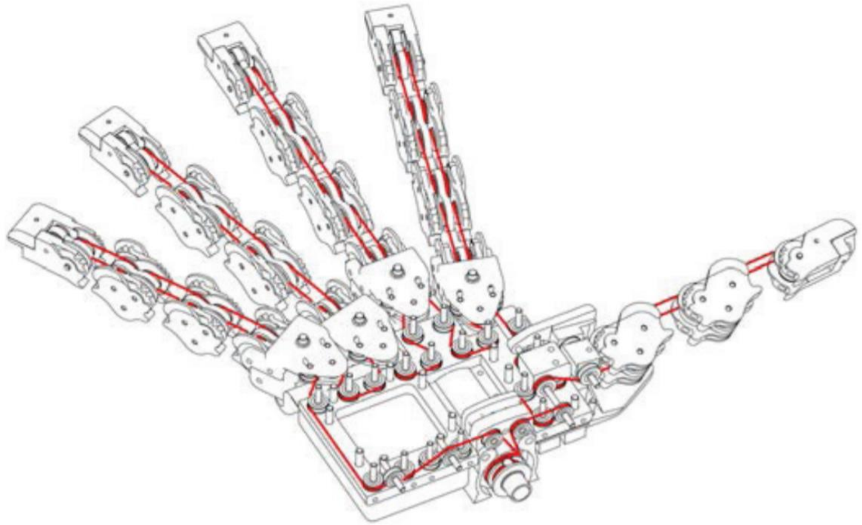
Adaptive synergies for the design and control of the Pisa/IIT SoftHand (IJRR, 2014)

Manuel G. Catalano, Giorgio Grioli, Edoardo Farnioli, Alessandro Serio, Cristina Piazza, and Antonio Bicchi

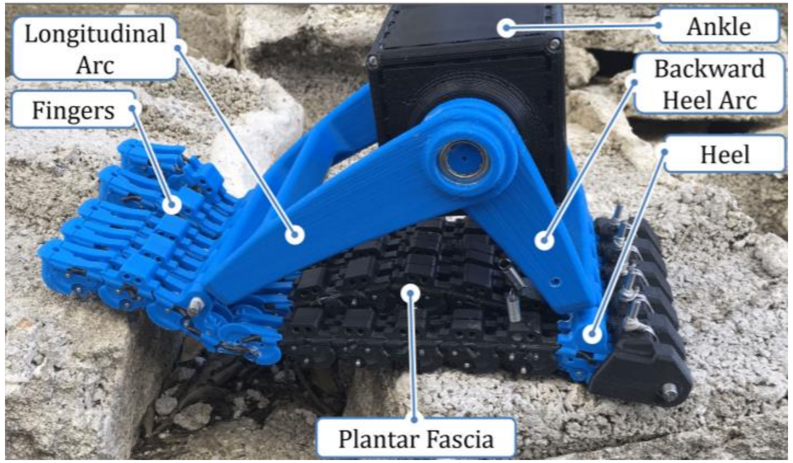


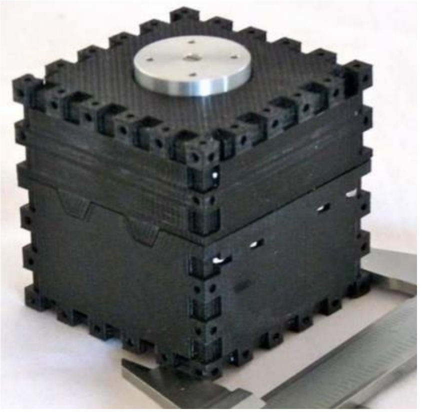
Presented by Ryan Coulson

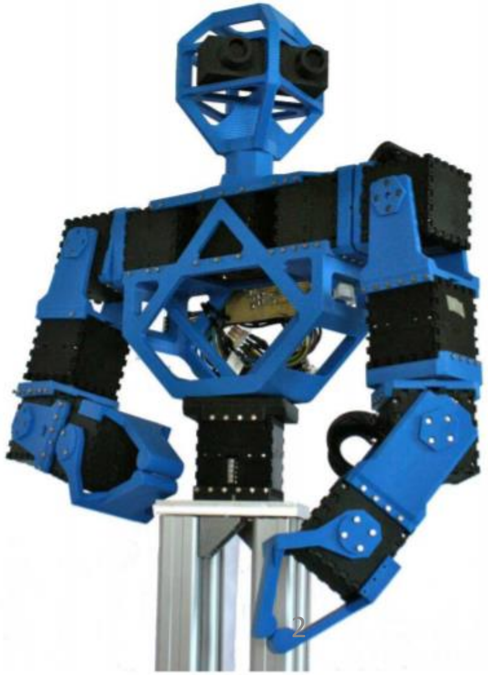
February 10th, 2020

Manuel Catalano

- University of Pisa/Istituto Italiano di Tecnologia
- Started robotics research in 2008







Antonio Bicchi

- Pisa/IIT
- 60 years old, started robotics research in 1984 (36 years)
- Has worked on grasping/dexterity, soft robotics, human-robot interaction, control theory, and more
- PI of Soft Robotics Lab for Human Cooperation and Rehabilitation
- Founded WorldHaptics Conference and IEEE RA-L magazine
- Has a Wikipedia page

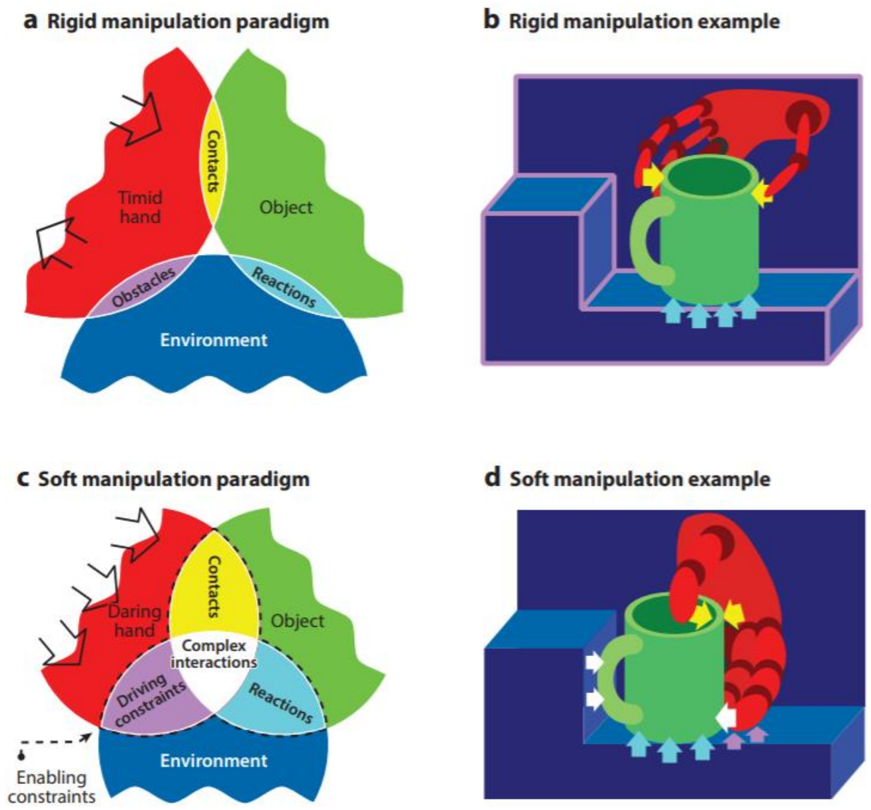
Annual Review of Control, Robotics, and Autonomous Systems

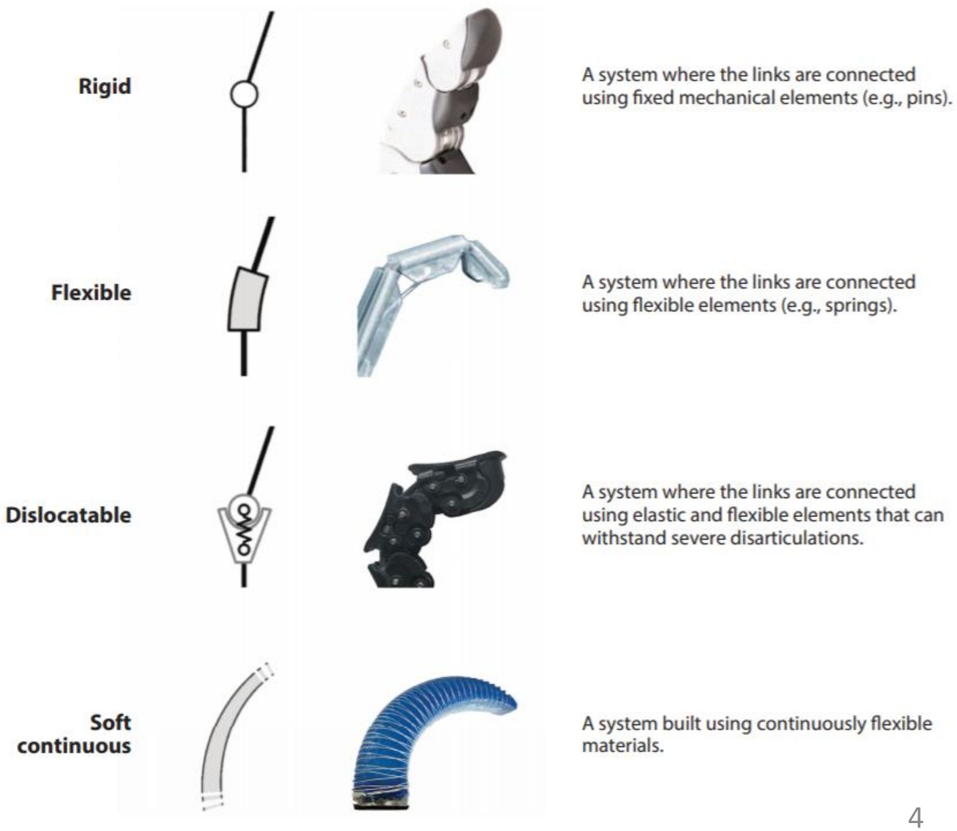
A Century of Robotic Hands

C. Piazza,[1] G. Grioli,[2] M.G. Catalano,[2] and A. Bicchi[1,2]

[1]Centro di Ricerca "E. Piaggio" and Dipartimento di Ingegneria Informatica, Università di Pisa, 56122 Pisa, Italy; email: cristina.piazza@ing.unipi.it

[2]Soft Robotics for Human Cooperation and Rehabilitation, Istituto Italiano di Tecnologia, 16163 Genova, Italy





Overview of Paper

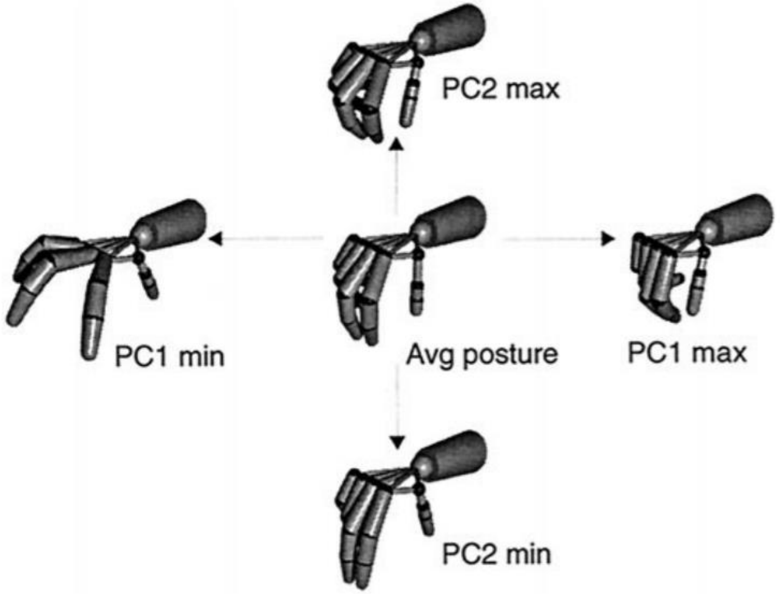
- Begins with thorough overview of hand actuation strategies
- Establishes mathematical framework necessary for implementing “adaptive synergies” in a robot hand
- Describes 19 DOF hand with a ***single*** actuator which implements the primary human synergy
- Capable of grasping many different objects, including 107 listed in paper

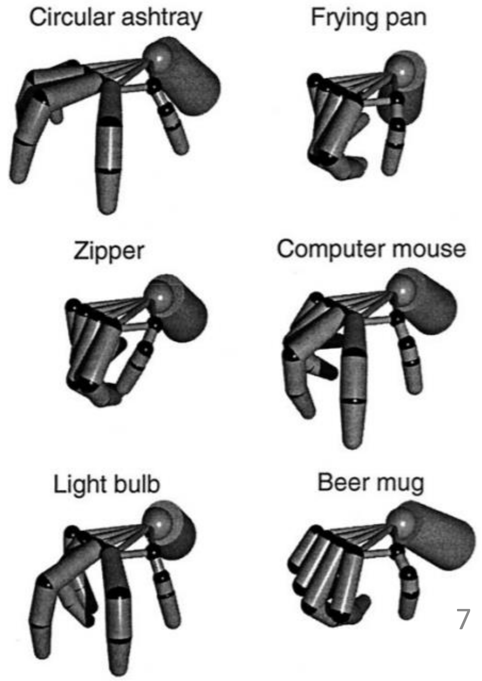
Synergies

- **Coordinated movements or control signals to accomplish a given task**
- **Motor primitives**
- Arise from physical couplings of tendons and muscles or neuro-muscular patterns
- Analogous to **vector bases**… linearly independent elements that combine to form the set of all movements (postural synergies/eigengrasp space)
- Often analyzed using **Principal Component Analysis**… data suggests that 80% of grasp posture information is explained by the first two synergies/components/bases

Related Work

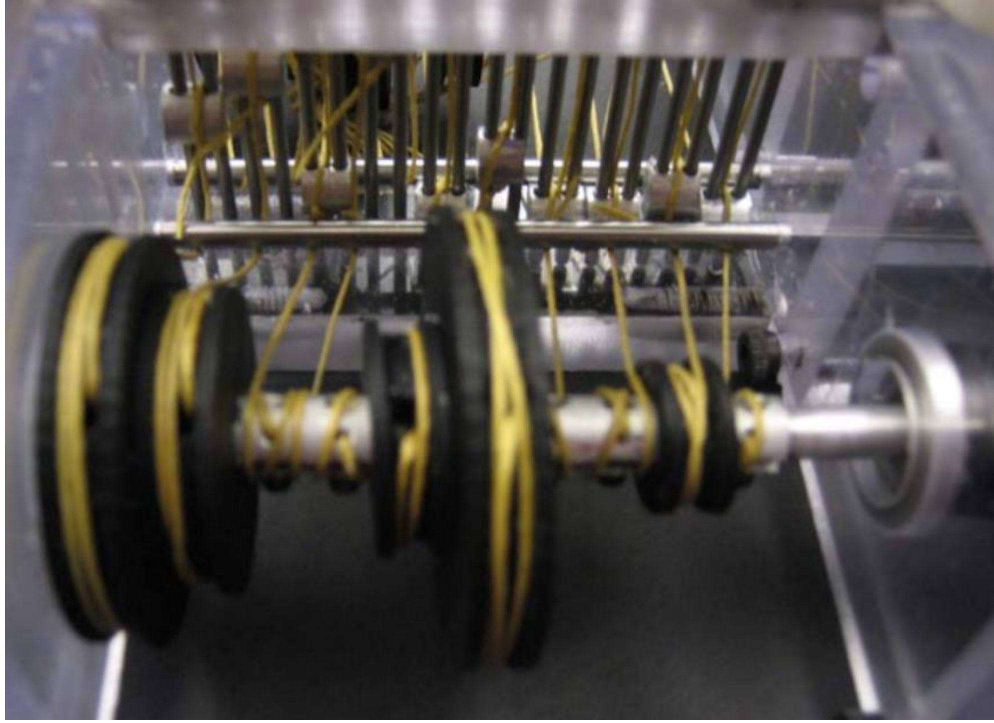
- ***Postural Hand Synergies for Tool Use*** (1998) by Santello, Flanders, and Soechting
- Subjects asked to grasp and use 57 *imagined* objects
- Found that hand postures were distributed along a continuum (as opposed to a discrete grasp taxonomy)
- PCA: 80% of posture info explained by first two synergies/components

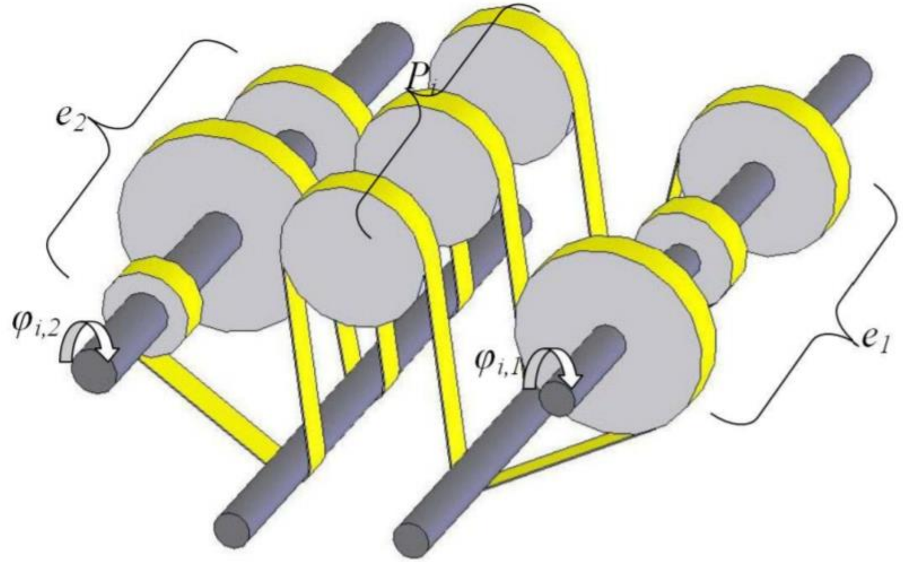


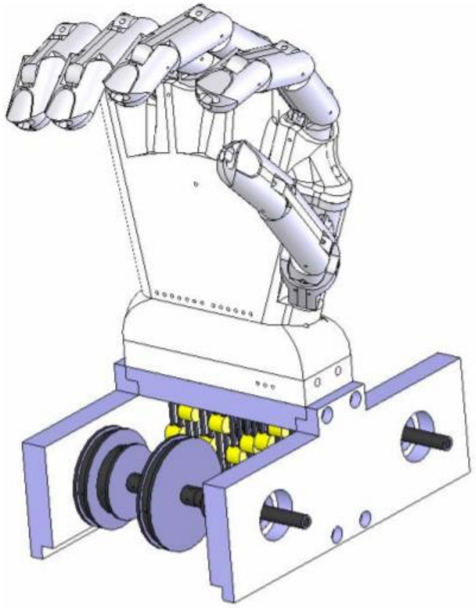


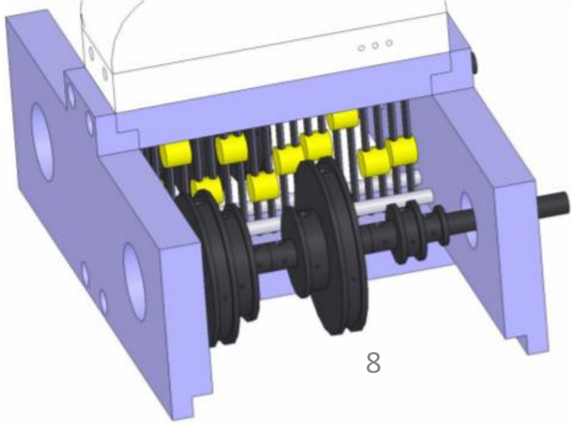
Related Work

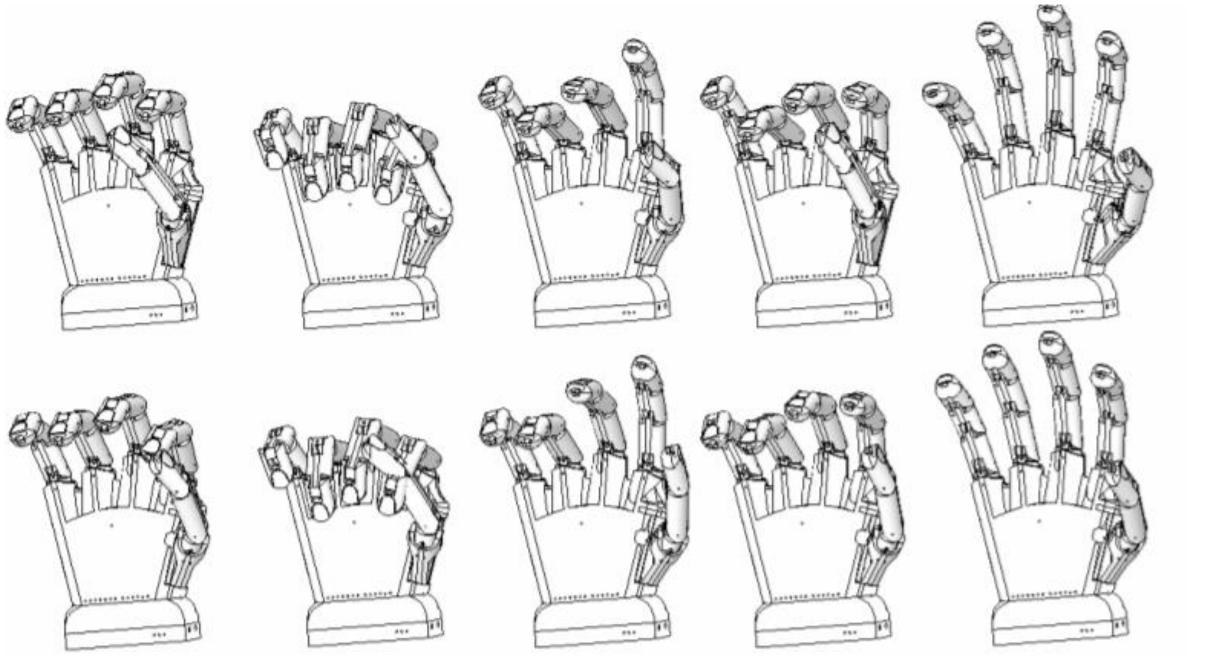
- ***Inter-Finger Coordination and Postural Synergies in Robot hands via Mechanical Implementation of Principal Component Analysis*** (2007) by Brown and Asada
- 17 DOF, 2 motors
- Implemented fist two synergies/components via two shafts with pulleys of different diameters

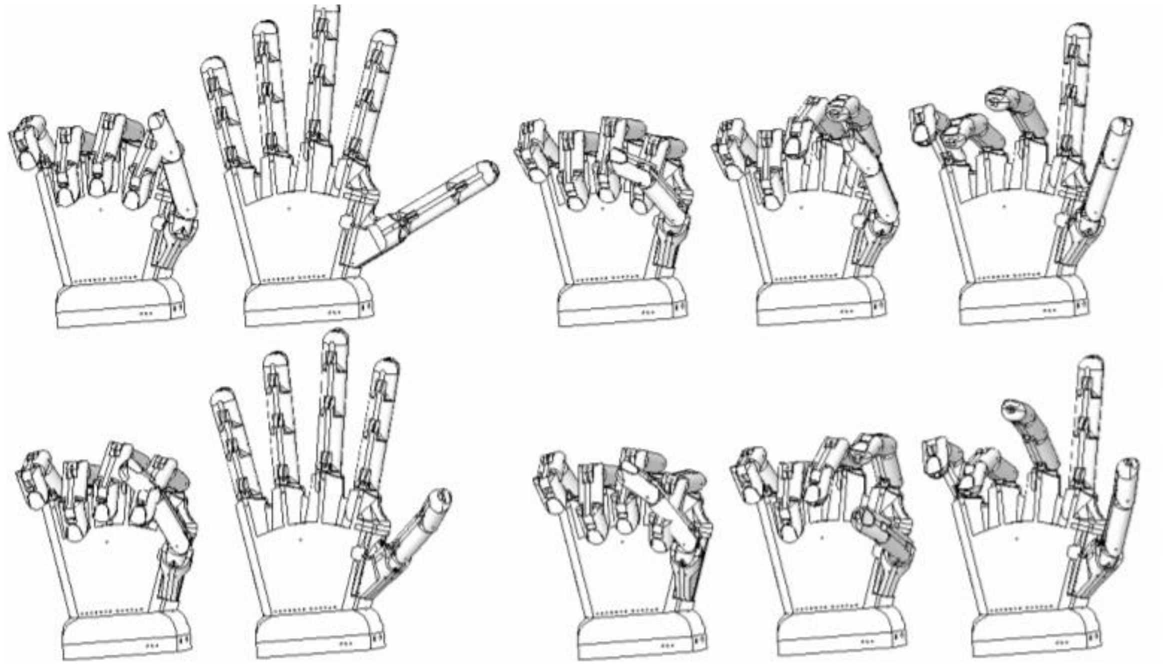


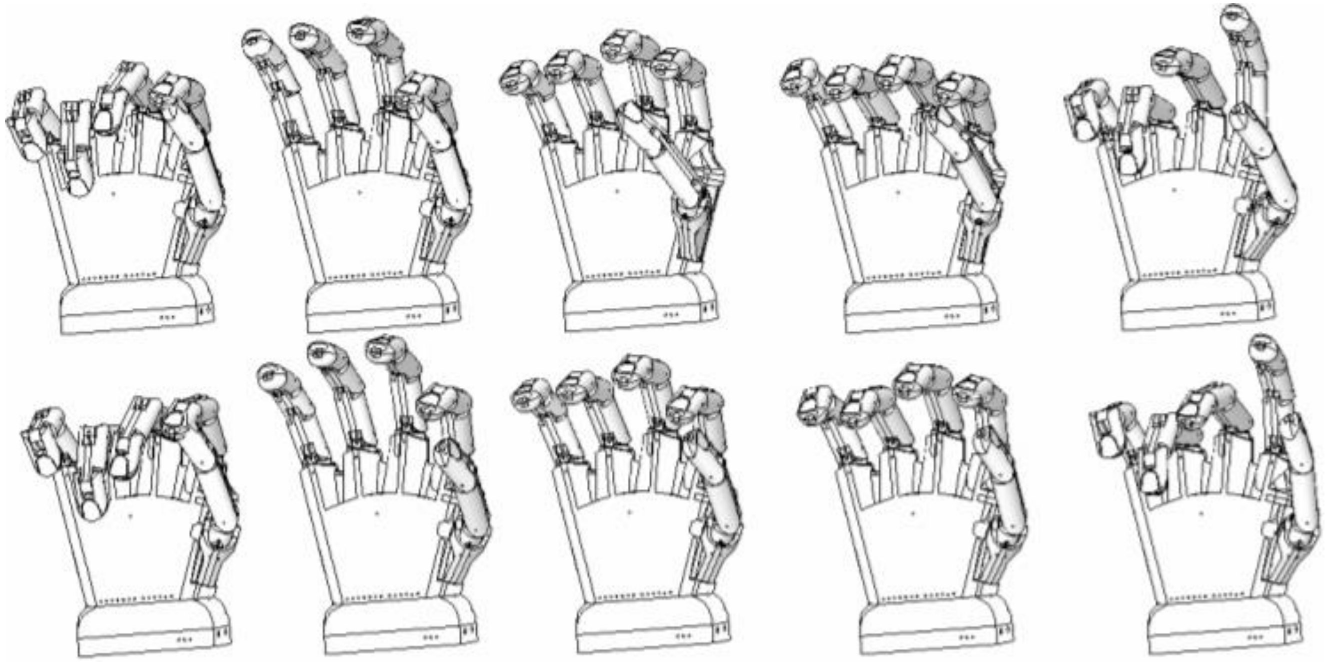










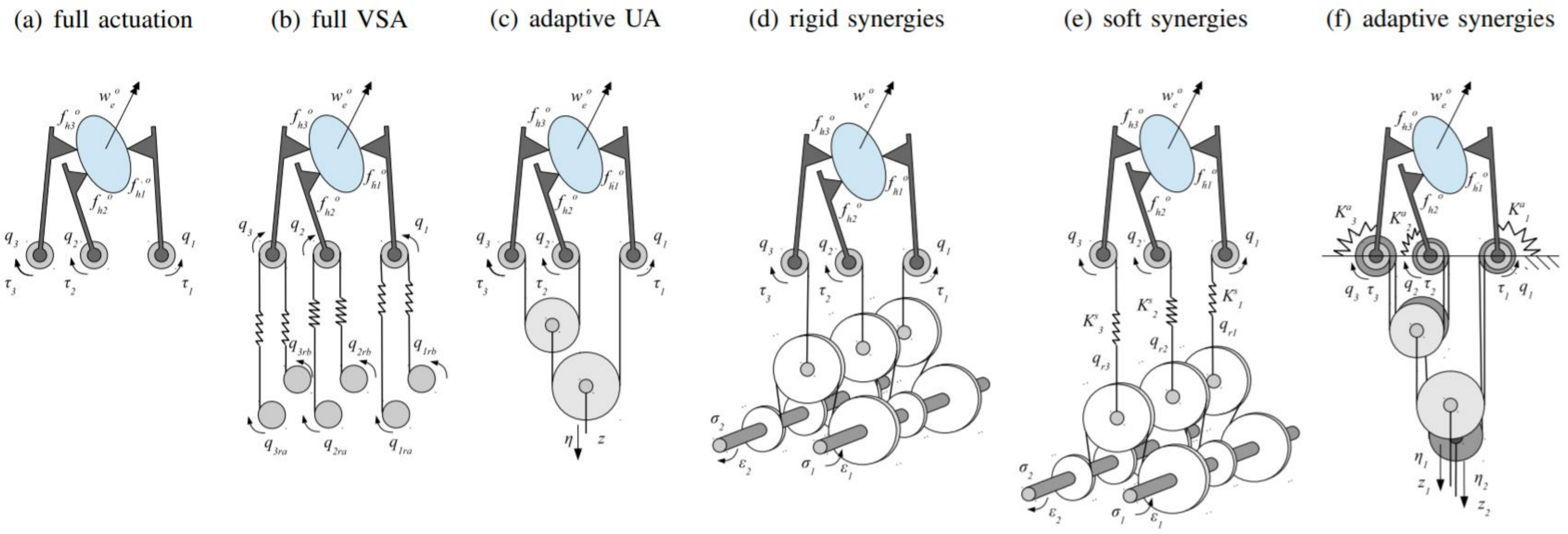


Top Row: Target
Bottom Row: Approximation

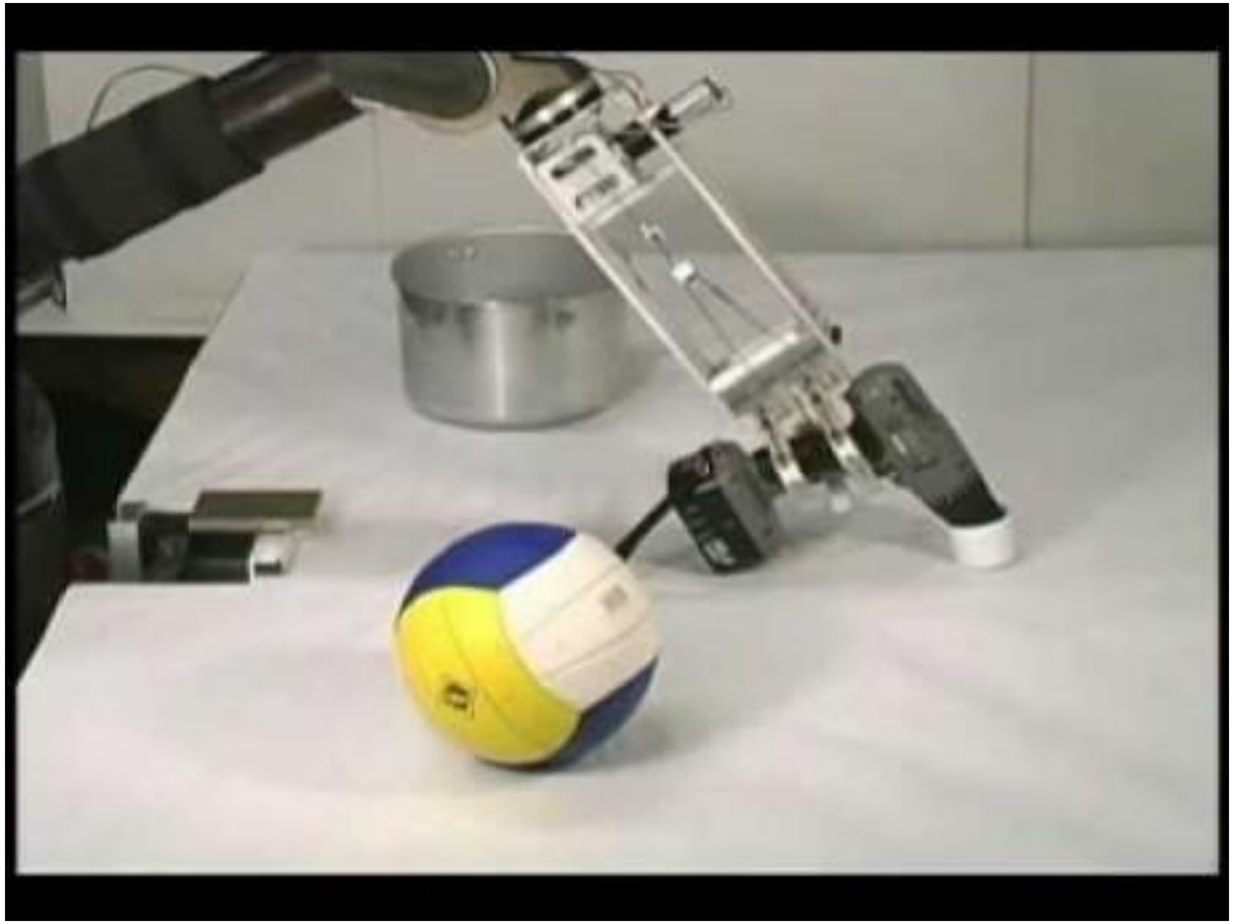
Contribution

- Established distinctions between different hand actuation strategies
- First implementation of synergies in a soft, self-contained hand
- One of the earlier “soft” robot hands
- Pioneered concept of “*adaptive* synergies”

Actuation Strategies



Shape-adaptive Underactuation



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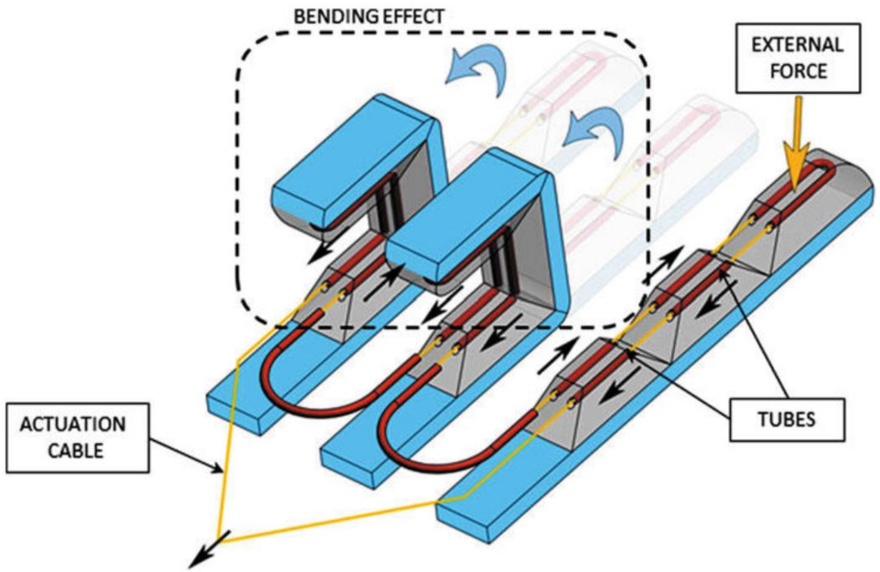
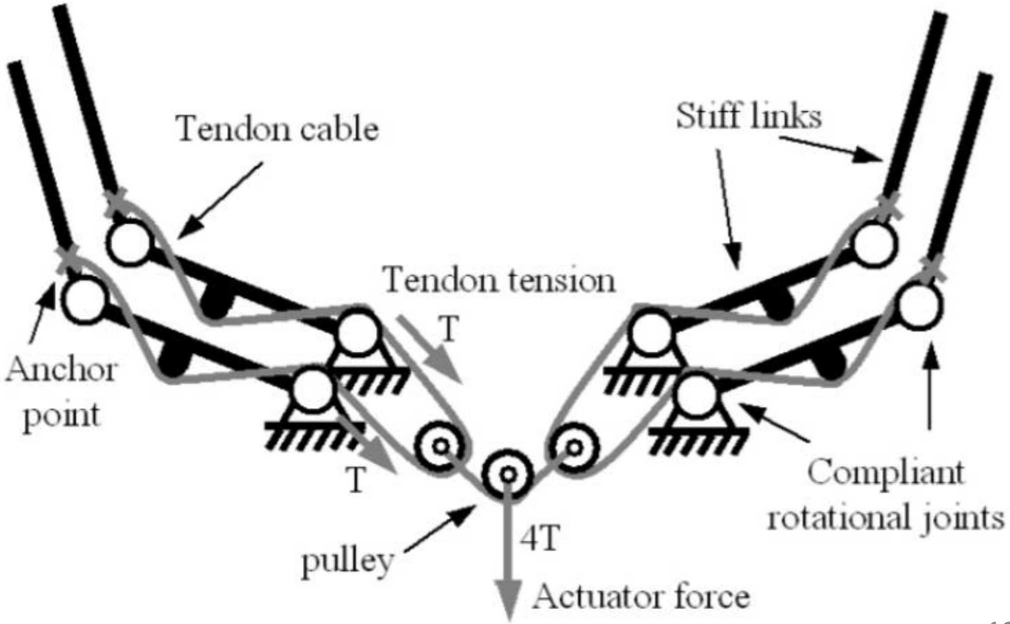




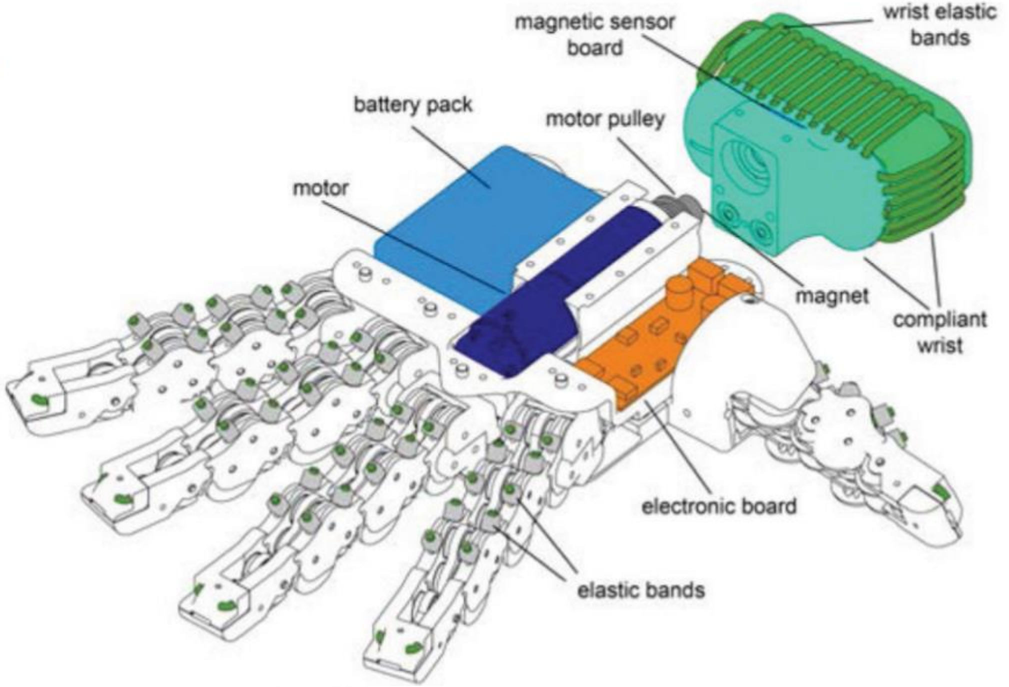
Pisa/IIT SoftHand Design

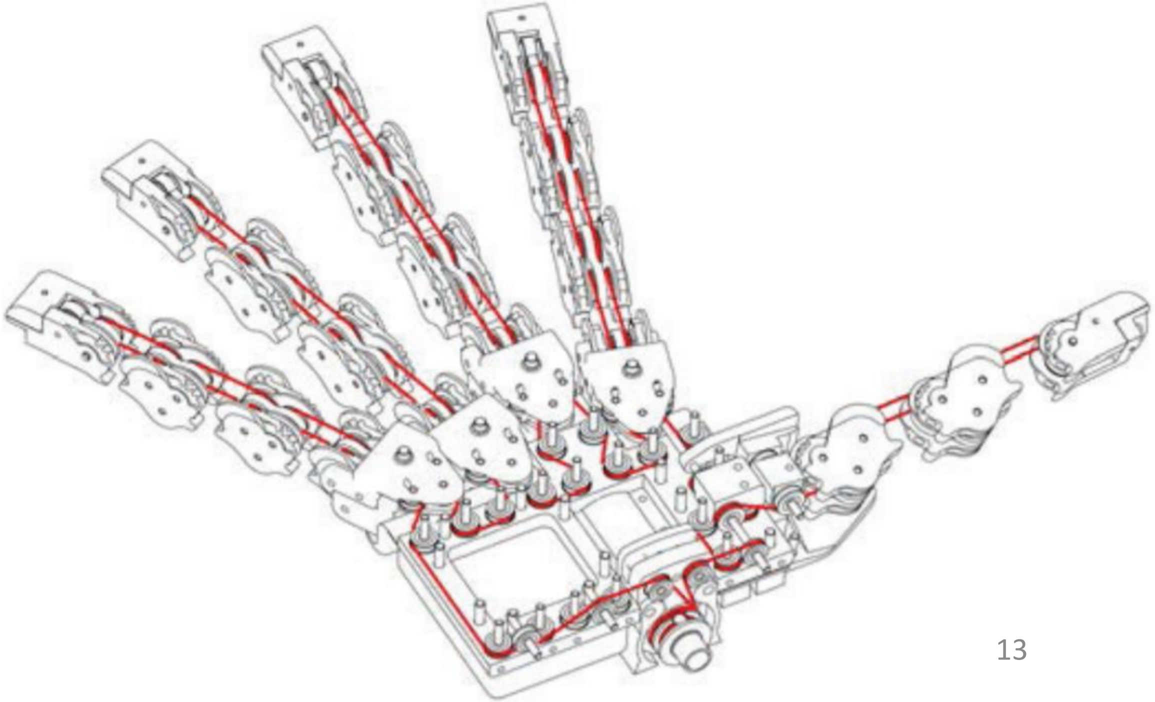
- "Mechanical implementation of soft synergy obtained via numerical evaluation of corresponding transmission matrix *R* and joint stiffness matrix *K*"

$$R\delta q = \delta z$$

$$\delta\tau = R^{\mathrm{T}}\delta\eta - K_q^a\delta q$$

δ: "variation"
q: joint configuration
z: adaptive synergy displacements
τ: joint torque
η: adaptive synergy forces

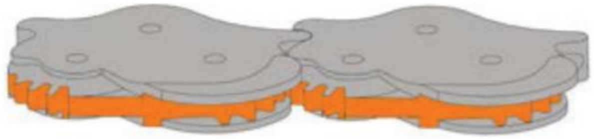




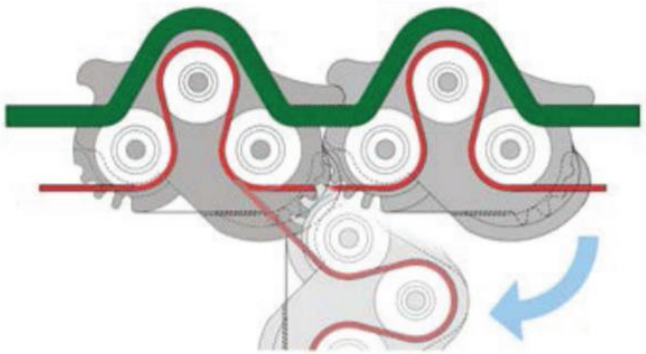
Joint Design

- Compliant Rolling-contact Elements (CORE)
- Held together by elastic ligaments
- Pre-tensioning of ligaments creates attractive equilibrium at rest configuration (fingers stretched)
- No screws/shafts/gears/bearings
- Low friction and wear

(a) Perspective view

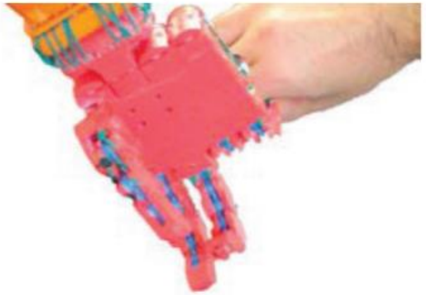


(b) Side view and movement



(a) Finger Side bend

(b) Finger Back bend

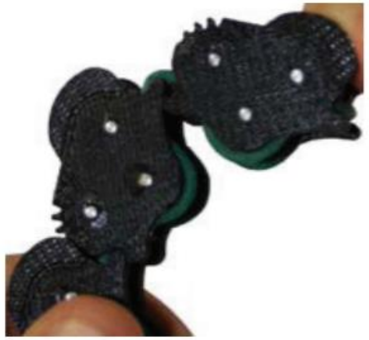


(c) Finger Twist

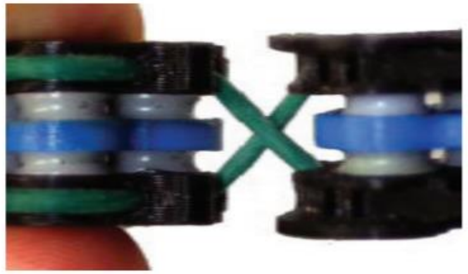
(d) Finger Skew bend

(e) Side bend

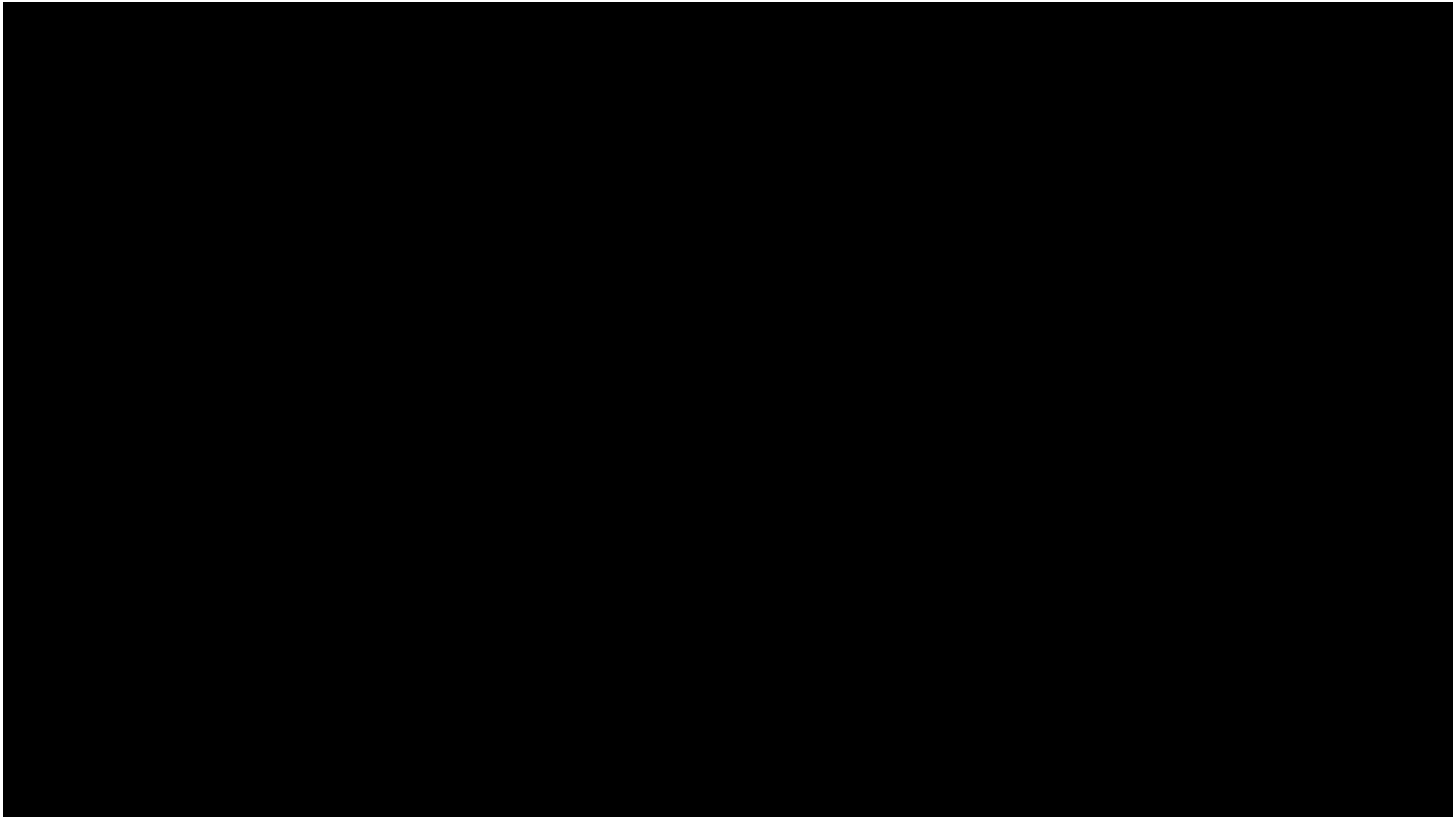
(f) Back bend

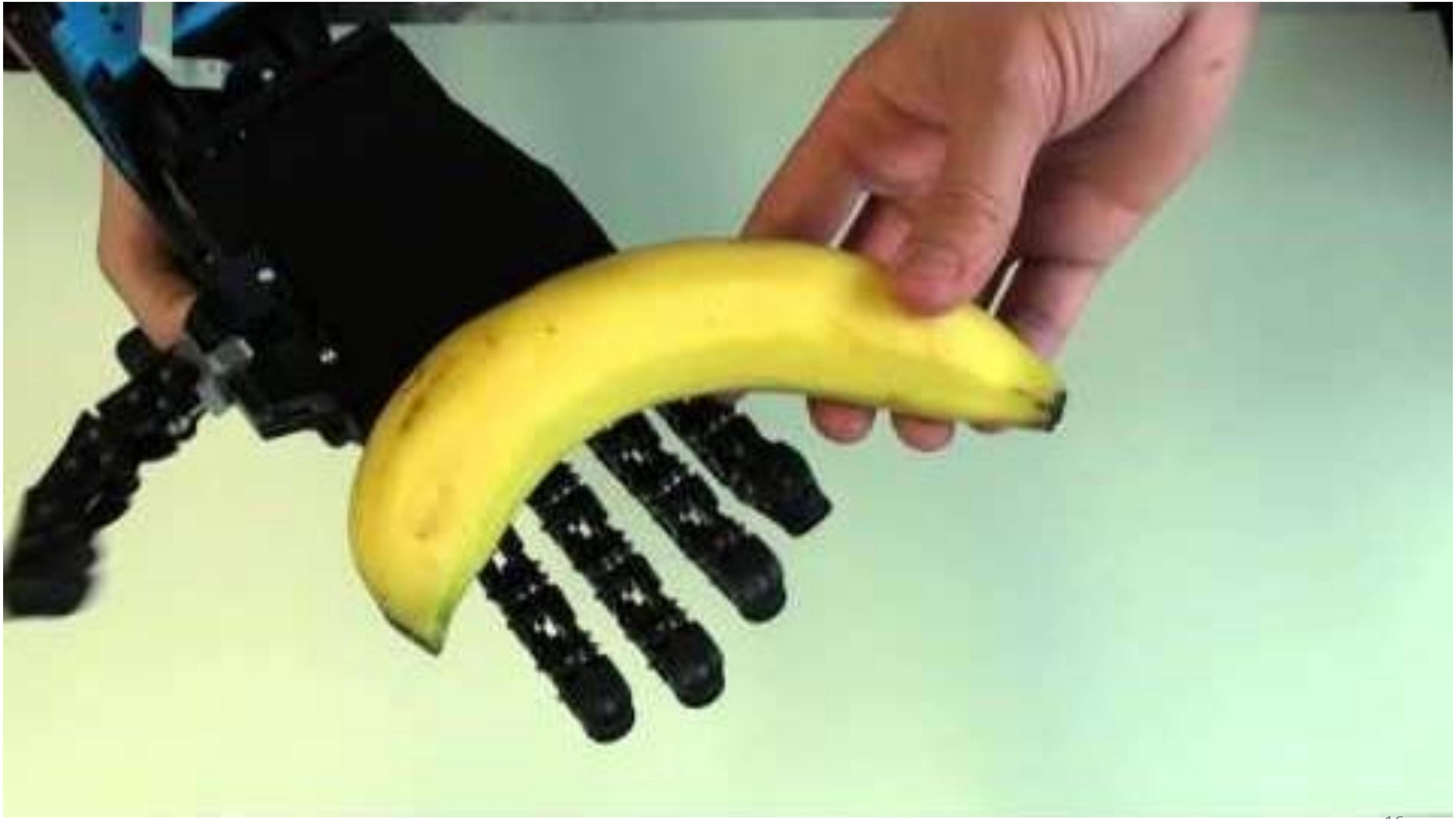


(g) Twist



(h) Skew bend



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(a) Cube Grasp

(b) Bottle Grasp

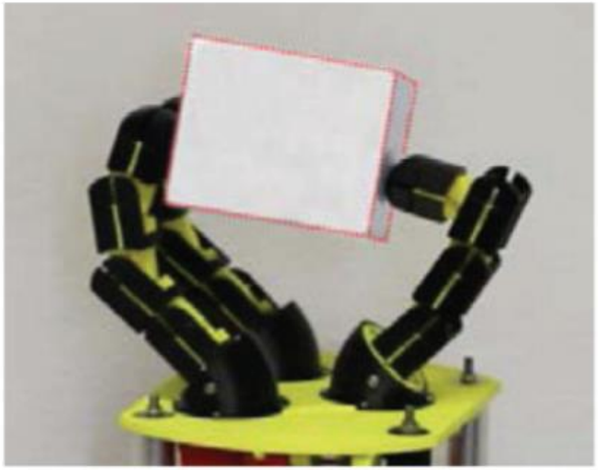
(c) Reel Grasp

(d) Pincer Grasp

(e) Stapler Grasp

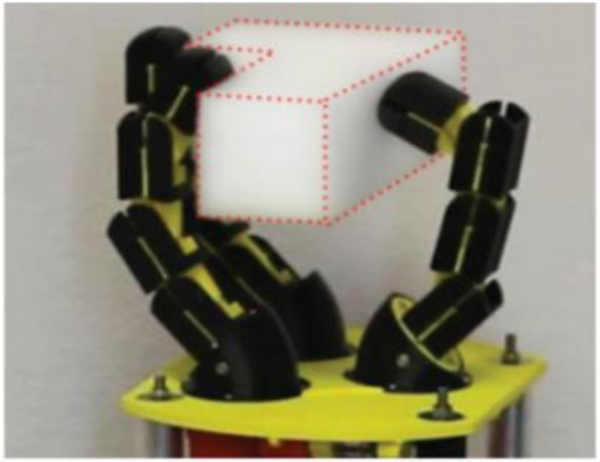
Max Holding Force: 20N

(a)



(b)

(c)



(d)

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Towards Dexterous Manipulation with Augmented Adaptive Synergies: the Pisa/IIT SoftHand 2

Cosimo Della Santina[1], Cristina Piazza[1], Giorgio Grioli[2],
Manuel G. Catalano[2] and Antonio Bicchi[1,2]

1 – Centro di Ricerca E. Piaggio – Università di Pisa
2 – Fondazione Istituto Italiano di Tecnologia – SoftBots

Discussion

- Is this hand more useful than a suction cup, parallel plate gripper, or jamming gripper?
- Does applying synergies to hand design make sense? Did it work?
- Is this hand “soft”?