Benchmarking grasps and hands

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IROS 2016 Workshop: Evaluation and Benchmarking of Underactuated and Soft Robotic Hands

Oct 10th, 2016

I. BENCHMARKING IN GRASPING/MANIPULATION

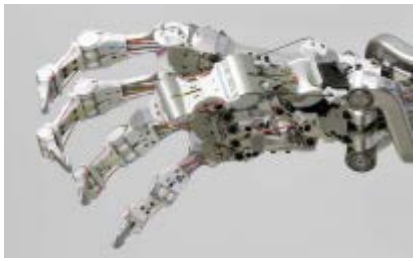
Robotic hands

PR-2

Schunk

Simple *grippers*

Shadow hand



Awiwi hand

General purpose *multi-finger hands*

Pisa hand

Robotiq 3-finger hand

Adaptive *underactuated hands*

Jamming gripper

RBO hand

Soft hands

DLR

Robotic hands

https://www.youtube.com/watch?v=oNEFXcWRIG8

[Byunghyun et al., ICRA'16, SNU Biorobotics Lab, Korea]

DLR

Benchmarking

Benchmarking is:

- A standard or point of reference against which things may be compared or assessed
- A problem designed to evaluate the performance of a computer system

[Oxford English Dictionary]

Requires:

precisely defined, standardized tasks with some quantitative evaluation

Remarks:

- State-of-the-art results are often difficult to reproduce outside the original lab setting
- Ongoing effort in robotics towards benchmarking: Experiments vs competitions
- Often, people do not really want a benchmark

DLR

Benchmarking in manipulation

Two main approaches

Hand-centered evaluation

- -Physical characteristics
- -Functional evaluation

System-centered evaluation

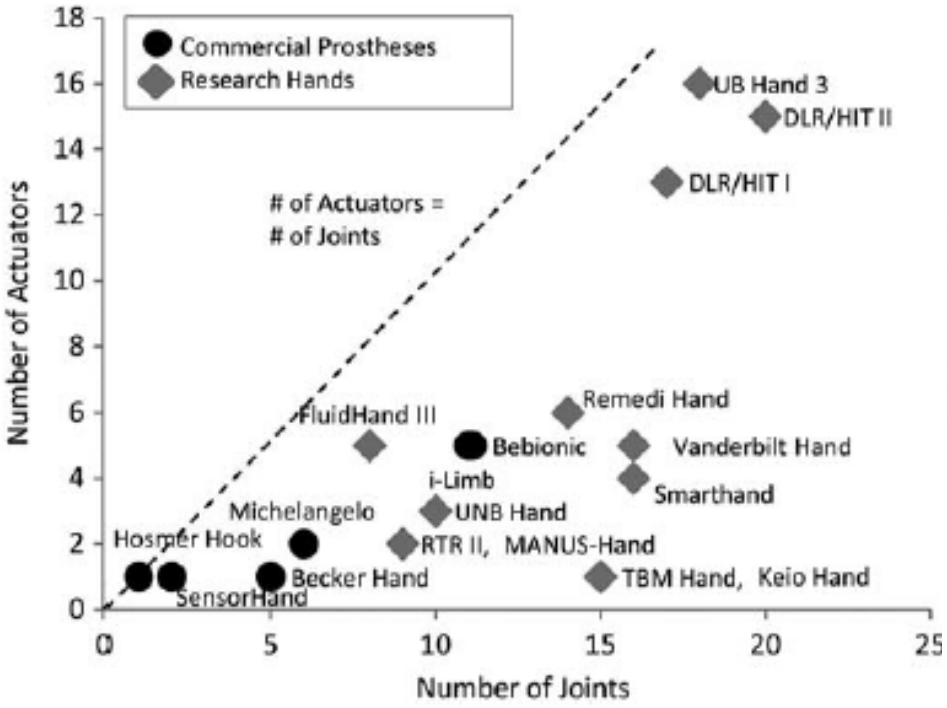
Comparison of capabilities

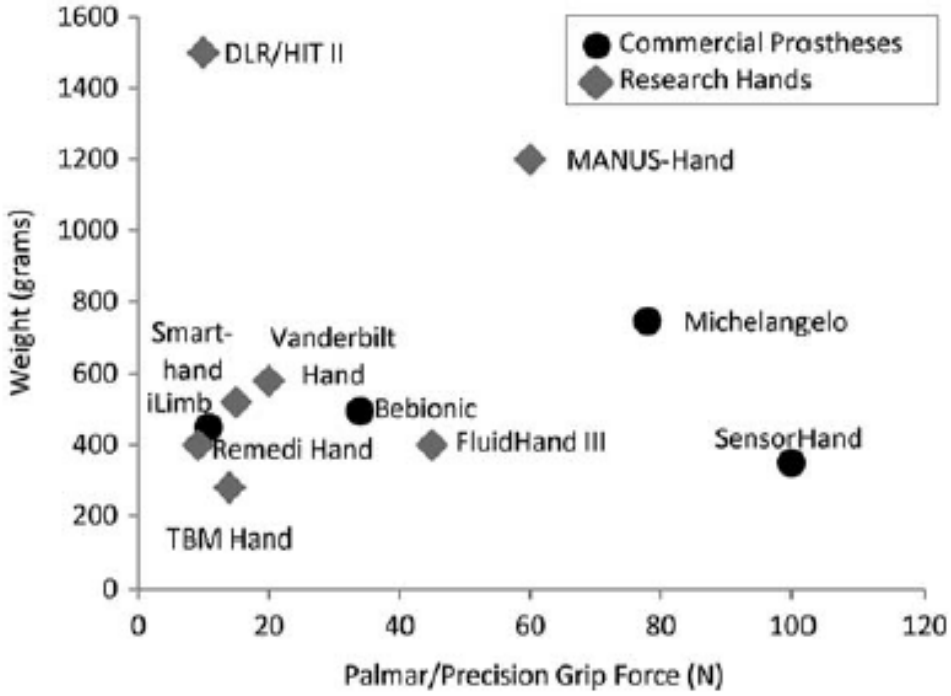
Physical characteristics

-Features: weight, number of fingers/DoF/joints/actuators

-Volume of workspace

-Index of anthropomorphism

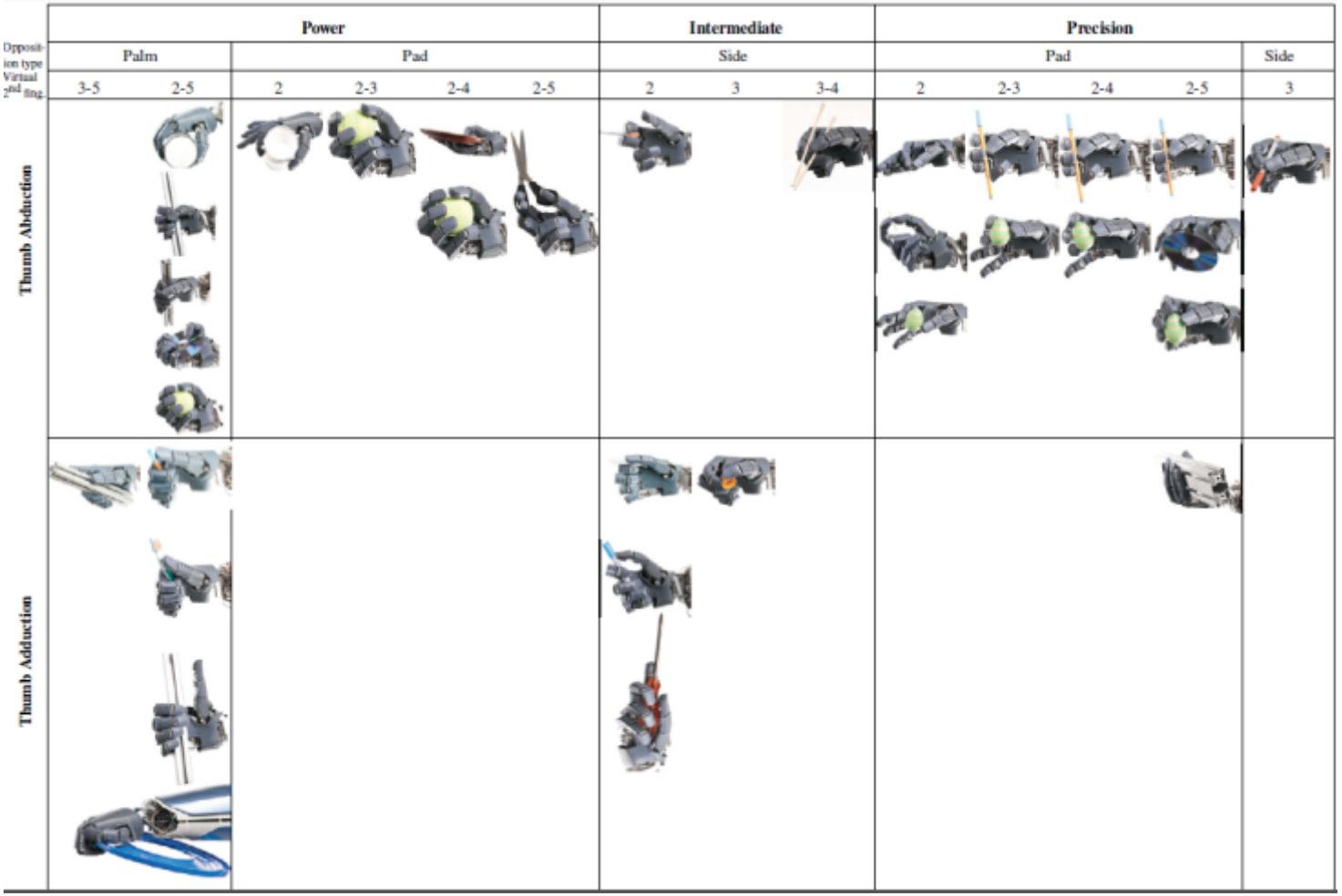




[Belter et al., JRRD'13]

Functional evaluation of grasps

Fulfilling one grasp taxonomy: Cutkosky, Feix,…

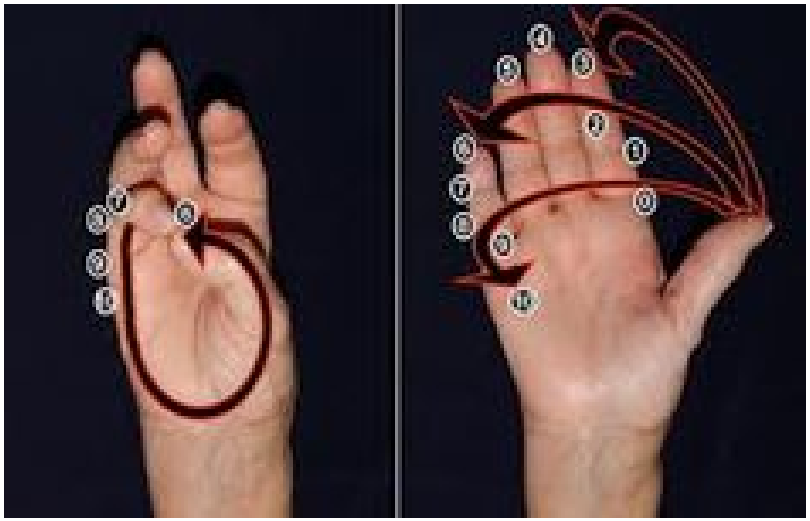


[Feix, RSS'09; Grebenstein, Springer'13]

FUNCTIONAL EVALUATION

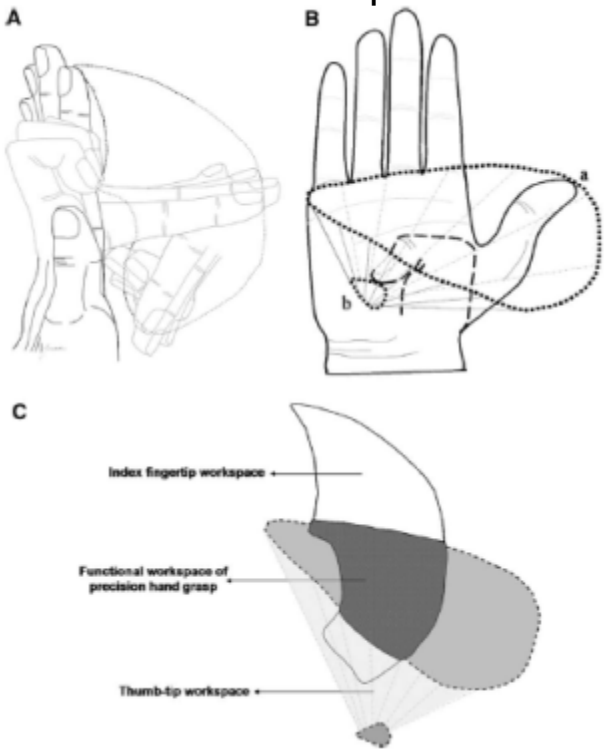
Precision grasp capabilities (indirect indications)

Kapandji test



[Kapandji, Chirurgie de la Main, 86]

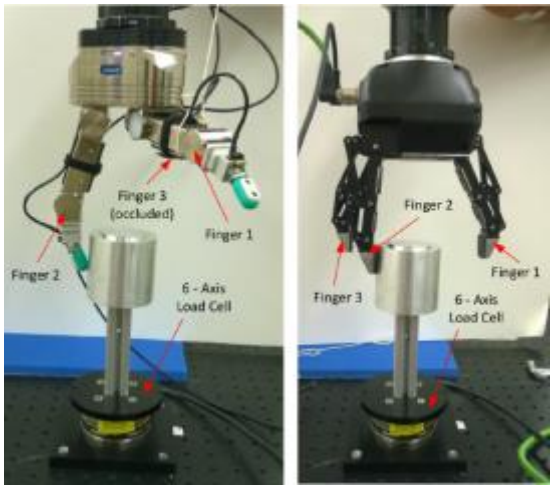
Functional workspace

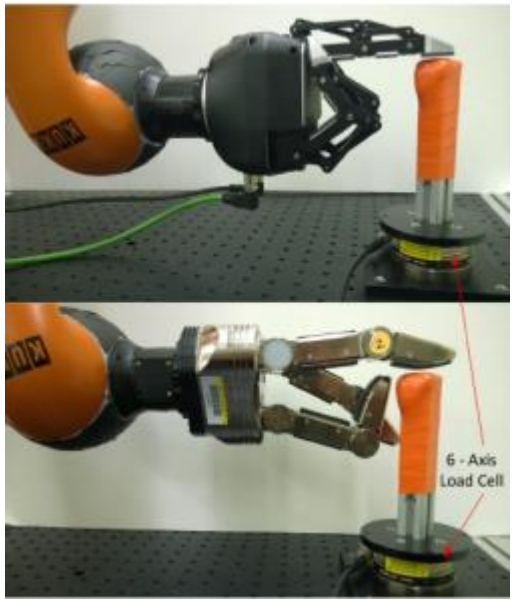


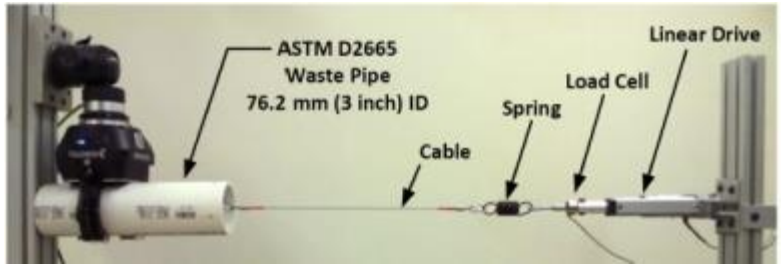
[Kuo et al., J. Electromy. And Kines., 09]

FUNCTIONAL EVALUATION

Functional performance tests – NIST (National Institute of Standards and Technology)





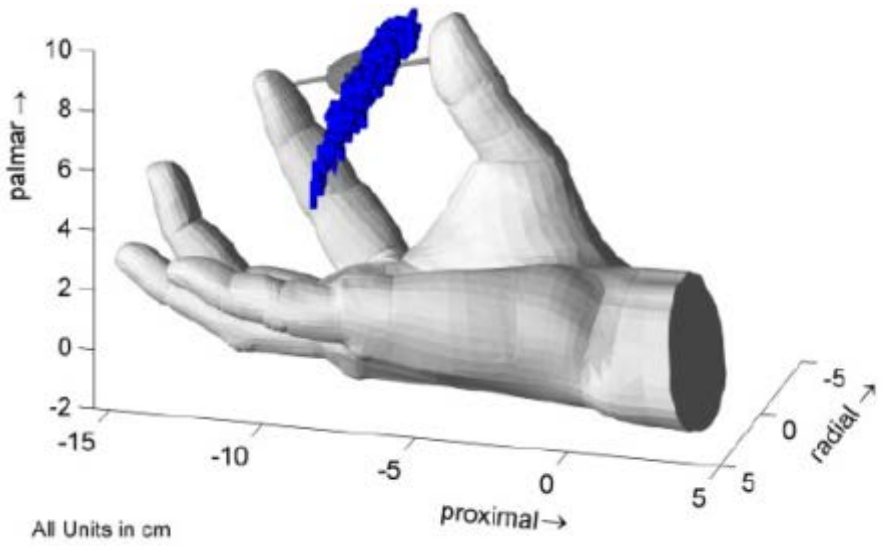


[Falco et al., RAM, 15]

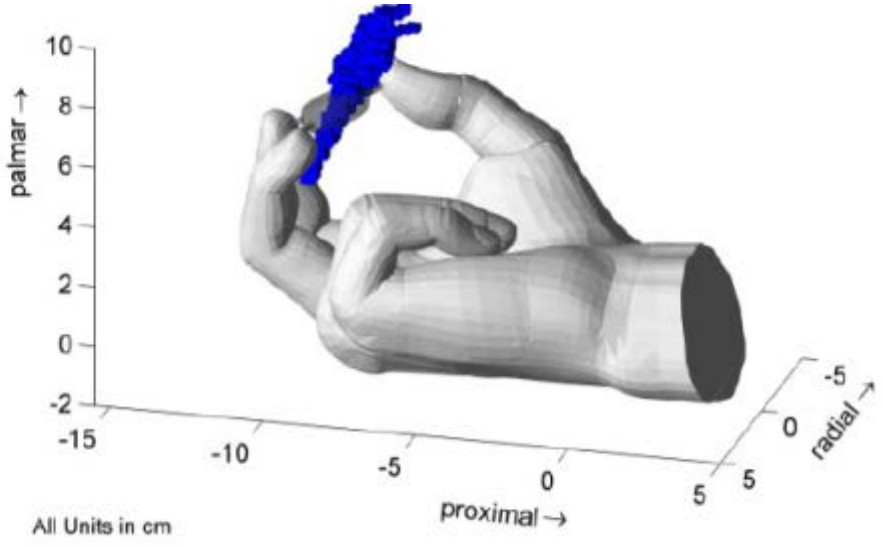
[Falco et al., RAM, 15]

Evaluation of fine manipulation capabilities

Manipulation workspace & range of manipulation



Two-finger workspace



Three-finger workspace

[Bullock et al., HAPTICS, 14]

System-centered evaluation

Performance-based evaluation

- Standard evaluation methods for prosthesis/impaired users: nine-hole peg test, SHAP, box and blocks, GRASSP, TEMPA, etc.

Abstract Object Tasks

1. Spherical [light|heavy]
2. Tripod [light|heavy]
3. Power [light|heavy]
4. Lateral [light|heavy]
5. Tip [light|heavy]
6. Extension [light|heavy]

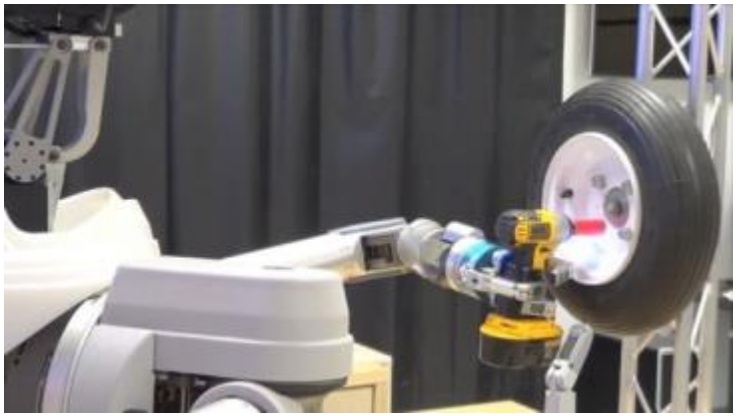
Activities of Daily Living (ADLs)

7. Pick Up Coins
8. Button Board
9. Simulated Food Cutting
10. Page Turning
11. Jar Lid
12. Glass Jug Pouring
13. Carton Pouring
14. Lifting a Heavy Object
15. Lifting a Light Object
16. Lifting a Tray
17. Rotate Key
18. Open/Close Zip
19. Rotate A Screw
20. Door Handle

SYSTEM-CENTERED EVALUATION

Evaluation of the whole manipulator: hand+arm+perception+planning+control+…

Measures of performance:
- Empirical success (e.g. lift 10 cm, rotate 30 deg, hold for 10 sec)
- Time to complete
- Success rate



DARPA ARM I/II

Amazon Picking Challenge

KEYPOINTS SO FAR

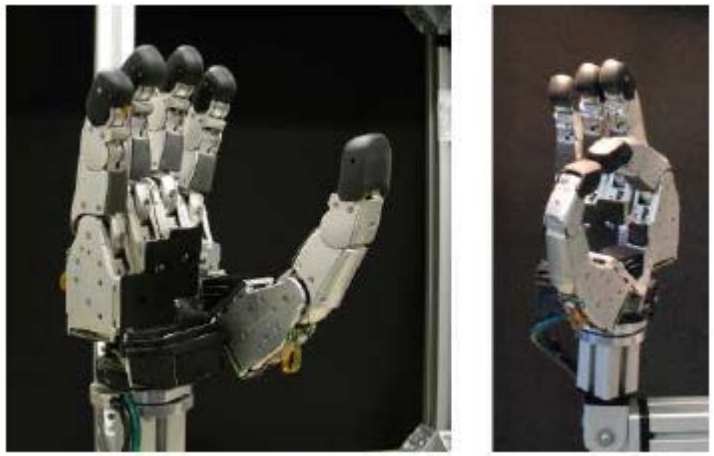
- Different forms to do benchmarking
  - Inspired by human performance
  - Adapted from human tests
  - Hand-centered or system-centered tests convey information on the hand performance

II. A CASE STUDY

PART 1: MECHANICAL DESIGN

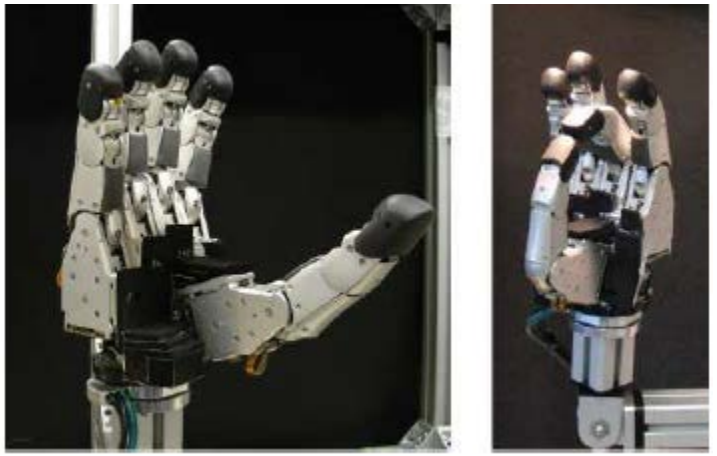
Experimental platform: modular testbed
DLR/HIT hand II

7 different thumb placements
(Thumb location is fixed)



I-50, I-60, I-70

Original



M-50, M-60, M-70

[Roa et al., ICRA 2014]

Evaluation results

Kapandji test

	M-50°	M-60°	M-70°	I-50°	I-60°	I-70°	Orig.
I-D	✓	✓	✓	✓	✓	✓	✓
I-I	✓	✓	✓	✓	✓	✓	✓
I-P	x	x	x	x	x	x	✓
M-D	✓	✓	✓	✓	✓	✓	✓
M-I	✓	✓	✓	✓	✓	✓	✓
M-P	x	x	x	x	x	x	✓
R-D	✓	✓	✓	✓	✓	✓	✓
R-I	✓	✓	✓	✓	✓	x	✓
R-P	x	x	x	x	x	x	✓
L-D	x	✓	✓	x	x	x	✓
L-I	x	✓	x	x	x	x	✓
L-P	x	x	x	x	x	x	✓
P_1	6	8	7	6	6	5	12
Rank	4 (tied)	2	3	4 (tied)	4 (tied)	7	1

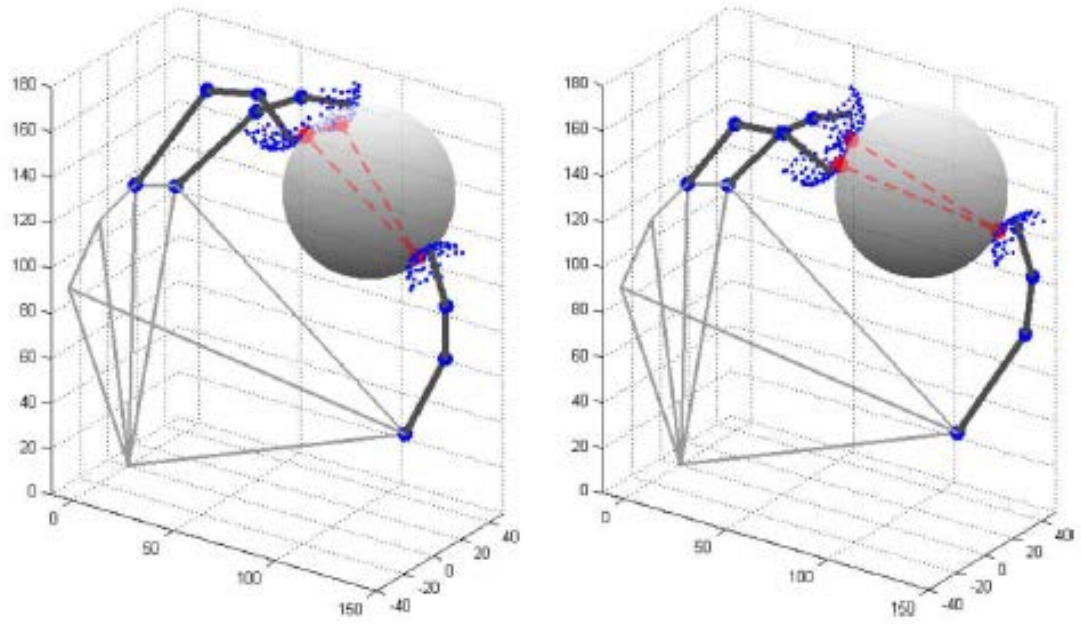
Functional workspace [cm^3]

	M-50°	M-60°	M-70°	I-50°	I-60°	I-70°	Orig.
Index	11.51	3.60	0.47	47.58	30.52	18.58	35.59
Middle	55.76	40.26	27.29	3.89	0.72	0.42	33.79
Ring	10.91	3.20	0.46	0	0	0	5.80
Little	0	0	0	0	0	0	0.003
P_2	78.17	47.07	28.23	51.46	31.24	19.01	75.18
Rank	1	4	6	3	5	7	2

DLR

Evaluation of fine manipulation capabilities

Manipulation workspace & range of manipulation



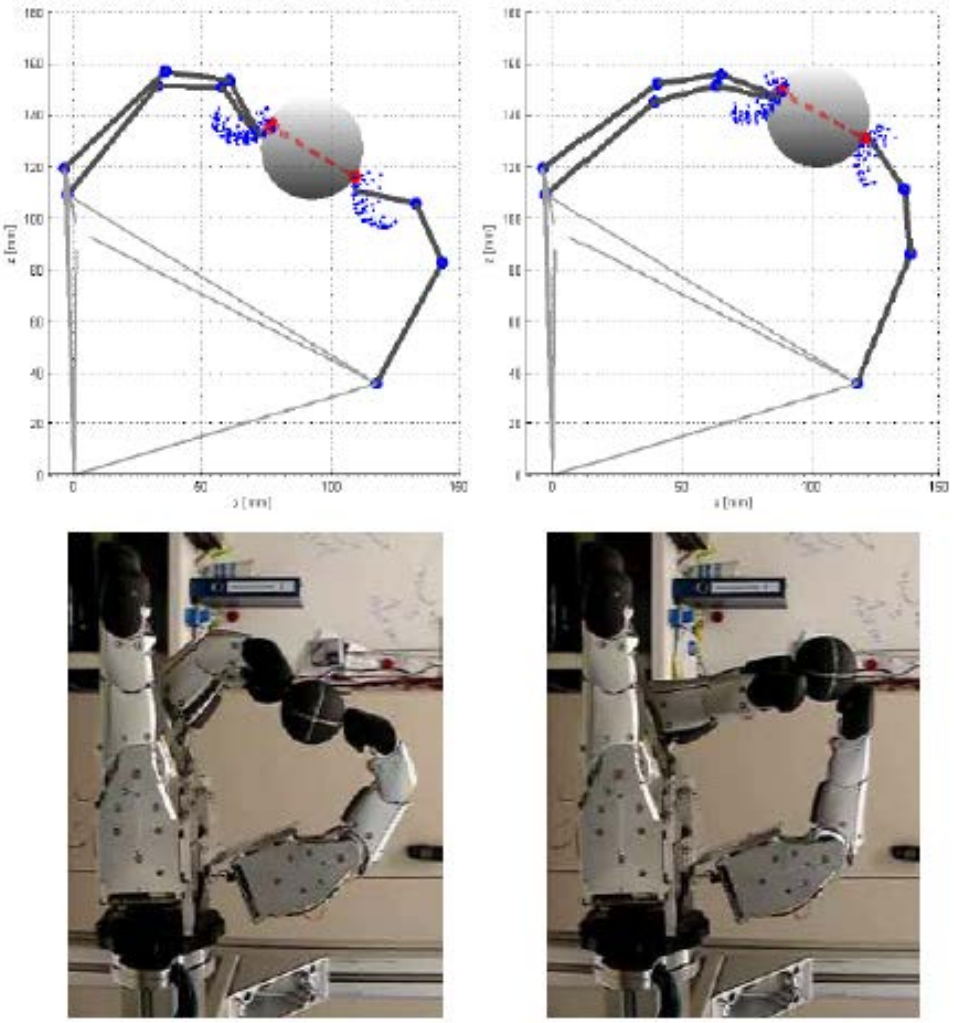
1. Initial position of the object
2. Find a FC grasp
3. Manipulate in the desired DoF until reaching joint limits or losing FC

Evaluation of fine manipulation capabilities

Fine manipulation:

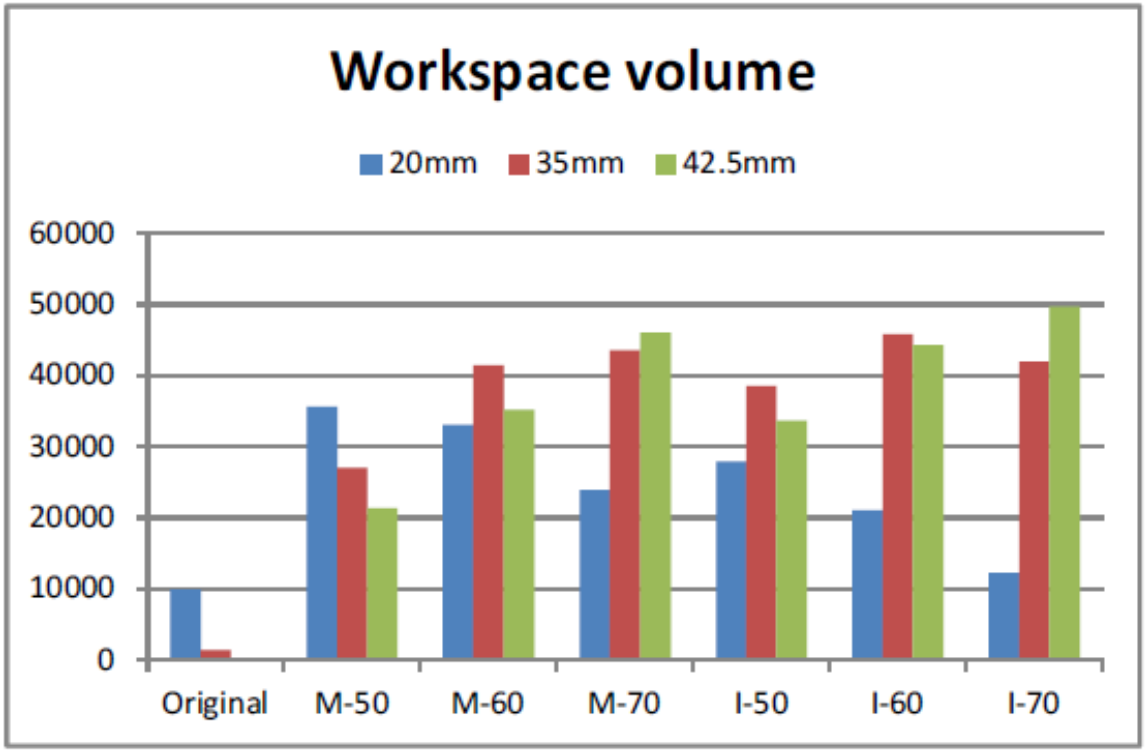
3 balls

(diam 20, 35, 42.5mm)



Evaluation results

Fine manipulation:



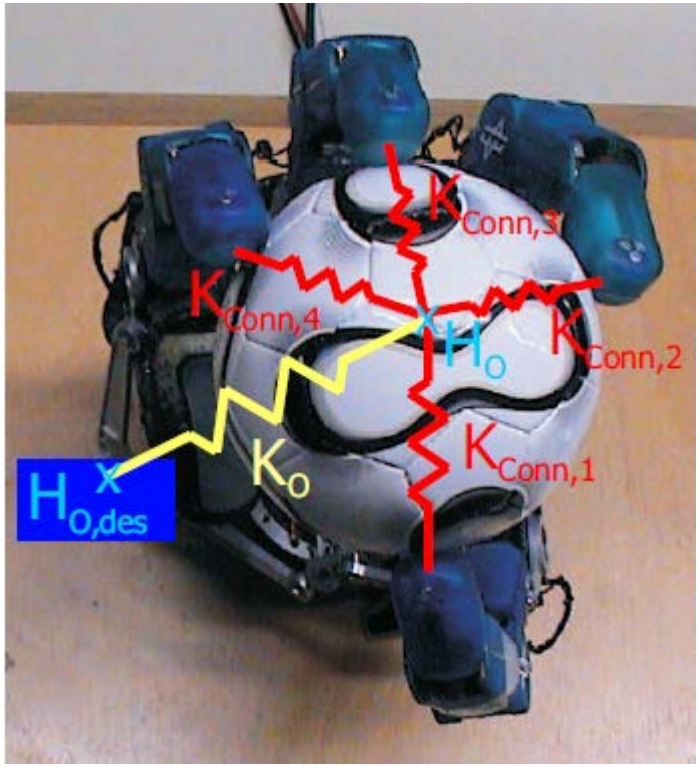
Compromise between thumb position and “ideal” object size

Evaluation results

Video attachment to
“Towards a Functional Evaluation of Manipulation Performance in Dexterous Robotic Hand Design.” M.A. Roa, Z. Chen, I. Staal, J. Muirhead, A. Maier, B. Pleintinger, N. Lii, C. Borst. IEEE Int. Conf. on Robotics and Automation – ICRA 2014
http://ieeexplore.ieee.org/document/6907863/

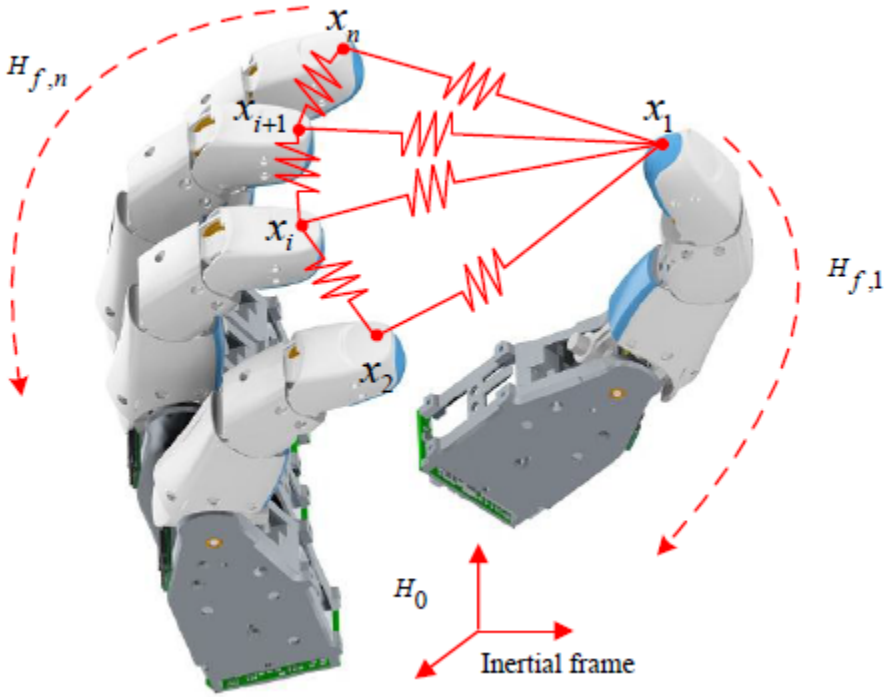
PART 2: HAND CONTROL

Object-level impedance control



[Wimbock-Ott, IROS06; IJRR11]

Compliant grasp: multi-finger impedance



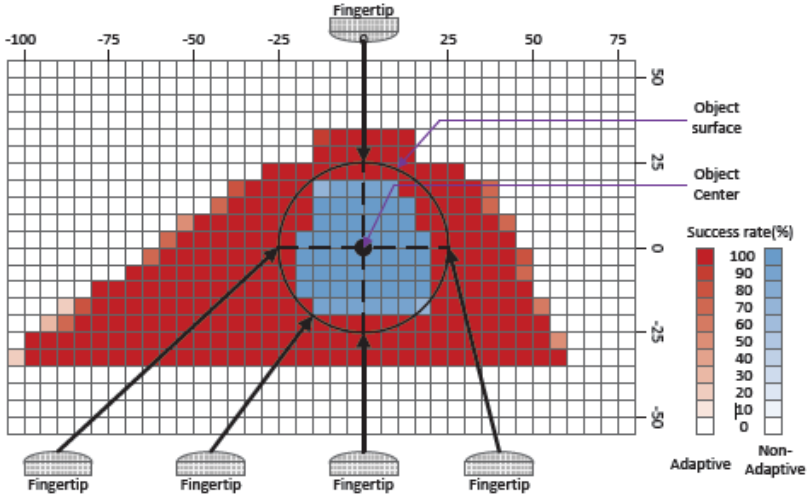
[Chen, Roa et al, ICRA15]

Functional evaluation: robustness against pose uncertainties

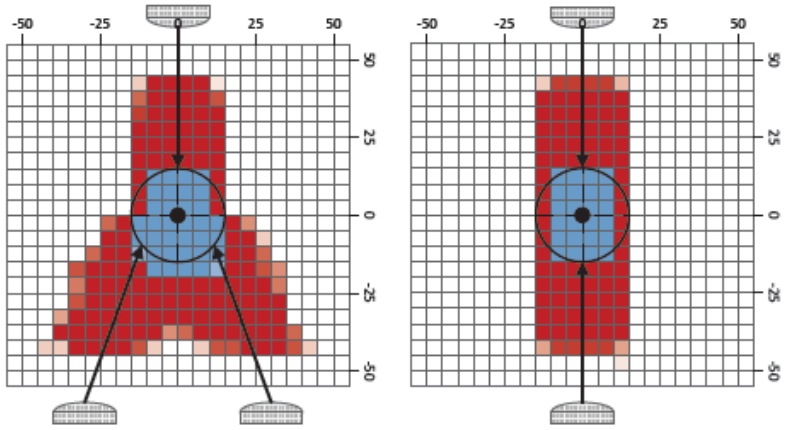
Video attachment to
“An adaptive compliant multi-finger approach-to-grasp strategy for objects with position uncertainties.” Z. Chen; T. Wimbock; M.A. Roa; B. Pleintinger; M. Neves; C. Ott; C. Borst; N. Lii. ICRA 2015.
http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7139881

[Chen, Roa et al, ICRA15]

Functional evaluation: robustness against pose uncertainties



(a) 5-finger grasp

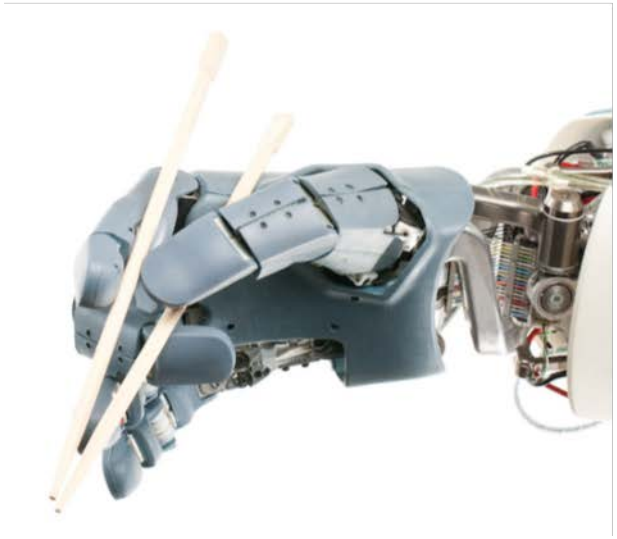


(b) 3-finger grasp

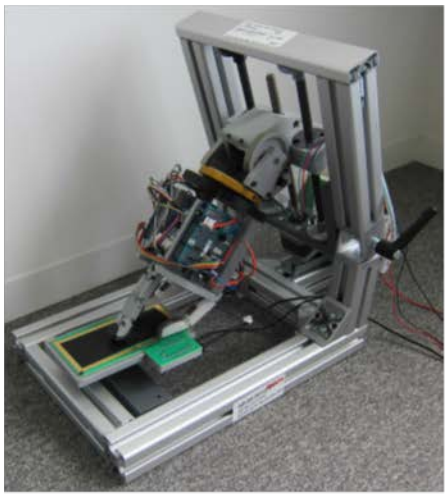
(c) 2-finger grasp

[Chen, Roa et al, ICRA15]

More challenges ahead!



Awiwi hand



ECE testbed

https://www.youtube.com/watch?v=YqmRKqFqiok

[Friedl, Roa et al, WS-IROS15]

KEYPOINTS SO FAR

- Using human-inspired measures not always leads to good and functional robotic hands
- In-hand manipulation abilities are an aspect often neglected in hand design
- Active compliant control (“active soft hands”) have a good behavior in front of uncertainties in position of the object and applied perturbations
- New designs follow the idea that planning and control must be at the same level as the design of the hand

III. BENCHMARKING ROBOT HANDS @ IROS16

Robotic Grasping and Manipulation Competition
IROS 2016, Oct. 10-12, 2016

TRACK 1: hand-in-hand
TRACK 2: fully autonomous

Stage 1: pick and place
Stage 2: manipulation

TRACK 3: simulation track

http://www.rhgm.org/activities/competition_iros2016/

Stage 1: pick and place stage

DLR

Stage 2: manipulation stage

Level 1 tasks

Pick up peas with a spoon

Shake salt

Stir with a spoon

Hang towel

Stage 2: manipulation stage

Level 2 tasks

Plug a USB / AC light

Hammer a nail

Insert a straw

Level 3 tasks

Screwing

Operate syringe

Level 4 task

Cut with scissors

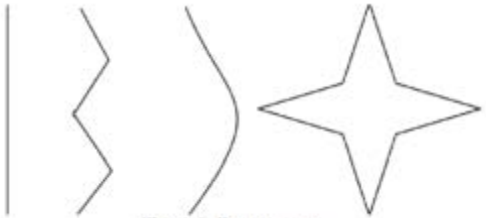
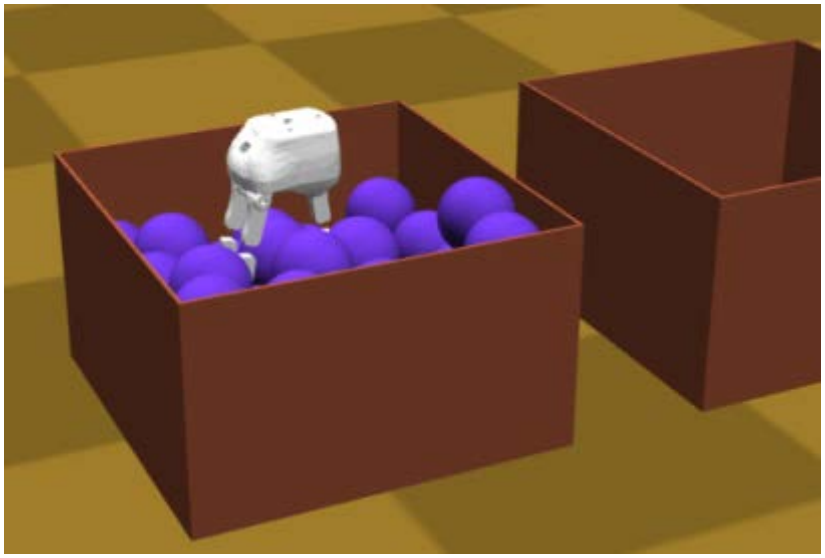


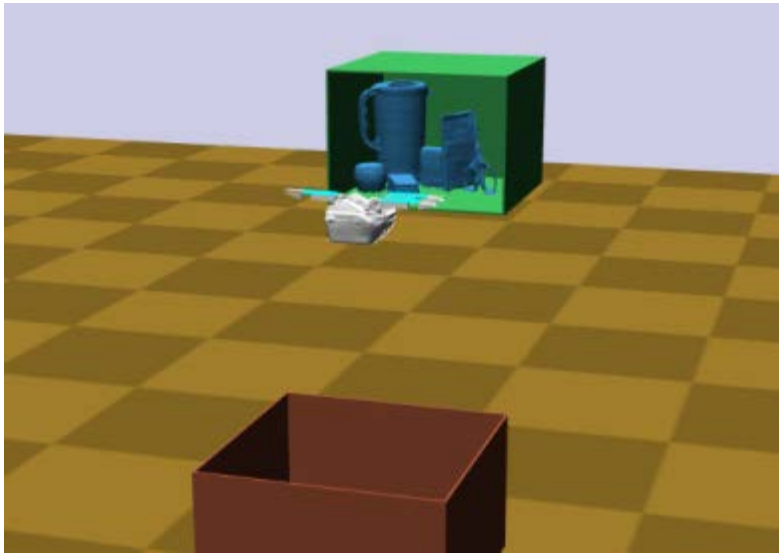
Figure 5: Four patterns

Track 3: simulation track

- Grasping simulator based on Klamp't [Kris Hauser, Duke University]
- Can use any model of a real robotic hand



Task 1



Task 2

DLR

Come and visit the competition!

Competition Area C

Schedule

Monday Oct 10, 8:30am-12:00pm, Dry-run

Tuesday Oct 11:

1:30pm-3:30pm, Manipulation, track 1

4:00pm-6:00pm, Manipulation, track 2

Wednesday Oct. 12:

9:00am-9:30am, pick-and-place, track 3

10:00am-10:30am, pick-and-place, track 2

11:00am-11:30am, pick-and-place, track 1

DLR

SOME REFERENCES

- An Adaptive Compliant Multi-finger Approach-To-Grasp Strategy for Objects with Position Uncertainties. Z. Chen, T. Wimboeck, M.A. Roa, B. Pleintinger, M. Neves, N. Lii. IEEE Int. Conf. on Robotics and Automation - ICRA, pp. 4911-4918. Seattle, USA, 26-30 May 2015.
- Towards a Functional Evaluation of Manipulation Performance in Dexterous Robotic Hand Design. M.A. Roa, Z. Chen, I. Staal, J. Muirhead, A. Maier, B. Pleintinger, N. Lii, C. Borst. IEEE Int. Conf. on Robotics and Automation - ICRA, pp.6800-6807. Honk Kong, China, 31 May - 7 June 2014
- ECE testbed - A hardware tool to benchmark fingers and hands on their capability to use environment constraints exploration. W. Friedl, H. Höppner, M.A. Roa, M. Grebenstein. IROS'16 Workshop on Benchmarking underactuated and soft robotic hands. Dajeon, Korea, October 2016.

http://rmc.dlr.de/rm/en/staff/maximo.roa/publications

Acknowledgments

Grasping & Manipulation Team: Oliver Porges, Ashok Sundaram, Igor Menkorwski, Dr. Katharina Hertkorn

Other groups: Dr. Ulrich Hillenbrand, Dr. Claudio Castellini, Dr. Tim Bodenmüller, Dr. Neal Lii, Dr. Zhaopeng Chen, Andreas Stemmer, Korbinian Nottensteiner, Werner Friedl, Hannes Höppner, Dr. Markus Grebenstein

Other places: Dr. Ulrike Thomas (TUC), Uwe Zimmermann (KUKA), Dr. Thomas Wimböck (EPO), Christoph Borst (KUKA), Dr. Yu Sun (USF)

Thanks for your attention!

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