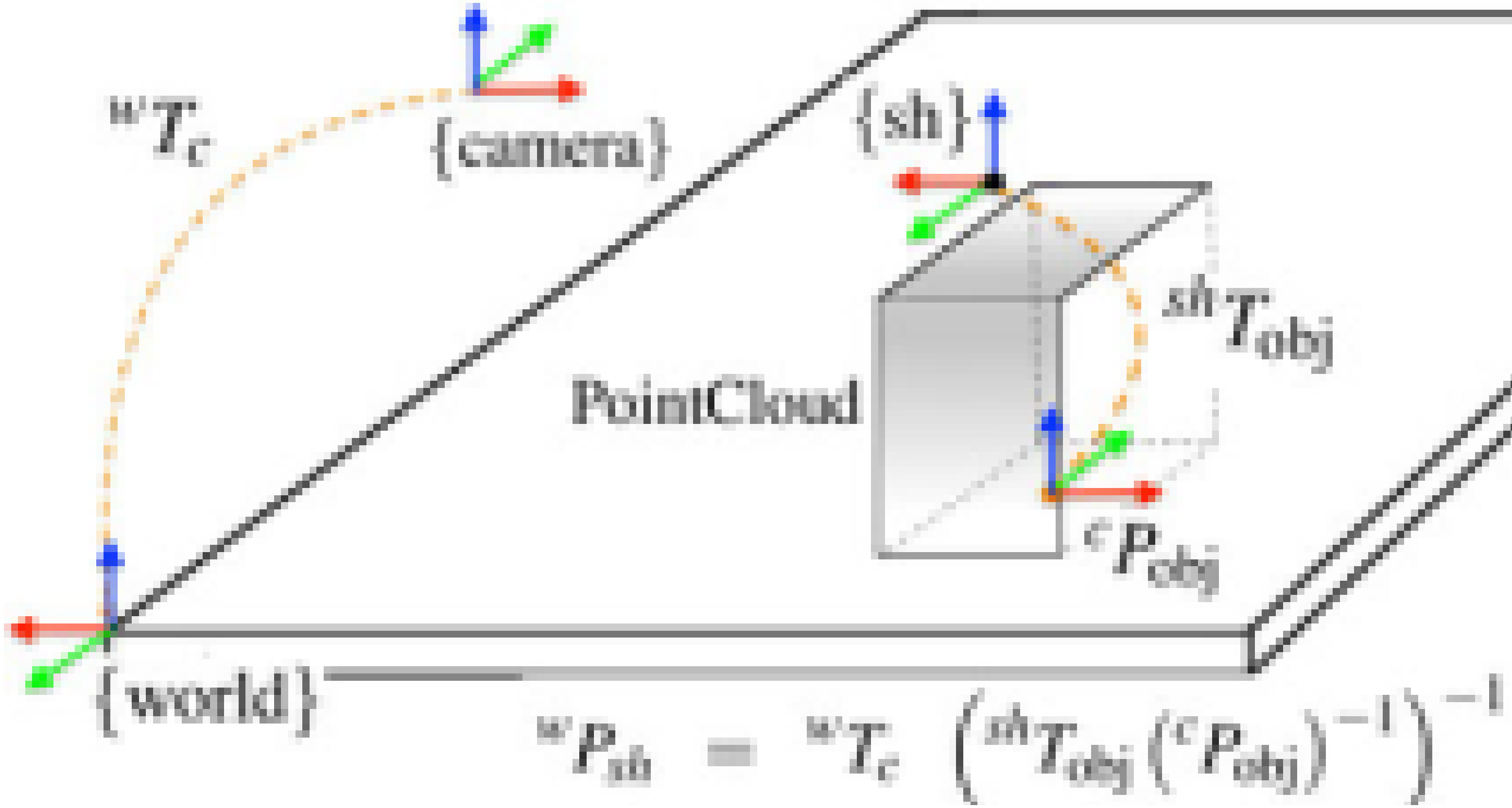
Approximate Object Position: Method 1



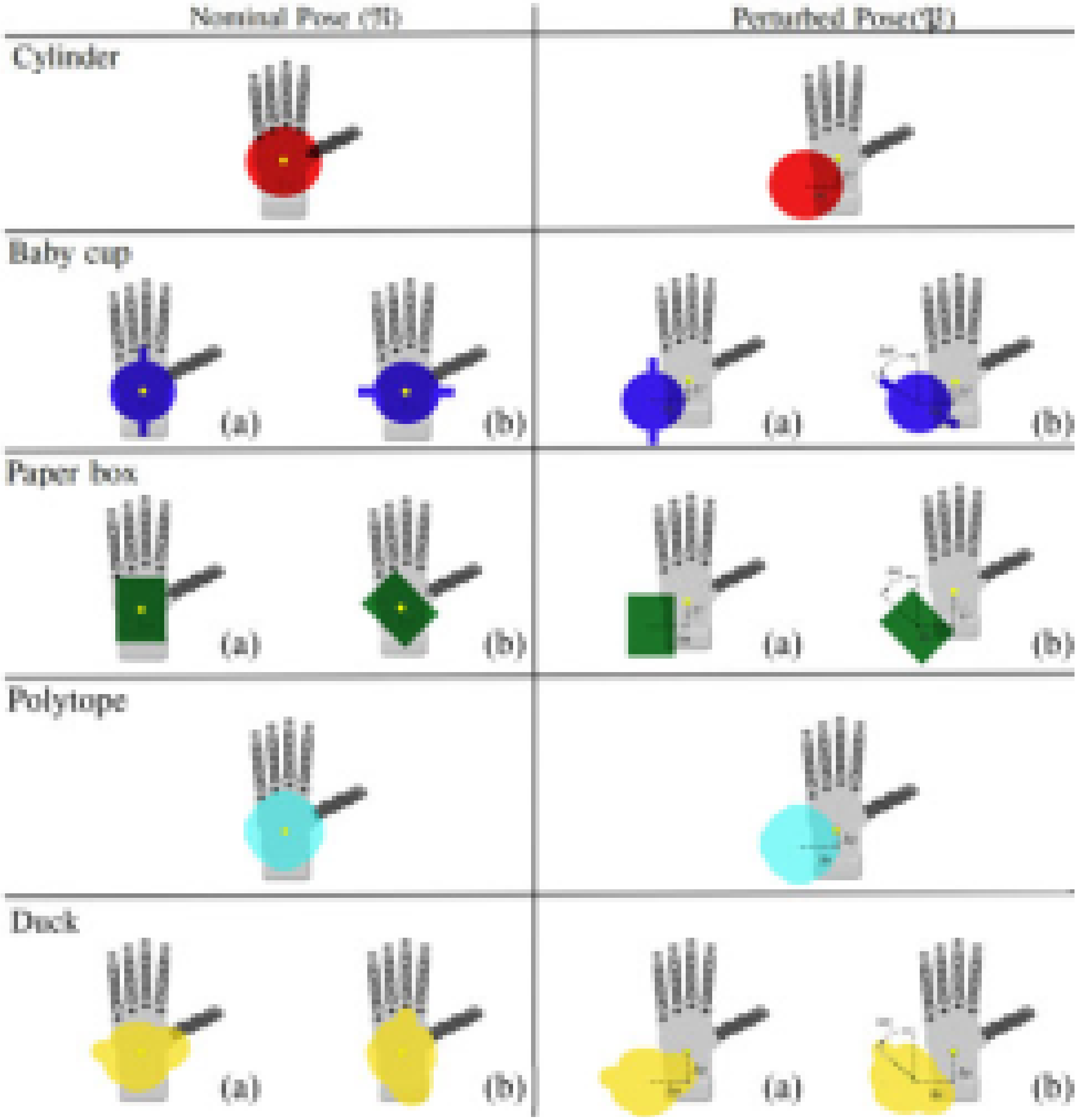
Sensor measurements during execution



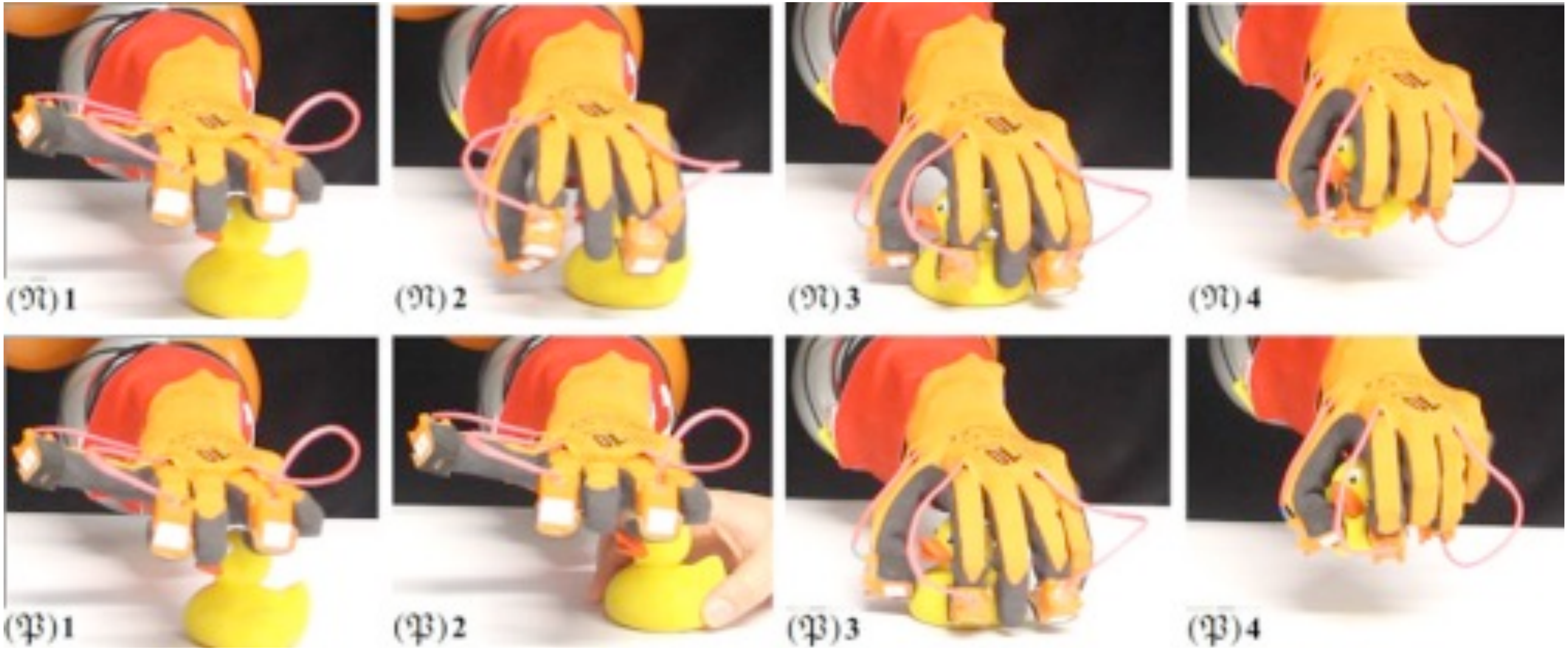
Approximate Object Position: Method 2



Nominal and Perturbed Object Poses



IR-Guided Grasp: Rubber Duck



Results

Object and reference pose	Nominal Pose ($\mathfrak{N}$)			Perturbed Pose ($\mathfrak{P}$)	
	Blind (M1)	Blind (M2)	IR-guided (M1)	Blind (M2)	IR-guided (M2)
Cylinder	0/3	2/3	3/3	0/3	2/3
Baby cup, pose (a)	0/3	3/3	2/3	0/3	2/3
Baby cup, pose (b)	1/3	3/3	3/3	0/3	2/3
Paper box, pose (a)	0/3	3/3	2/3	0/3	2/3
Paper box, pose (b)	1/3	3/3	3/3	0/3	2/3
Polytope	1/3	3/3	3/3	0/3	3/3
Duck, pose (a)	1/3	3/3	2/3	0/3	2/3
Duck, pose (b)	0/3	3/3	2/3	0/3	2/3
Total	4/24	23/24	20/24	0/24	17/24

Touch-Based Grasp Primitives for Soft Hands: Applications to Human-to-Robot Handover Tasks and Beyond

Matteo Bianchi[1], Giuseppe Averta[1,2], Edoardo Battaglia[1], Carlos Rosales[1], Manuel Bonilla[1], Alessandro Tondo[1], Mattia Poggiani[1], Gaspare Santaera[2], Simone Ciotti[1,2], Manuel G. Catalano[1,2], and Antonio Bicchi[1,2]

[1]Universita di Pisa
[2]Instituto Italiano di Tecnologia

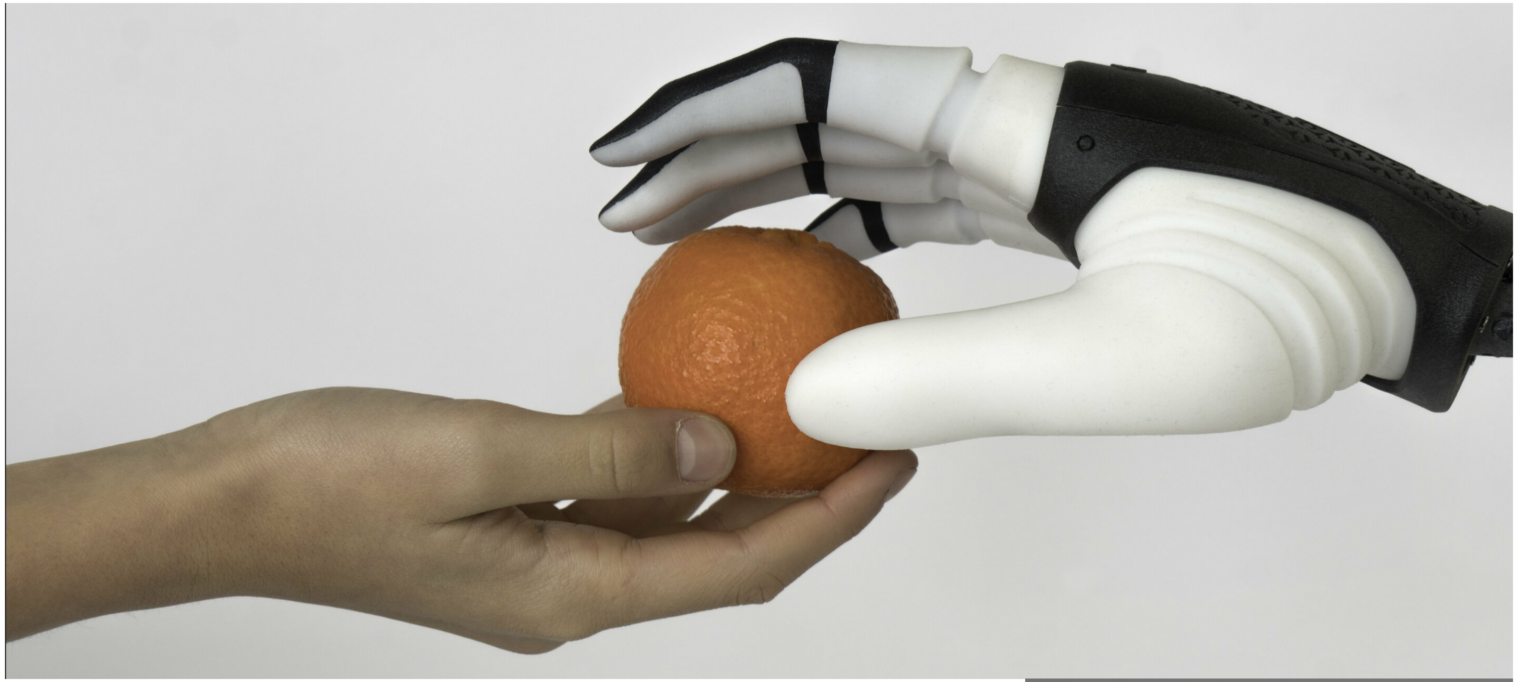
First Author: Matteo Bianchi

- Assistant Professor Centro di Ricerca “E. Piaggio”, Univesita de Pizza
- Clinical research affiliate at Mayo Clinic (Rochester, USA)
- Co-Chair of the RAS Technical Committee on Robot Hands, Grasping and Manipulation
- Principal Investigator of the EU Project SoftPro

- Editor of the book "Human and Robot Hands", Springer International Publishing

Goal

- Explore the potential of Soft End Effectors(SEEs) in human robot interaction
- Introduce a simple touch-based approach for human-to-robot handover



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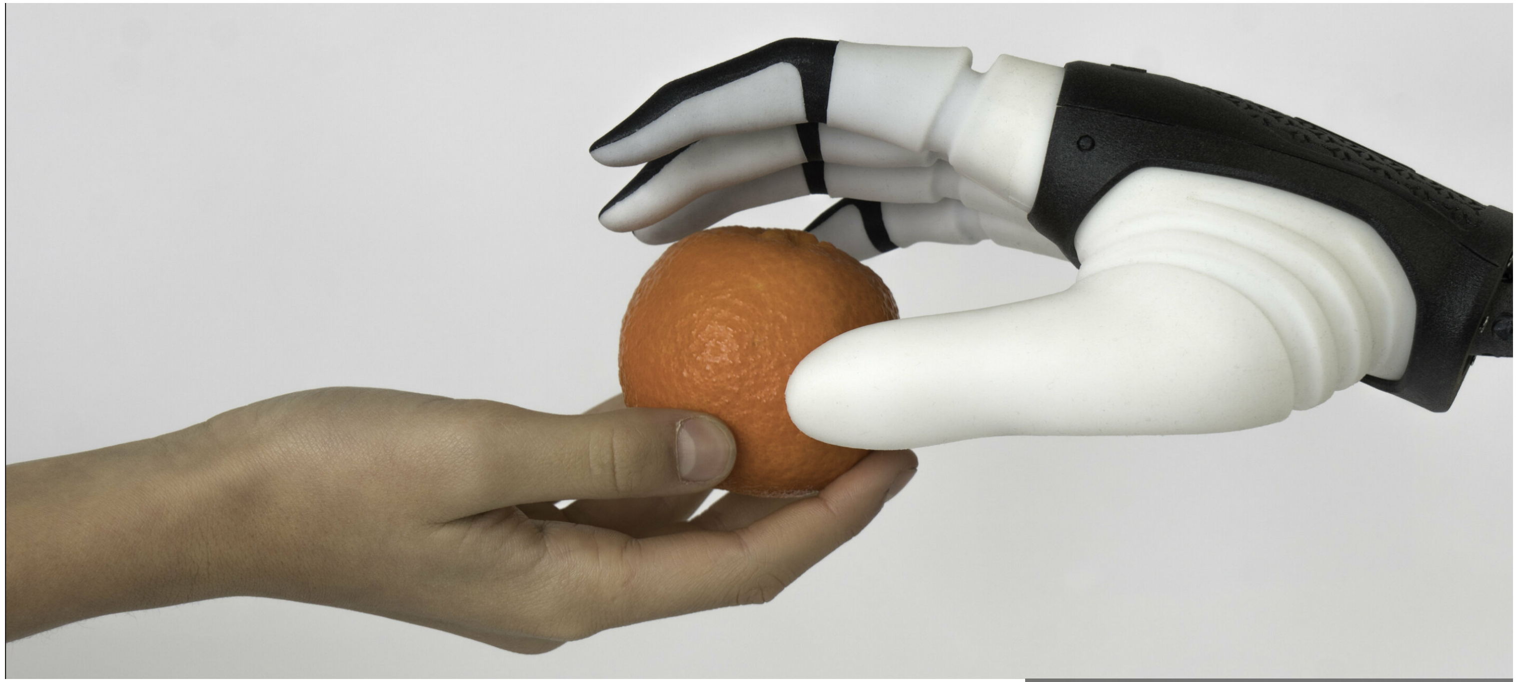
Human-robot handover: Challenges

- Communication
- Prediction
- Safety
- Planning



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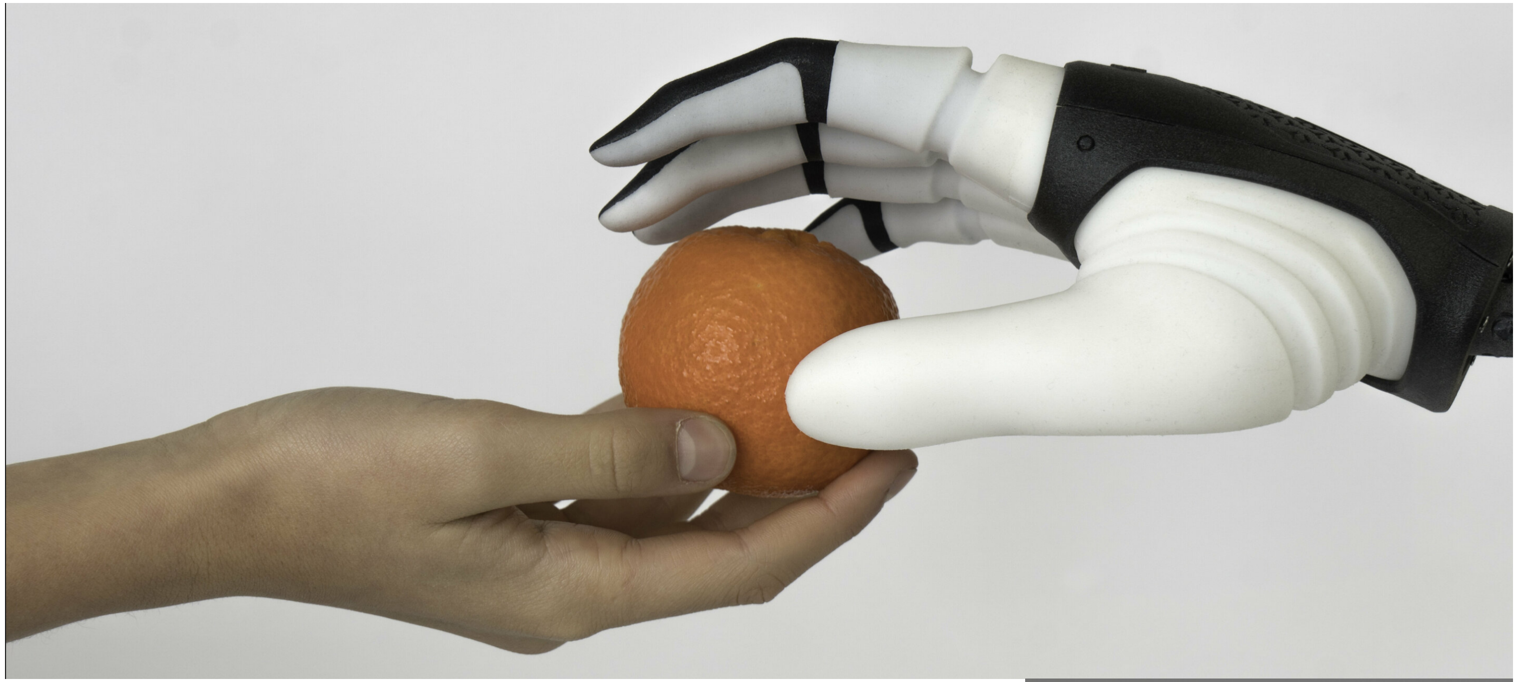
Human-robot handover: phases

- Approach
- Passing ← This paper
- Retraction



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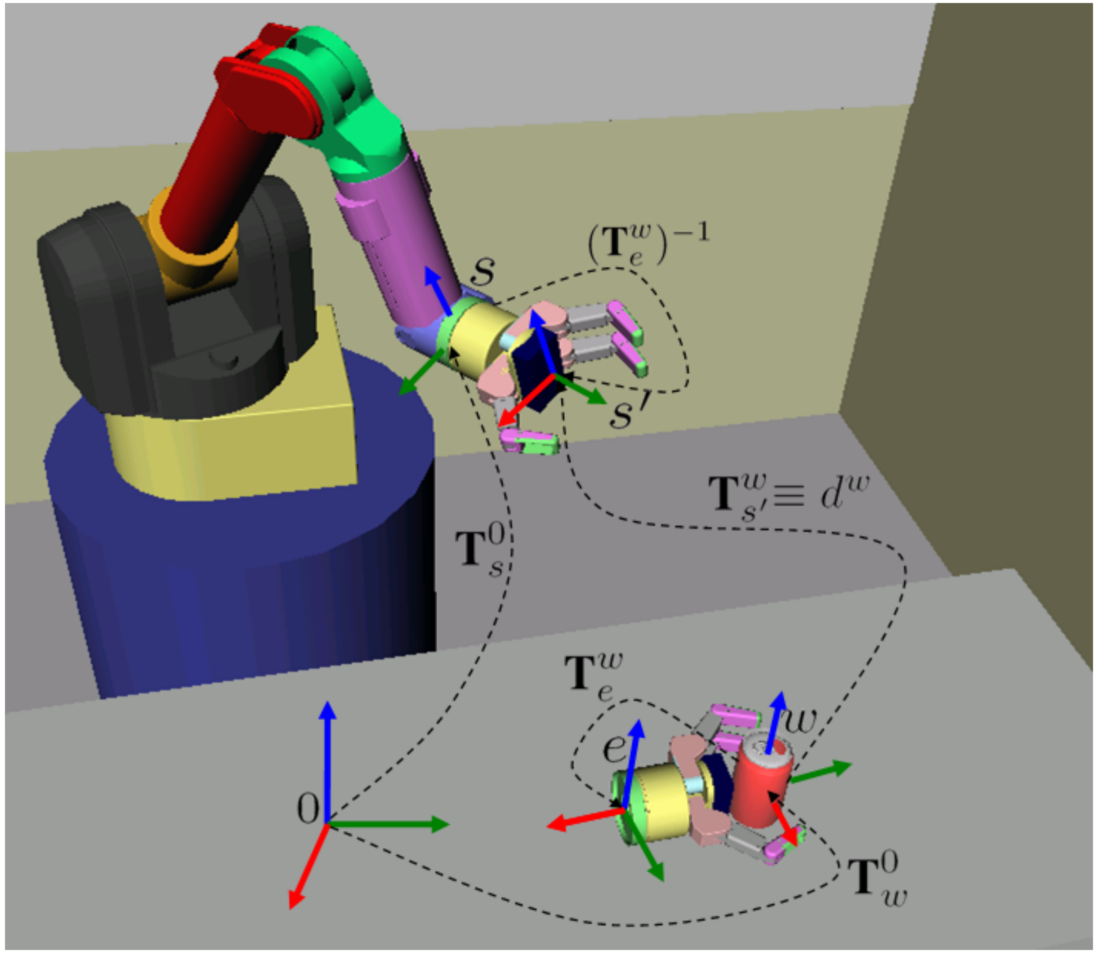
Previous Work

- Sensors: Visual and tactile
- Analytic and data-driven approaches
  - Grasp planning
  - Grasp adaptation
  - Force control



Picture: ARM Lab University of Michigan

Previous Work: Reactive Behavior

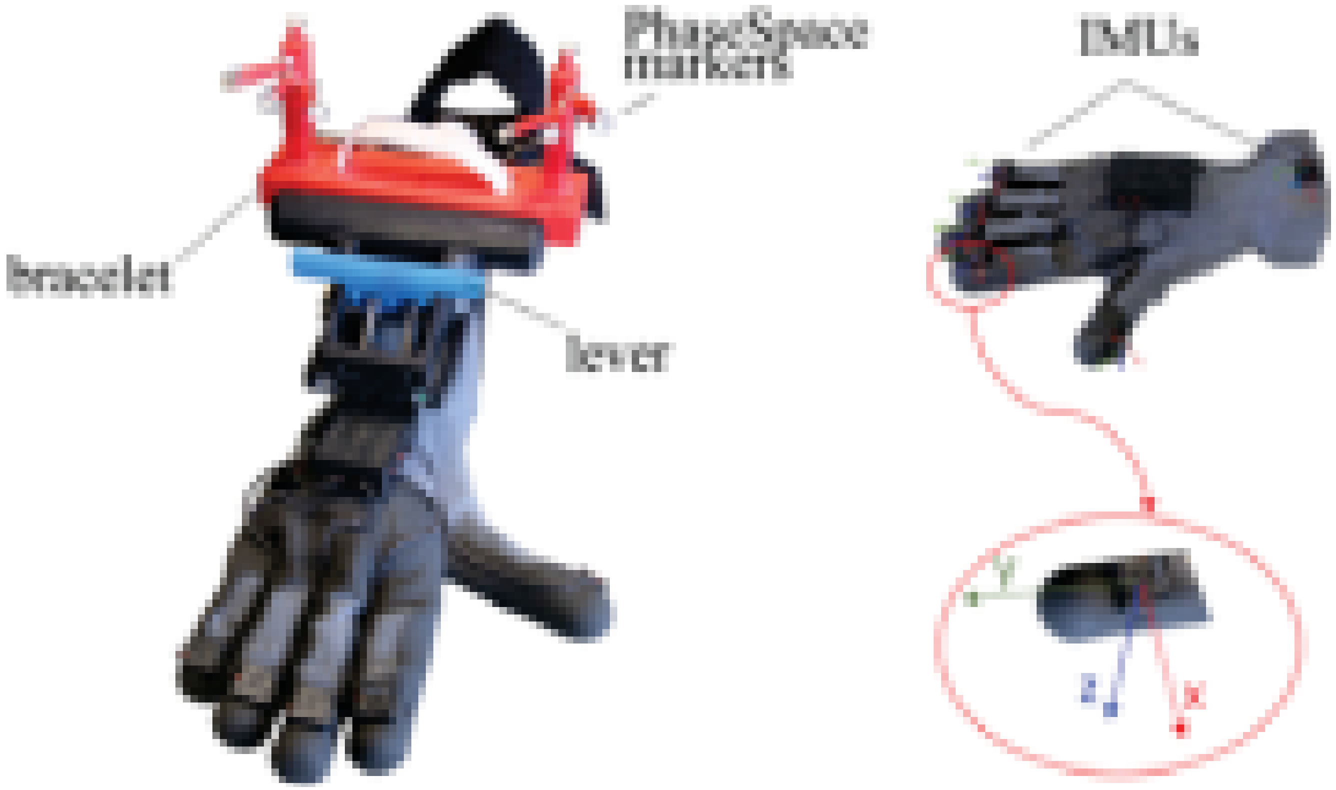
- Evidence
  - Soft hand molds around items
  - Rough estimate object geometry and robot hand pose
  - short-range or non-ranged sensors → more effective grasping

Main Idea = Contribution

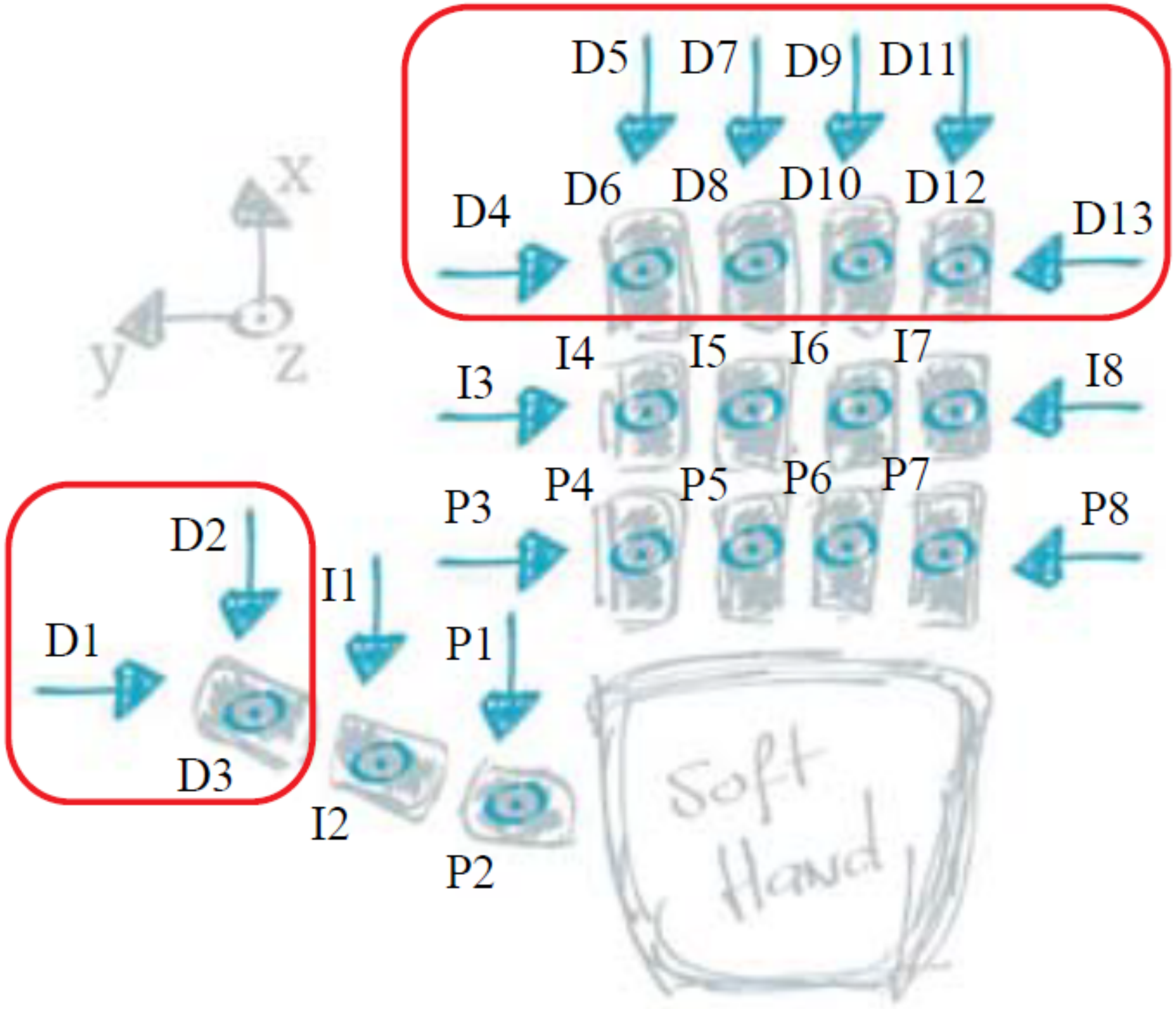
- Inertial Measurement Units(IMUs) at fingertips
- Sensory-motor primitives in human-to-robot handover

(a) Contact detection. (b) Primitive trigger. (c) Grasp.

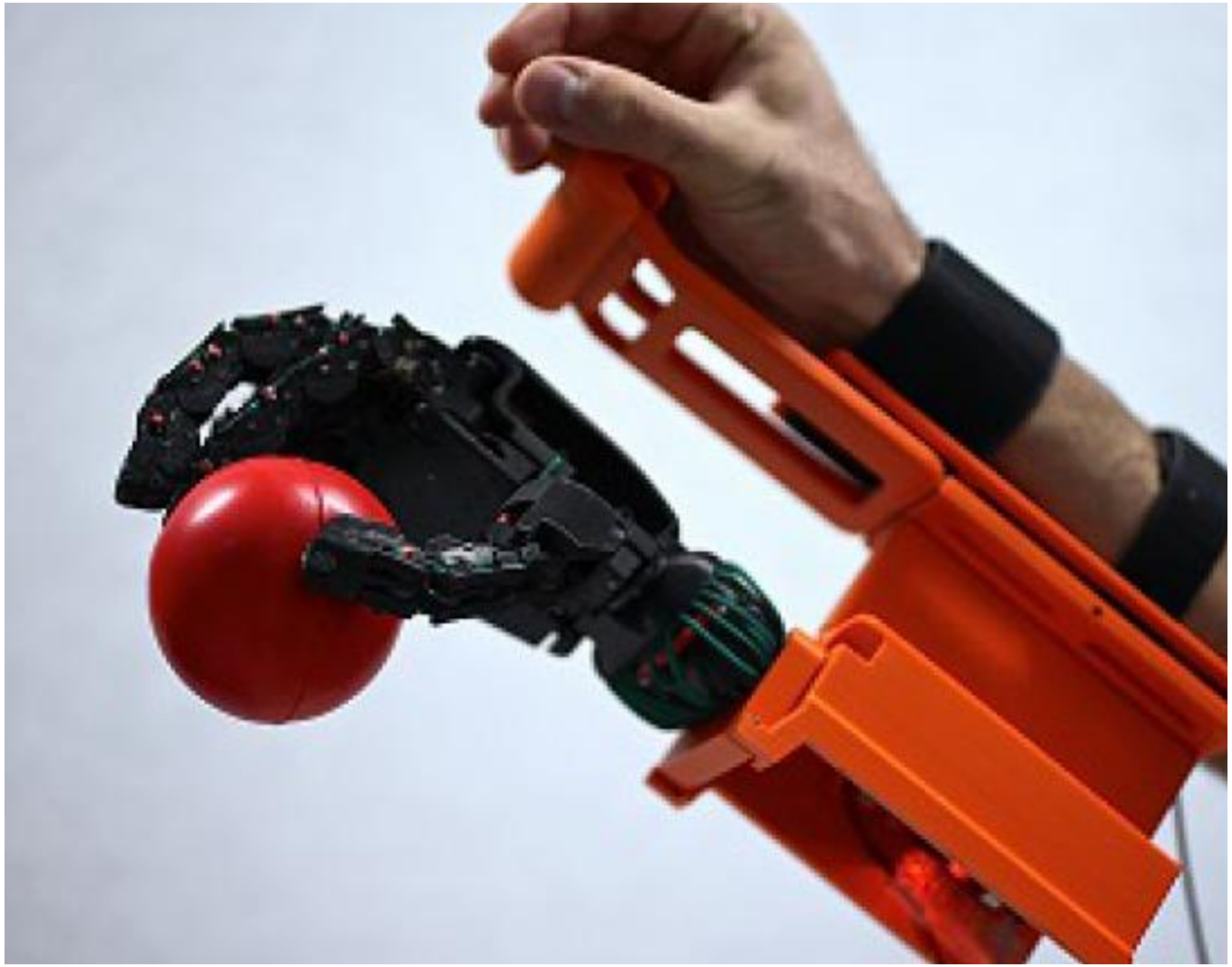
Method: Hardware



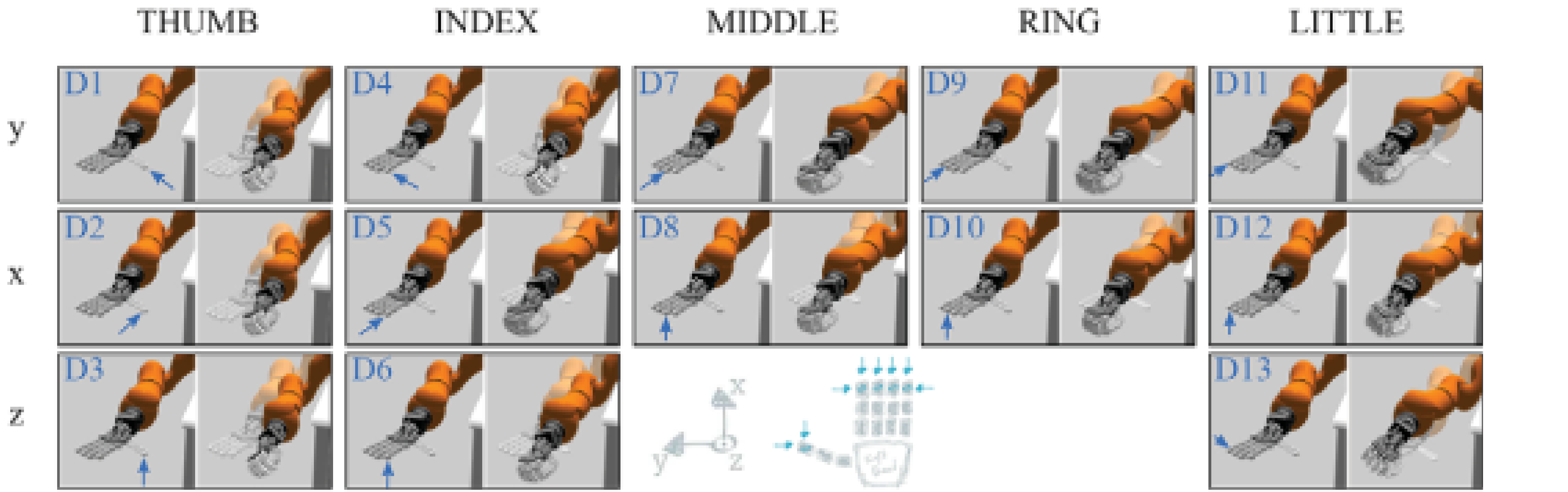
Method: Contacts and Directions



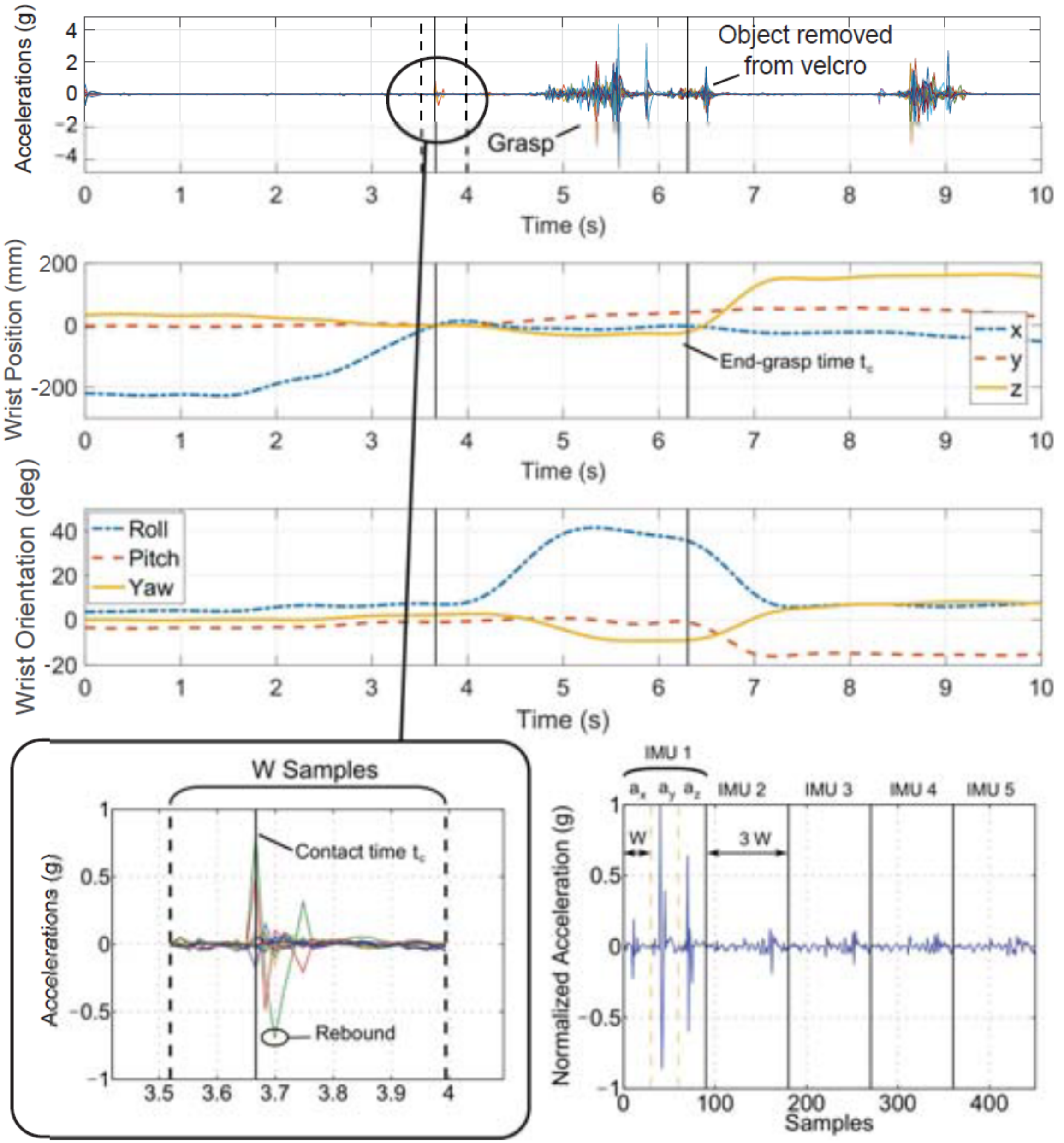
Method: Acquisition Phase



Method: Grasp Primitives



Method: Mapping Acceleration to Wrist Pose



Acceleration > 0.5g followed by rebound = Initial contact

Method: Experiment

- Kuka Light Weight Robot 4+
- Same sensorized glove on SH
- Hand facing down
- Successful grip >= 15 seconds
- Disturbed by experimenter
- Release if acceleration > 0.5g

Results: Objects

(A)	screwdriver	(B)	wrench	(C)	reel
(D)	battery (AA)	(E)	pincers	(F)	plier
(G)	hammer	(H)	hotglue gun	(I)	caliper
(J)	pen	(K)	stapler	(L)	bottle
(M)	torch	(N)	computer mouse	(O)	cell phone
(P)	eraser	(Q)	lighter	(R)	table tennis ball
(S)	human hand	(T)	mug	(U)	can
(V)	teddy bear				

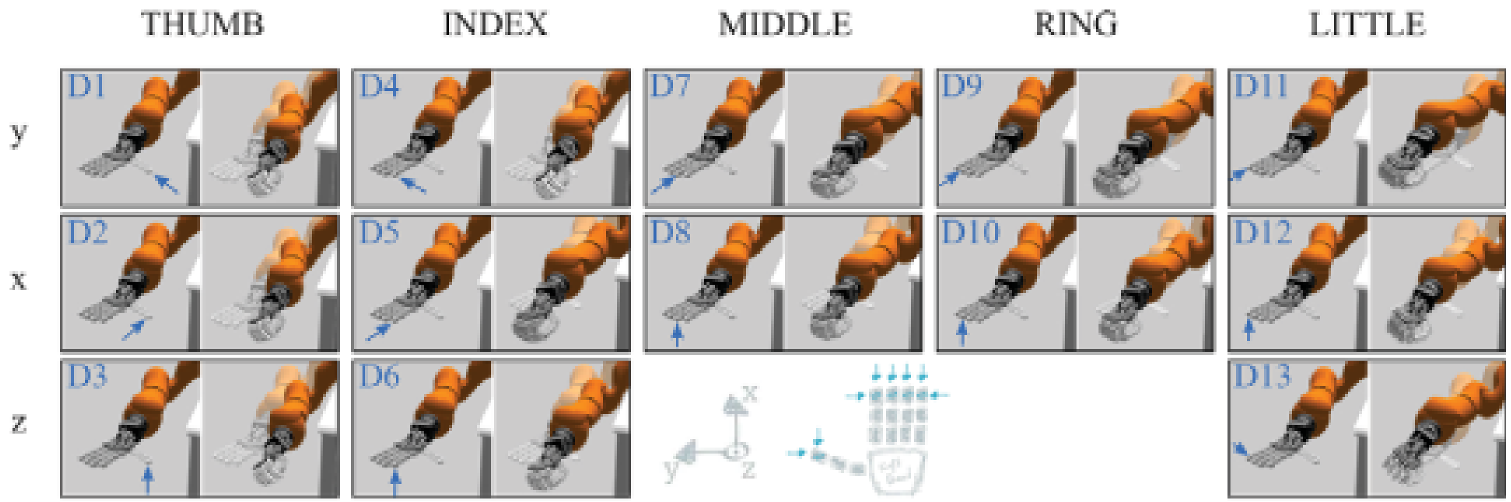
Average success rate = 86%

Lowest:
- Offset CoM
- Failure contact at Distal Phalanx ring and little finger

(G) Hammer
(I) Caliper
(L) Bottle (had fluid inside)

Object	Successes	Failures	Success %
(A)	71	16	81.61%
(B)	84	3	96.55%
(C)	77	10	88.51%
(D)	78	9	89.66%
(E)	77	10	88.51%
(F)	80	7	91.95%
(G)	65	22	74.71%
(H)	78	9	89.66%
(I)	68	19	78.16%
(J)	77	10	88.51%
(K)	78	9	89.66%
(L)	59	28	67.82%
(M)	70	17	80.46%
(N)	75	12	86.21%
(O)	73	14	83.91%
(P)	79	8	90.8%
(Q)	73	14	83.91%
(R)	74	13	85.06%
(S)	82	5	94.25%
(T)	72	15	82.76%
(U)	74	13	85.06%
(V)	81	6	93.1%

Results: Direction



Direction	Successes	Failures	Success %
D1	58	8	87.88%
D2	63	3	95.45%
D3	61	5	92.42%
D4	62	4	93.94%
D5	63	3	95.45%
D6	65	1	98.48%
D7	65	1	98.48%
D8	66	0	100%
D9	59	7	89.39%
D10	63	3	95.45%
D11	56	10	84.85%
D12	59	7	89.39%
D13	53	13	80.3%
I1	66	0	100%
I2	58	8	87.88%
I3	58	8	87.88%
I4	63	3	95.45%
I5	63	3	95.45%
I6	63	3	95.45%
I7	52	14	78.79%
I8	48	18	72.73%
P1	56	10	84.85%
P2	54	12	81.82%
P3	47	19	71.21%
P4	50	16	75.76%
P5	45	21	68.18%
P6	54	12	81.82%
P7	40	26	60.61%
P8	35	31	53.03%

Experiment on a table: Reactive Grasping

Conclusion

- Generalizes wheel
- Autonomous grasping
- Different objects
- Different points of contatcs
- Big potential for autonomous tasks
  - Robot
  - Assistive robotics
    - user intention captured by sensors
    - task accomplished by primitives

Future Work

- More complex designs during data capture to allow roll, pitch & yaw
  - Actuated artificial wrist
- Unstructured environments
- Feedback control
- Additional sensors: IMUs and force sensor
- Use a larger number of naive human users
- More extensive quantitative comparison success with and without primitives
- Try same method on other kinds of hand designs (source: author)

Discussion

- Why 13 primitives. Would more have helped?
- Benefit of more sensors?
- Benefit of more flexibility while testing? Not limiting to roll only
- Would this work on rigid hand?
- Big Ones:
  - Are these local sensor reactive control approaches valid methods for grasping in the wild?
  - Could this sensor → primitive mapping be implemented even more simply?
  - Is grasping primitives mapping a good policy? Different sensors? Reinforcement learning?