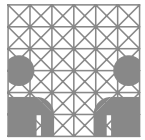

Dexterous Manipulation With Hand Synergies

Berk Güngör

University of Hamburg
Faculty of Mathematics, Informatics and Natural Sciences
Department of Informatics

Technical Aspects of Multimodal Systems

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Outline

- Introduction
- Pisa/IIT SoftHand
- Pisa/IIT SoftHand 2
- Augmented Adaptive Synergies
- Design
- Experiments
- Evaluation

Motivation

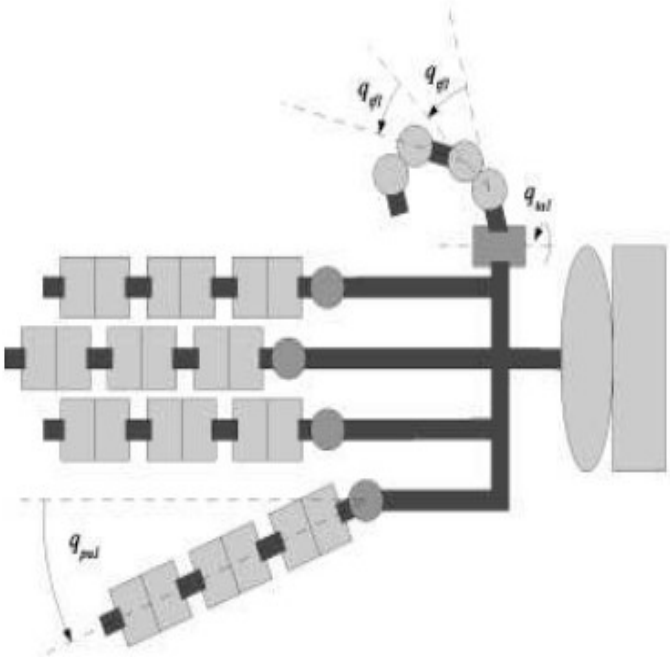
- Design and control of a new version SoftHand
- Perform a wide range of grasping and manipulation tasks
- Develop a robot hand that can perform complex manipulation tasks with a high degree of dexterity

Introduction

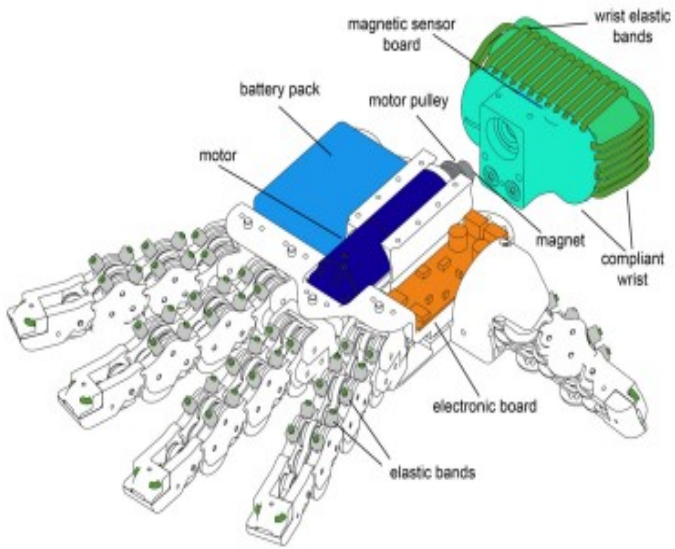
- Dexterous manipulation needs a high degree of adaptibility to different environments and objects.
- The Pisa/IIT SoftHand has previously been introduced.
- The SoftHand 2 has a new kinematic structure.
- SoftHand 2 uses a new control strategy based on the concept of adaptive synergies.

Pisa/IIT SoftHand

- Designed for dexterous manipulation [2]
- One DoA in a compact setup [2]
- Mostly focused on grasping tasks
- Winner of Robotics Grasp and Manipulation Challenge at IROS 2016



(a)



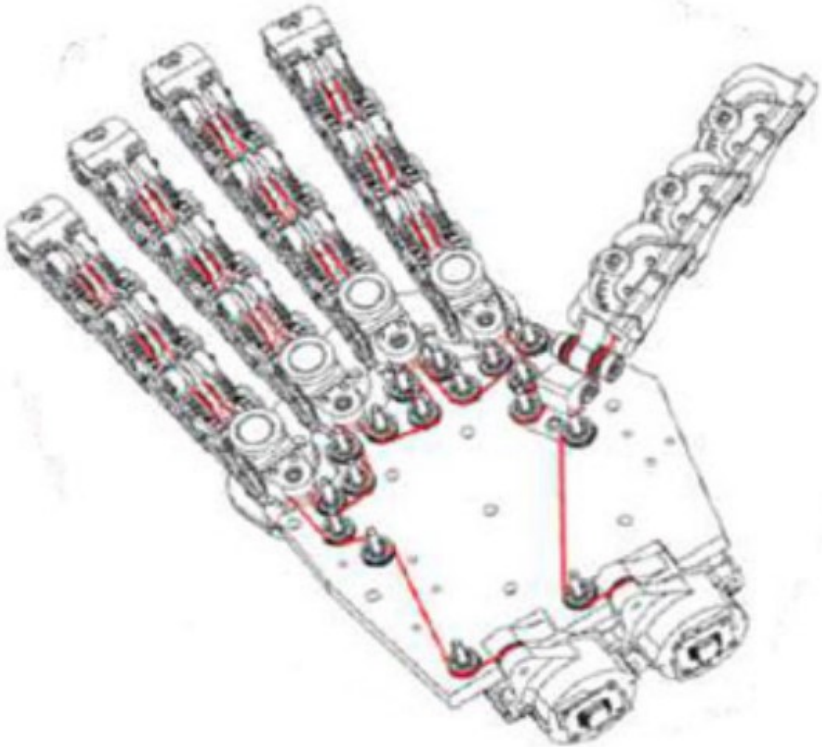
(b)

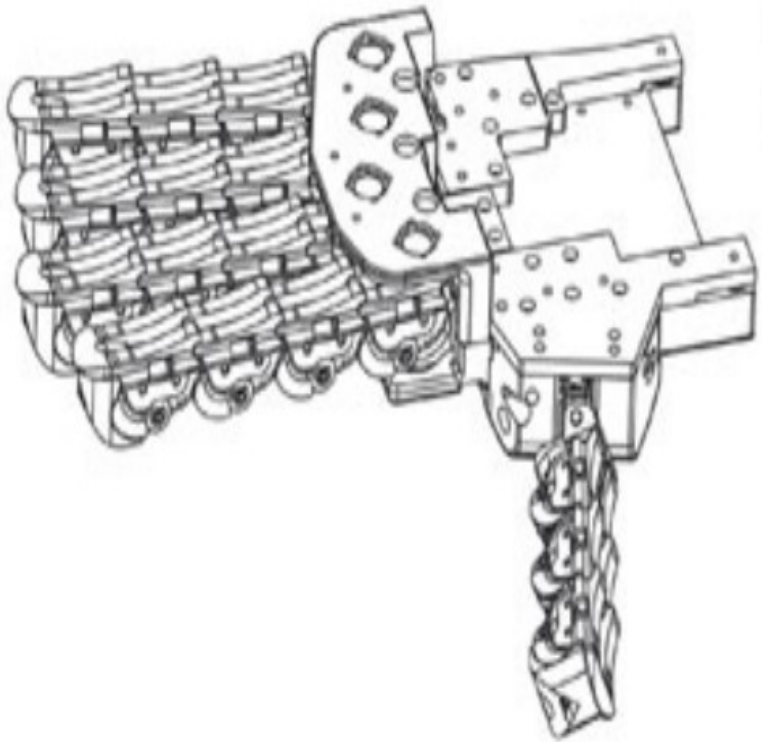
Pisa/IIT SoftHand 2

- Softhand 2 combines good grasping performance and dexterous in-hand manipulation capabilities.[4]
- Two DoA in a compact setup [4]
- Wider range of grasping and manipulation [4]
- Uses augmented adaptive synergies for control [4]

Pisa/IIT SoftHand 2

- Pisa/IIT SoftHand 2 has a total of 19 DOF [4]
- 2 Motors actuate tendon. [4]
- Wider range of grasping and manipulation [4]
- Uses augmented adaptive synergies for control [4]

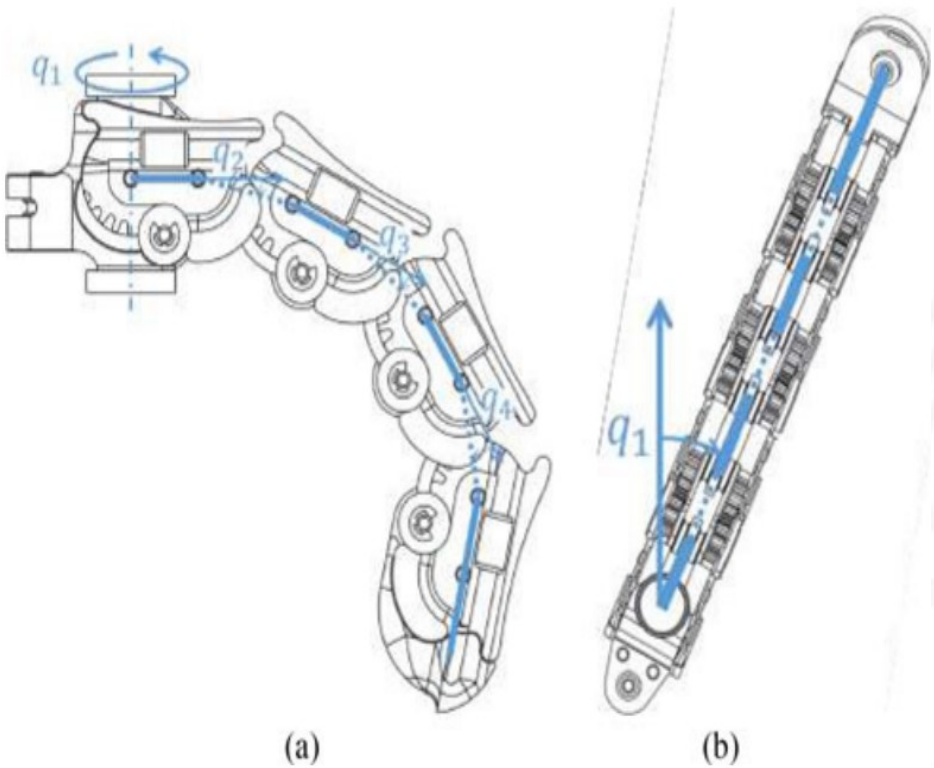


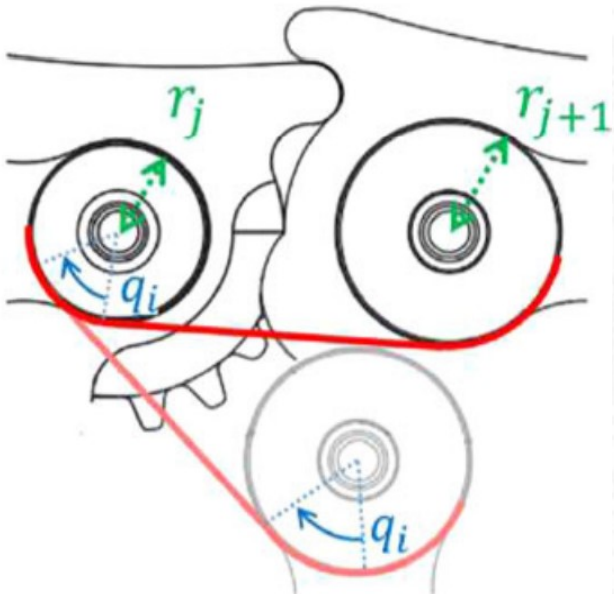


Santina et al. Toward Dexterous Manipulation With Augmented Adaptive Synergies: The Pisa/IIT SoftHand 2 [4]

Pisa/IIT SoftHand 2

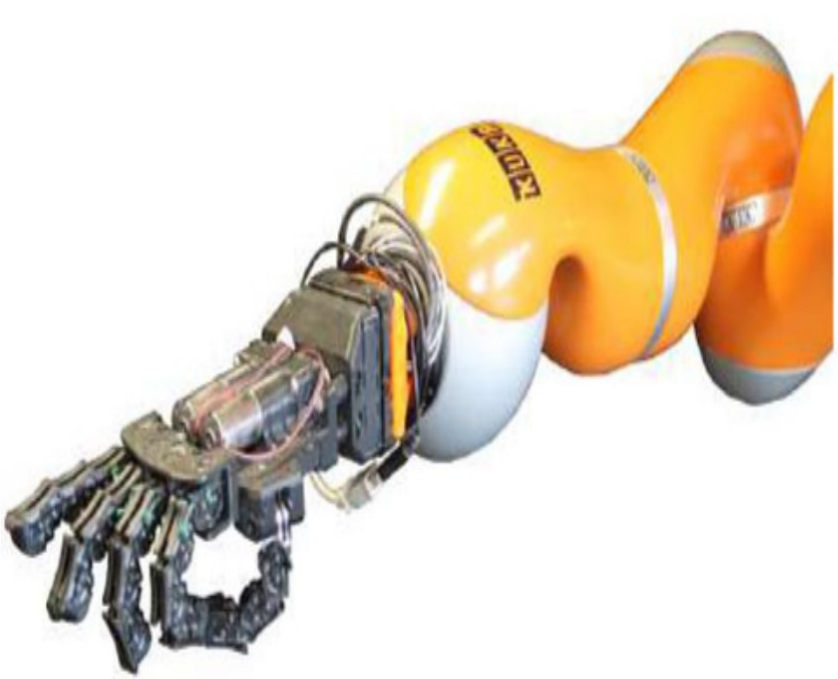
- Hand Kinematics
- Revolute-Revloute arm
- red line : tendon
- q : joint angle





Pisa/IIT SoftHand 2

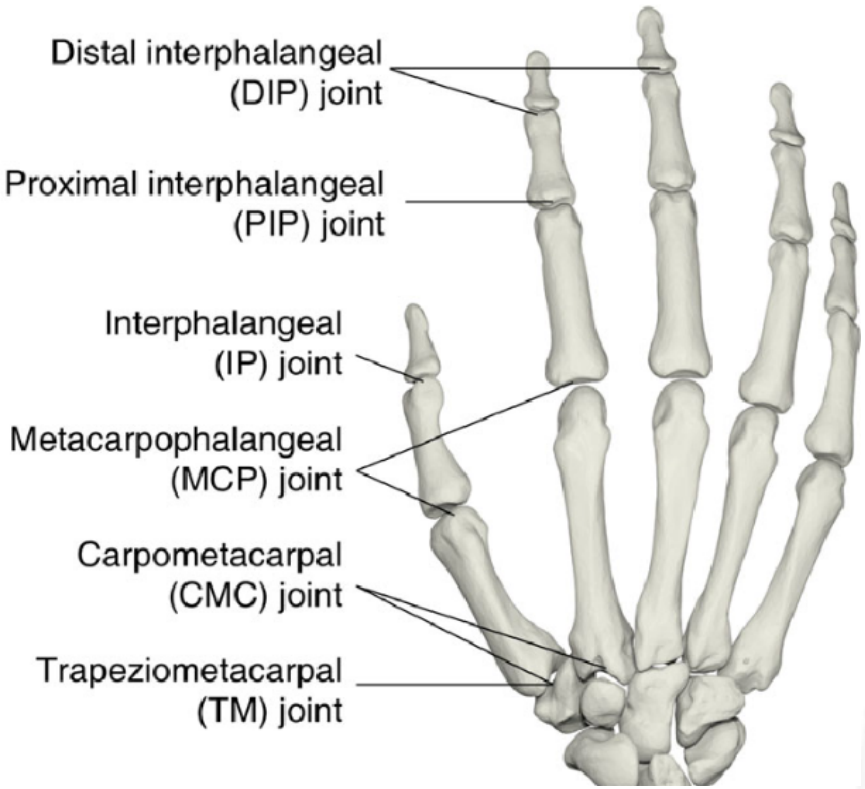
- Compact design
- Manual control option
- Robotic arm integration



Santina et al. Toward Dexterous Manipulation With Augmented Adaptive Synergies: The Pisa/IIT SoftHand 2 [4]

Postural Hand Synergies

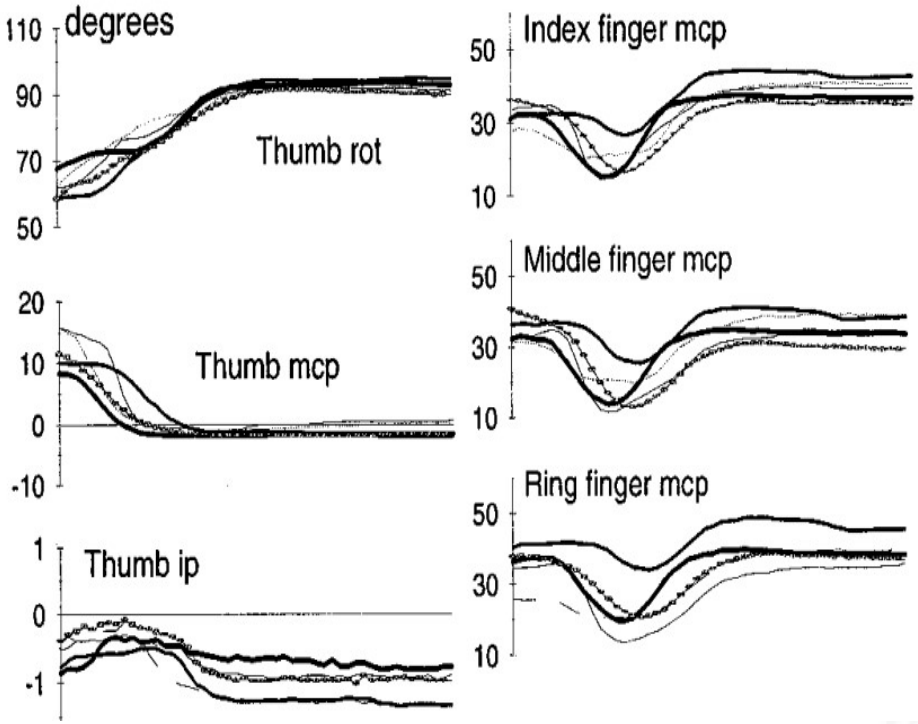
- How humans use their hands to manipulate tools ?
- Grasping synergies

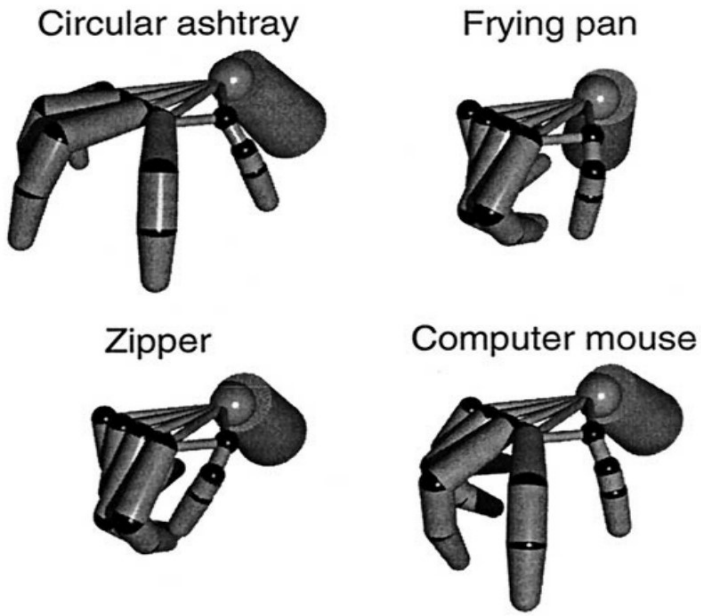


[https://orthofixar.com/anatomy/hand-anatomy-bones-muscles/]

- mcp and pip joints of four fingers
- angle of abduction(abd)
- For the thumb, the mcp, abd and ip

Postural Hand Synergies

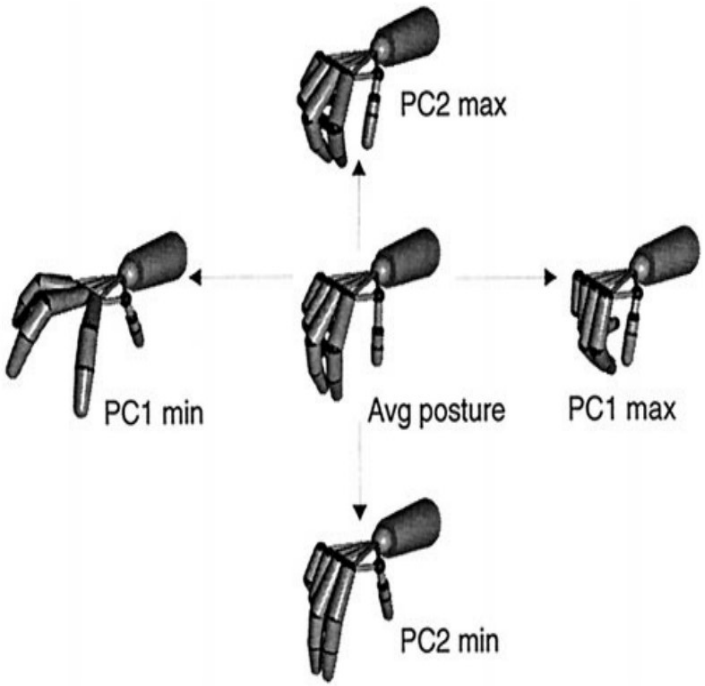


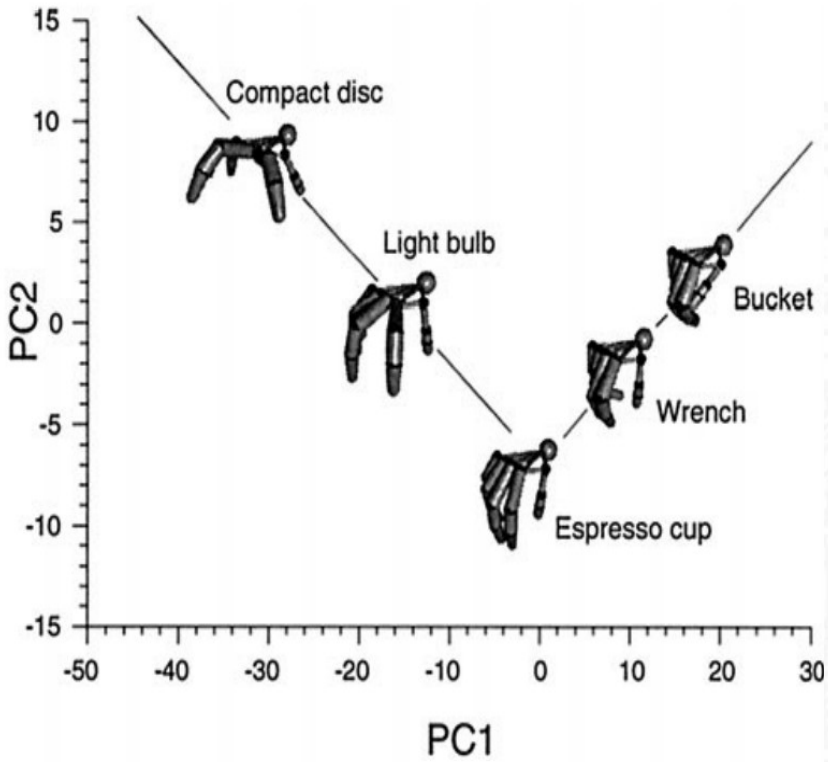


Santello et al. Postural hand synergies for tool use [3]

Postural Hand Synergies

- Principal Component Analysis
- Tested with 57 different objects





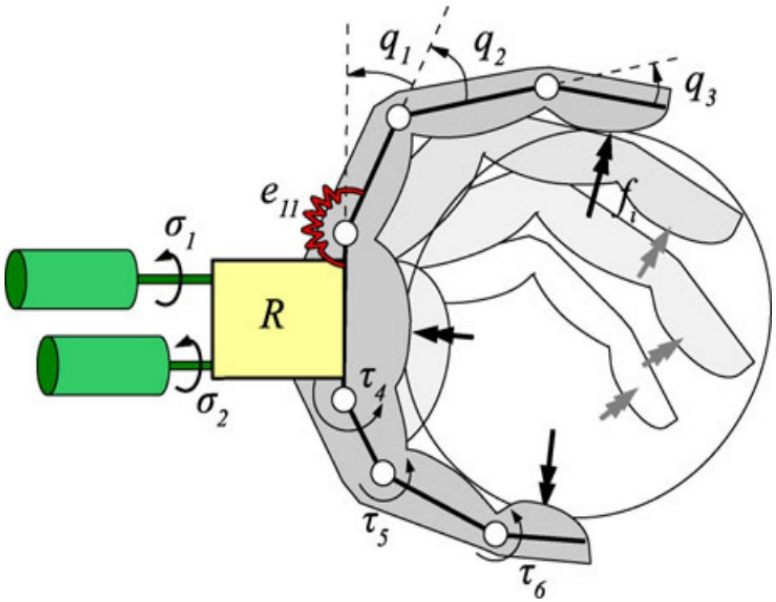
Santello et al. Postural hand synergies for tool use [3]

Synergies

- Synergies : aiming to reproduce a similar human hand motions.
  - Soft Synergies : allow for more natural and efficient movement[1]
  - Adaptive Synergies : allow the hand to adapt to new[4]
  - Final posture of the hand depends on the external wrenches, internal torques and springs elasticity [4]

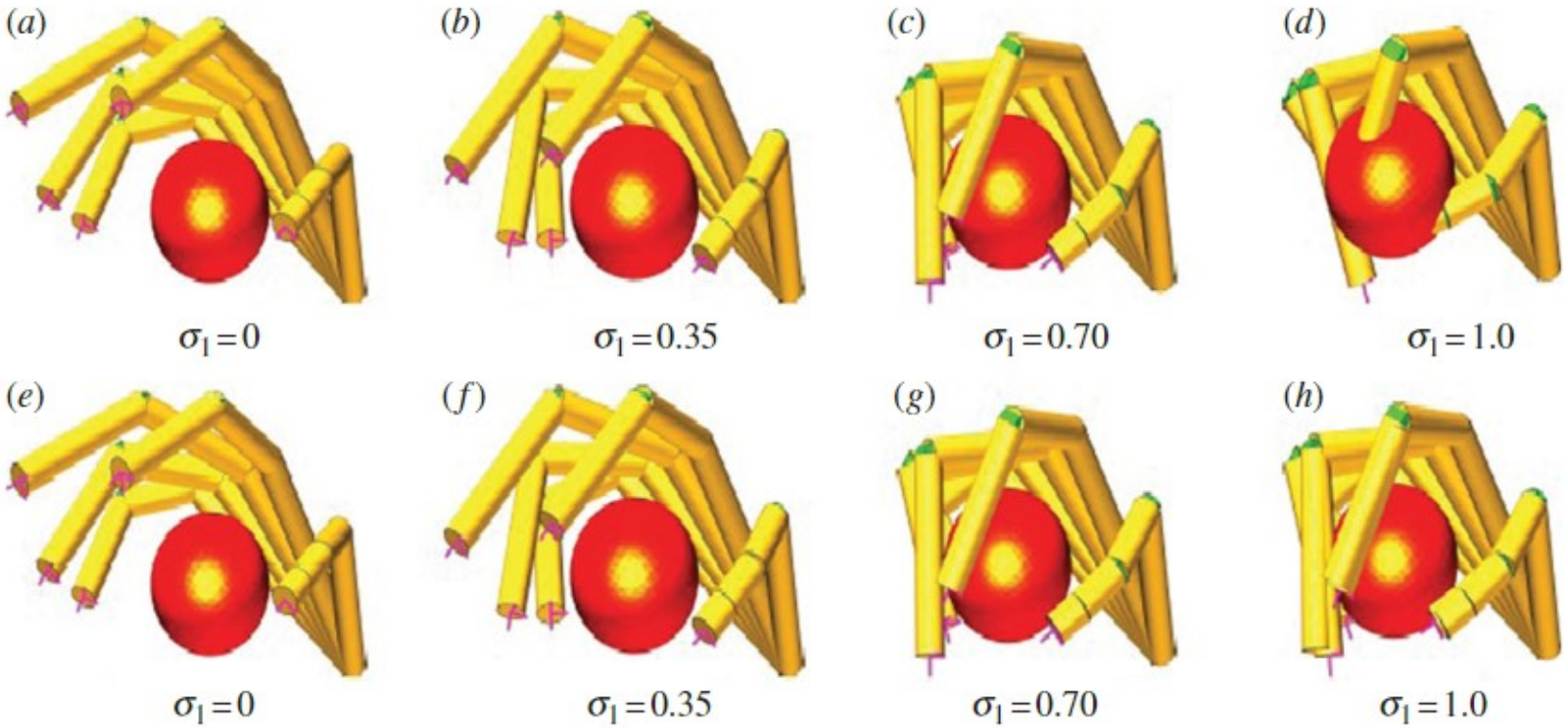
$$q = S\sigma$$

$$q = S\sigma - CJ^T f_{ext}$$



- q : Hand joint angles
- S : Synergy matrix
- σ : motion angles (posture in synergy)
- $J^T f_{ext}$:all contact forces

Soft Synergies

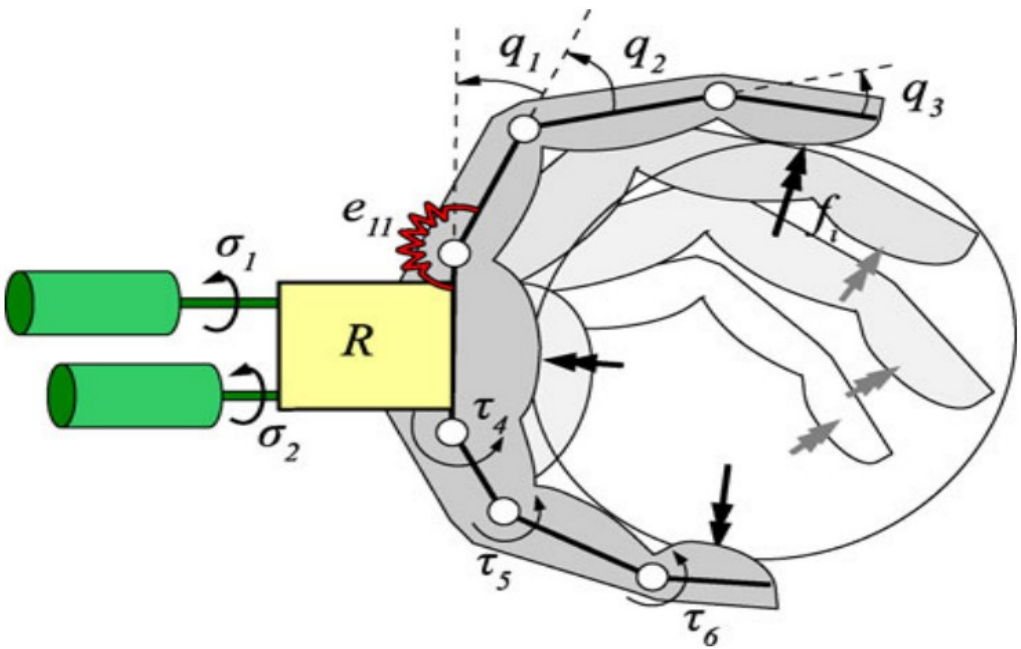


- a-d : rigid manifold
- e-h : soft synergies which which is repelled by contact forces with the object

Santello et al. Modelling natural and artificial hands withsynergies [1]

Adaptive Synergies

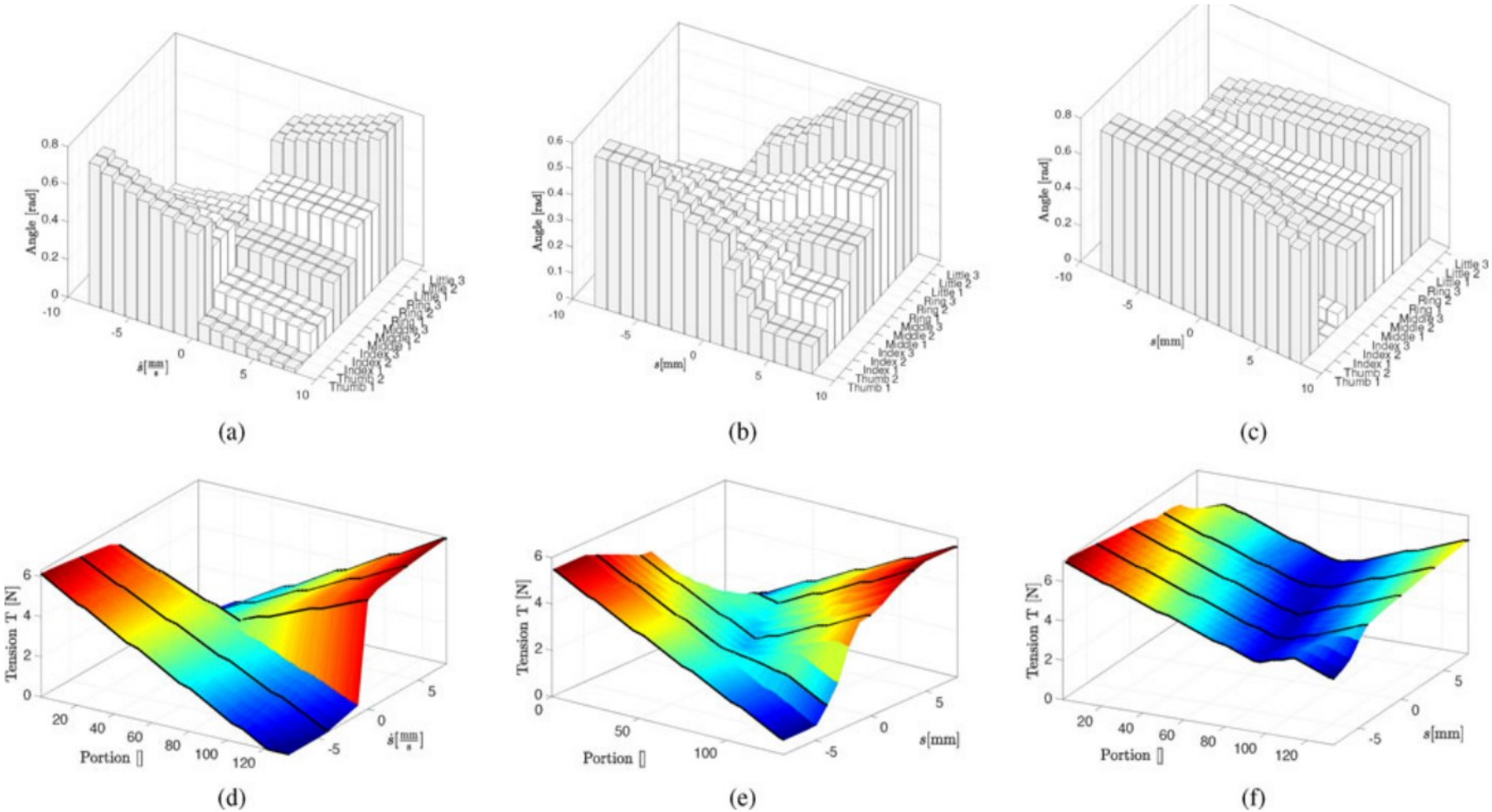
- Adaptive Synergies exploits differential mechanisms and space of self-motions to adapt to the environment.
- Augmented Adaptive Synergies
  - Reduces the number of parameters that the control system needs to estimate and update.
  - Fixed + Adaptive components to improve the overall performance of the hand control.



Santello et al. Modelling natural and artificial hands withsynergies [1]

Simulative Results

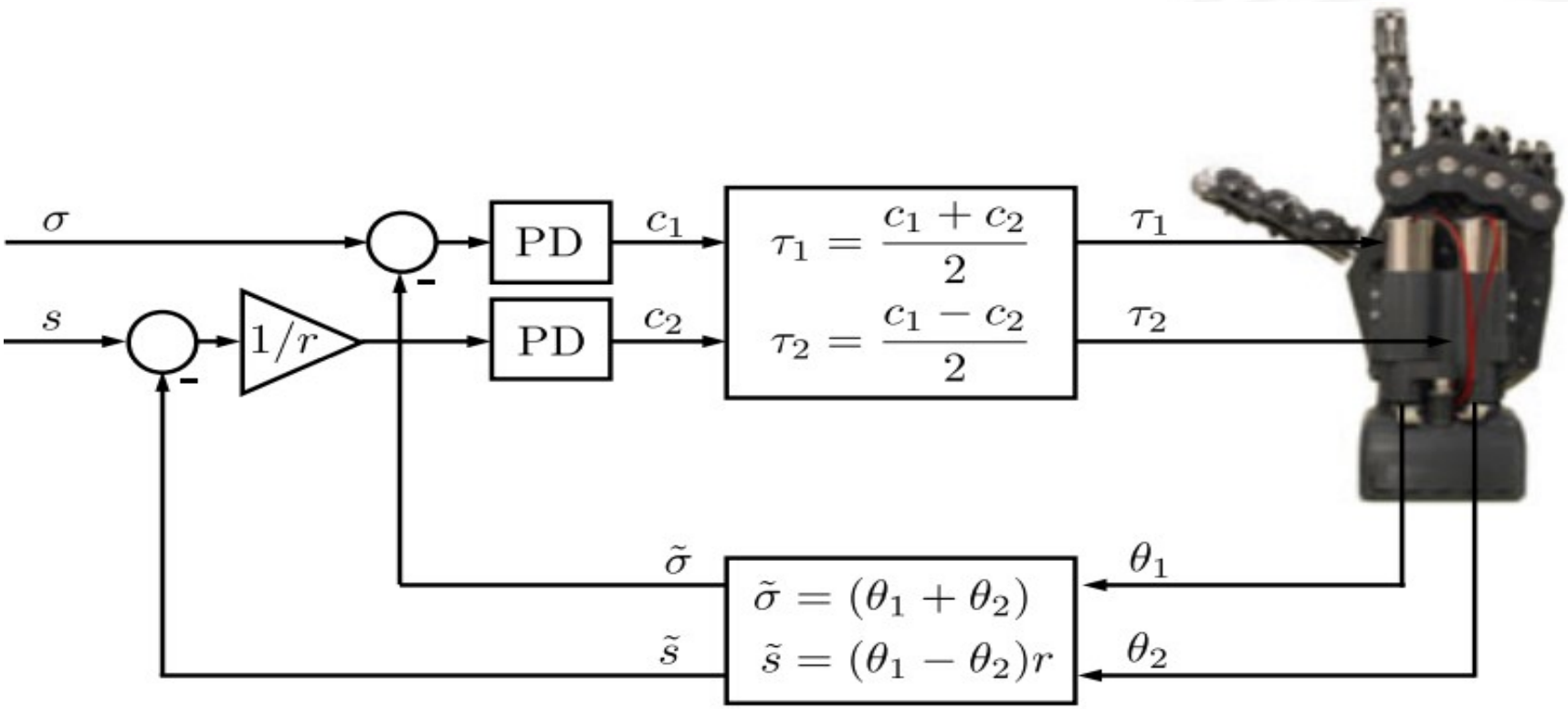
- Effect of sliding in the steady-state posture
- When 2N force is applied, index finger did not react.
- The constant sliding generates a tension redistribution.



Santina et al. Toward Dexterous Manipulation With Augmented Adaptive Synergies: The Pisa/IIT SoftHand 2 [4]

Experiment

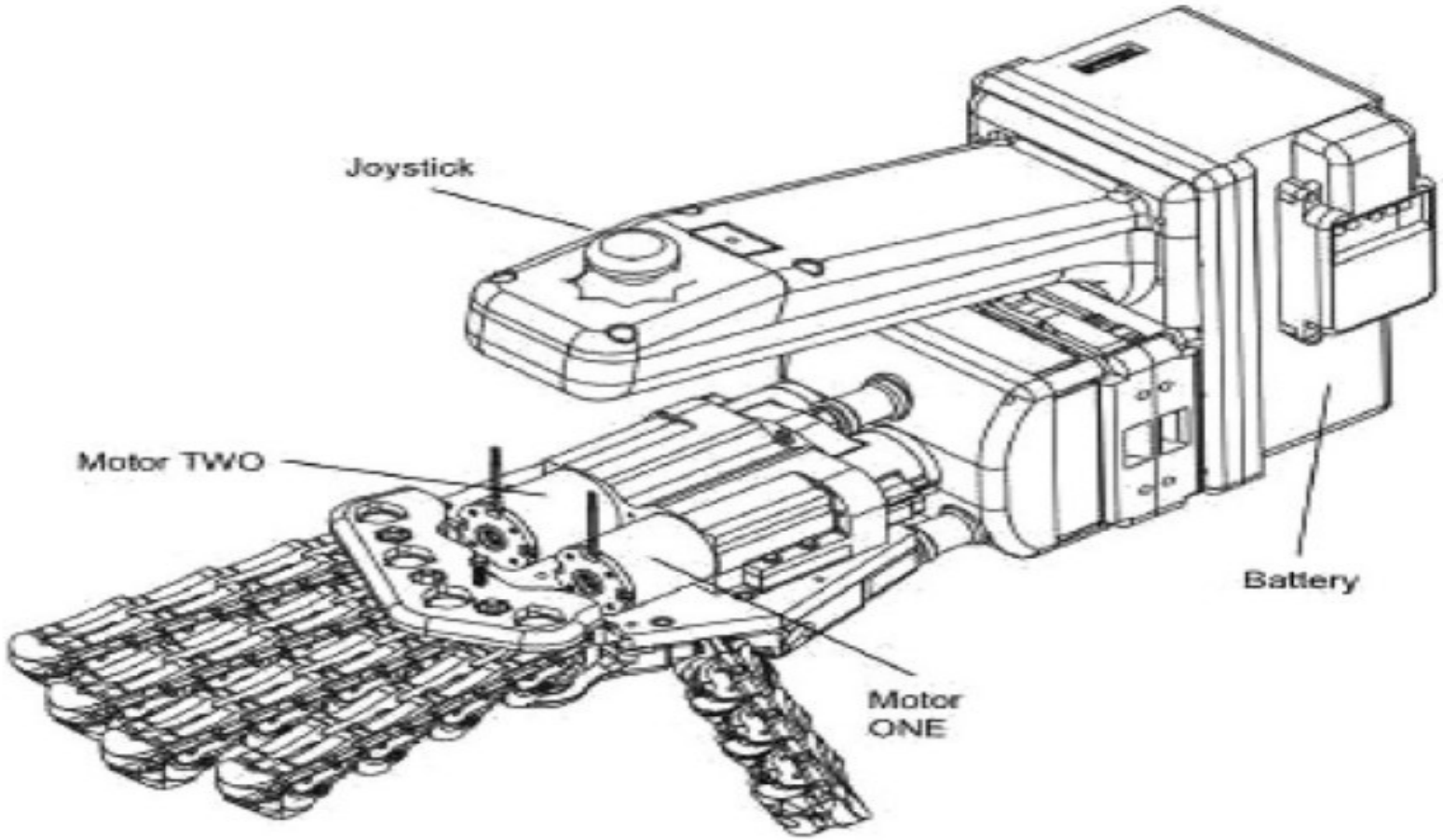
- A. Control by error-based PD controller
  - motor pulley radius r
  - τ represents motor torques
  - motor angles θ_1 and θ_2 are mapped into σ and s
  - The control is mapped back to motor inputs/



Santina et al. Toward Dexterous Manipulation With Augmented Adaptive Synergies: The Pisa/IIT SoftHand 2 [4]

Experiment

- B. Human–Machine Interface
  - Joystick control
  - Enables quick experiment



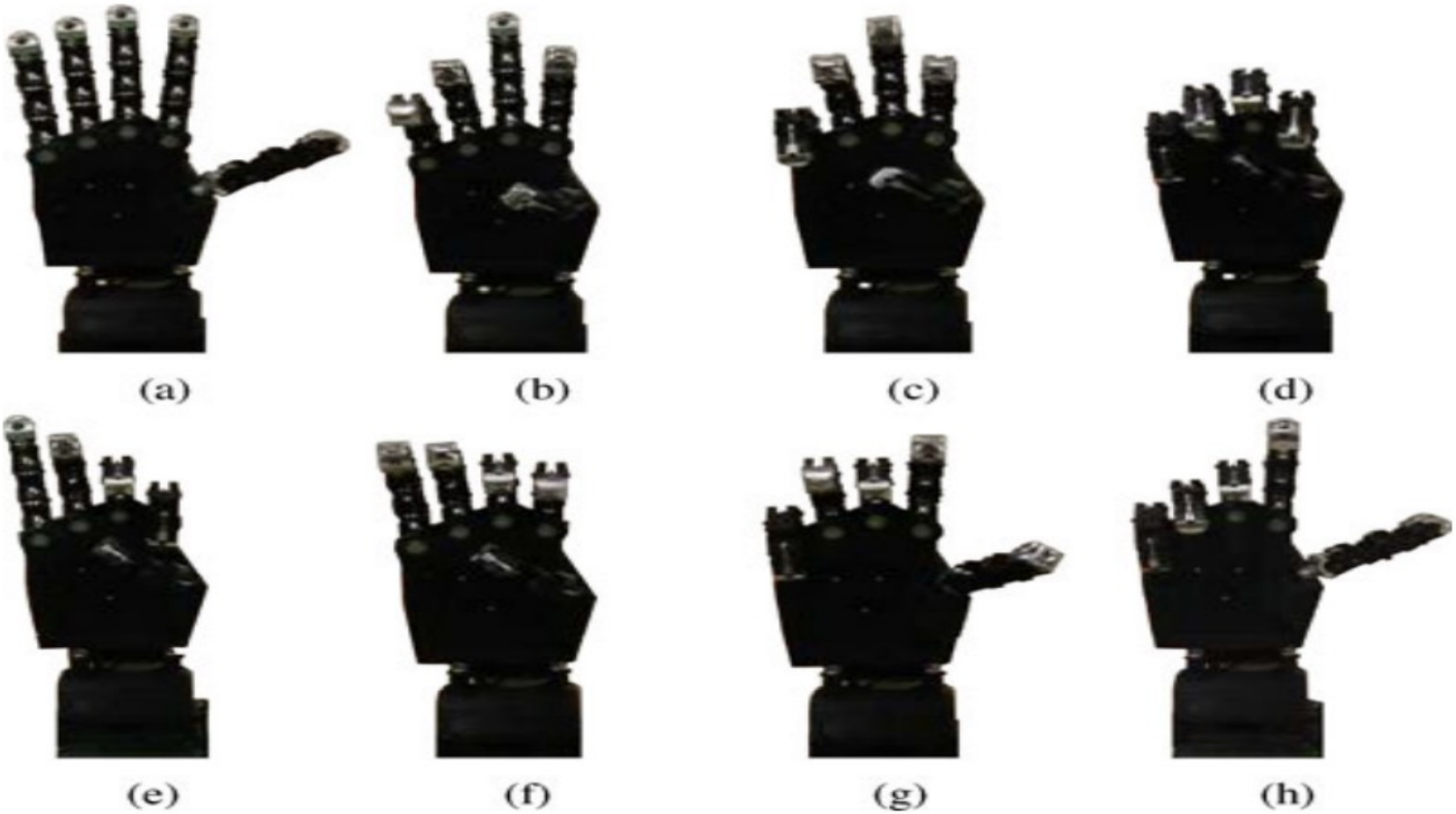
Santina et al. Toward Dexterous Manipulation With Augmented Adaptive Synergies: The Pisa/IIT SoftHand 2 [4]

Experiment

Video

Experiment

- First synergy of grasping (opening-closing)
- High-order synergies of grasping (reconfiguration)



Santina et al. Toward Dexterous Manipulation With Augmented Adaptive Synergies: The Pisa/IIT SoftHand 2 [4]

Experiment

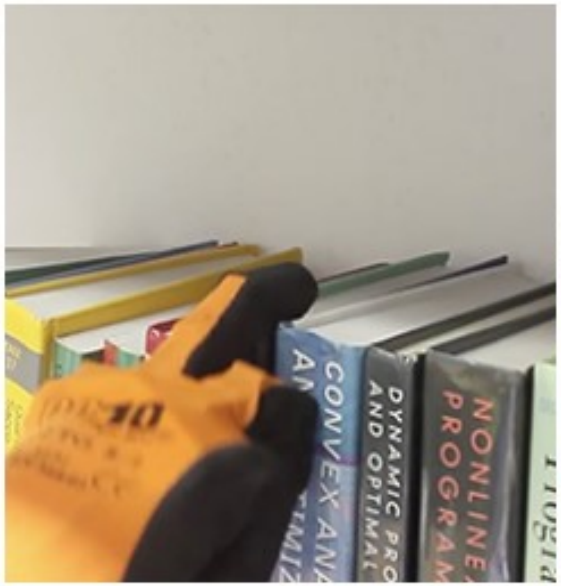
- Comparison of grasping capabilities, between one DoA and two DoAs.

Santina et al. Toward Dexterous Manipulation With Augmented Adaptive Synergies: The Pisa/IIT SoftHand 2 [4]

Experiment

(a) (b) (c)

Experiment



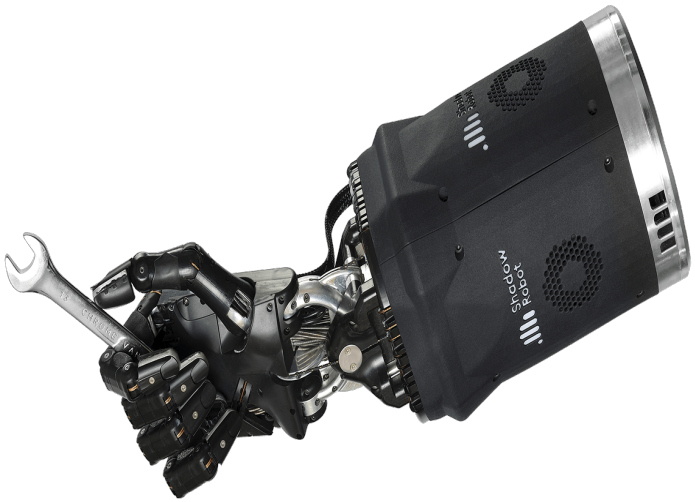
Benchmark

Shadow Dexterous Hand

- 29 active joints and tendons
- High degree of dexterity
- Suitable for grasping with teleoperation

Pisa/IIT Softhand 2

- Designed to be soft
- Allows to conform to the shape of objects
- better for fragile/soft objects with good grasping force



Conclusion

- Pisa/IIT Softhand 2 has two DoA and 19 DoFs.
- Objects are grasped with first DoA and manipulated with second DoA.
- Grasping capability is increased compared to Softhand1.
- Augmented Adaptive Synergies helps to optimize grasping.

[1] Antonio Bicchi, Marco Gabiccini, and Marco Santello.
Modelling natural and artificial hands with synergies.
Philosophical Transactions of the Royal Society B: Biological Sciences, 366(1581):3153–3161, 2011.

[2] Edoardo Farnioli Giorgio Alessandro Serio Cristina Piazza Manuel G. Catalano, Giorgio Grioli.
From soft to adaptive synergies: The pisa/iit softhand.
IEEE Transactions on Robotics, 2016.

[3] Soechting JF Santello M, Flanders M.
Postural hand synergies for tool use.

[4] Cosimo Della Santina, Cristina Piazza, Giorgio Grioli, Manuel G. Catalano, and Antonio Bicchi.
Toward dexterous manipulation with augmented adaptive synergies: The pisa/iit softhand 2.
IEEE Transactions on Robotics, 34(5):1141–1156, 2018.