An Adaptive, Humanlike Robot Hand with Selective Interdigitation: Towards Robust Grasping and Dexterous, In-Hand Manipulation

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Workshop: New Challenges in Humanoid Grasping and Manipulation
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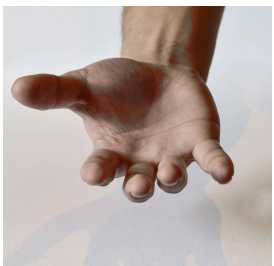
Motivation

Q1: Can we make robot hands dexterous with simple control schemes?

Q2:

Q3:

Q4:



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Q1: Can we make robot hands dexterous with simple control schemes?

Q2: What design and mechanisms will simplify the dexterity of robot hands?

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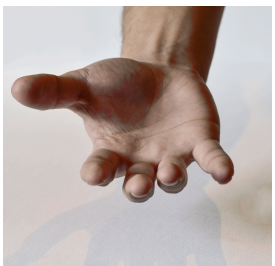

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Q3: Can we offer affordable dexterity?

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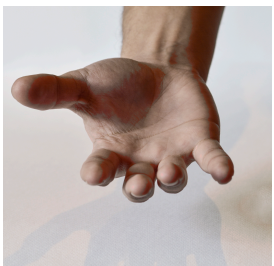
Q3: Can we offer affordable dexterity?

Q4: How bioinspiration by human hand can assist us to achieve our goals?



Hands in Robotics

- **Class 1**: Rigid, fully actuated, multi-fingered hands
  - + Great grasping and manipulation capabilities
  - – Sophisticated sensing elements and complicated control laws
  - – Very expensive
- **Class 2**: Adaptive robot hands
  - + Affordable
  - + Good grasping capabilities even in unstructured environments
  - + Simple control laws (open-loop control)
  - – Limited in-hand manipulation capabilities

DLR/HIT Hand II
[Butterfaß, 2001]

Gifu Hand II
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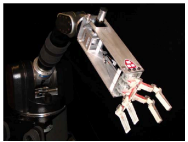

SDM Hand
[Dollar, 2010]

Pisa/IIT SoftHand
[Catalano, 2014]

RBO Hand
[Deimel, 2015]

Adaptive Robot Hands for In-Hand Manipulation

iRobot-Harvard-Yale (iHY) hand

- Non-anthropomorphic design
- 5 actuators - 1.6 actuators/finger
- In-hand manipulation: Object reorientation and finger pivoting

iHY hand
[Odhner, 2014]

Pisa/IIT SoftHand II

- Anthropomorphic design
- 2 actuators - 0.4 actuators/finger
- In-hand manipulation: Rolling of various objects

Pisa/IIT SoftHand II
[Della Santina, 2018]

Actuator Distribution of Adaptive Robot Hand

Q: Given limited number of actuators, which motions should we target to facilitate the robust grasping and dexterous in-hand manipulation with adaptive robot hands?

Facts of human hand:

1. Flexion/extension (F/E) is the dominant motion
2. Metacarpophalangeal joint is one of the most crucial joints (F/E and adduction/abduction (A/A))
3. Thumb is the most significant finger

Actuator Distribution:

1. Actuator 1: F/E of four fingers
2. Actuator 2: A/A of four fingers
3. Actuators 3,4: F/E and opposition of thumb

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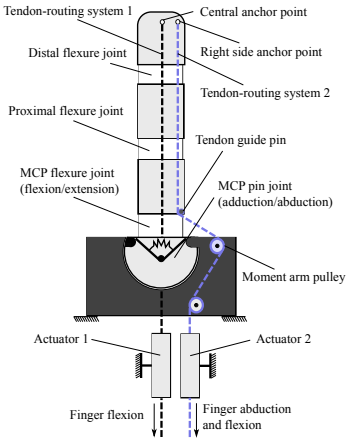
Single Finger Structure[1]

- Metacarpophalangeal (MCP) joint implements:
  - Flexion/extension
  - Adduction/abduction
- **Key idea:**
  - Moment arm pulleys
  - Anchor point on distal phalange $\rightarrow$ enhance force exertion capabilities
- Different position of anchor points and moment arm pulleys produces:
  - Clockwise motion (CW)
  - Counterclockwise motion (CCW)
  - Bidirectional motion

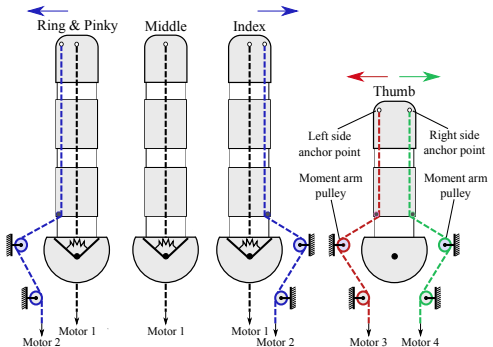


[1] Kontoudis et al., "*An Adaptive Actuation Mechanism for Anthropomorphic Robot Hands*," Frontiers in Robotics and AI, 2019.

Multifinger Structure

Right hand adduction motions

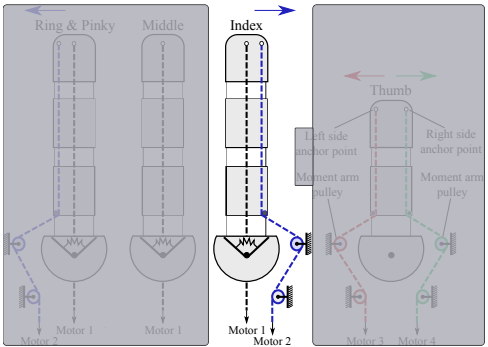
-
-
-
-



Multifinger Structure

Right hand adduction motions

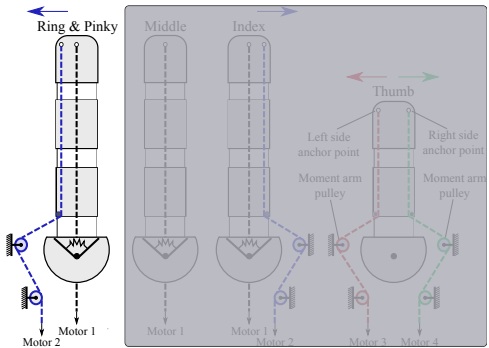
- **CW - index:** right side anchor
-
-
-



Multifinger Structure

Right hand adduction motions

- **CW - index:** right side anchor
- **CCW - ring and pinky:** left side anchor
-
-



Multifinger Structure

Right hand adduction motions

- **CW - index:** right side anchor
- **CCW - ring and pinky:** left side anchor
- **Bidirectional - thumb:** both side anchors
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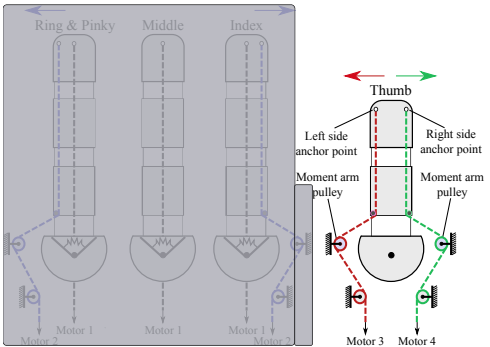
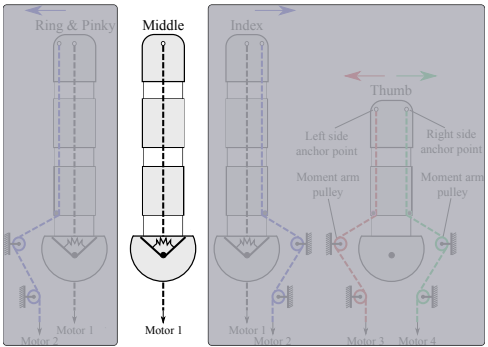


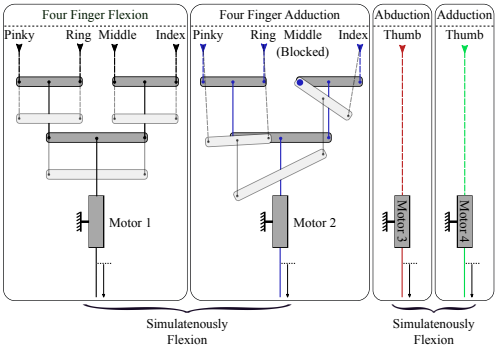
Multifinger Structure

Right hand adduction motions

- **CW - index:** right side anchor
- **CCW - ring and pinky:** left side anchor
- **Bidirectional - thumb:** both side anchors
- **Fixed - middle**

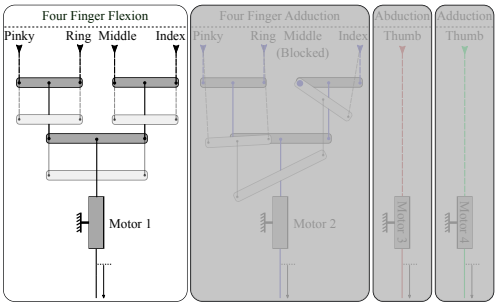


Actuation Scheme



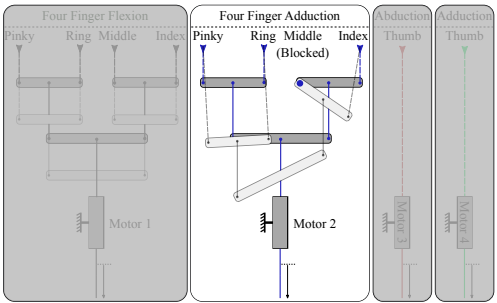
Actuation Scheme

- Differential mechanism for F/E of the four fingers
-
-



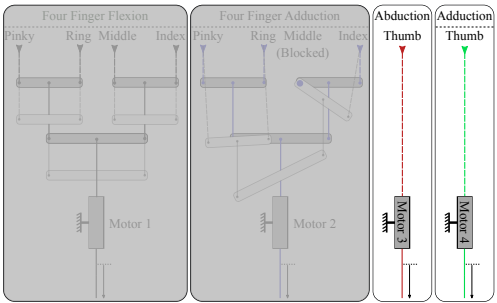
Actuation Scheme

- Differential mechanism for F/E of the four fingers
- Differential mechanism for A/A of the four fingers
-



Actuation Scheme

- Differential mechanism for F/E of the four fingers
- Differential mechanism for A/A of the four fingers
- Individual motors assigned for the adduction and abduction of thumb



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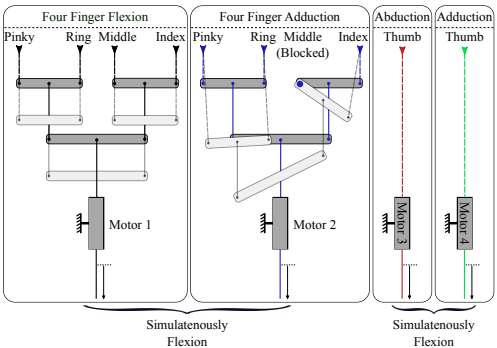
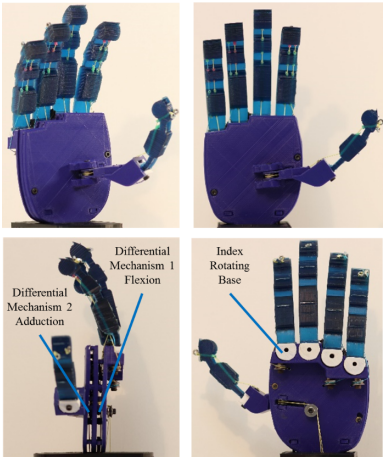


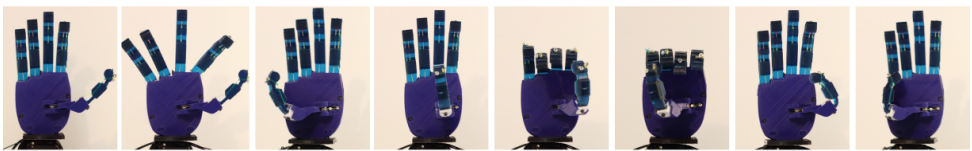
Simultaneous actuation of differential mechanisms
results to flexion at current adduction angle

Adaptive Anthropomorphic Robot Hand

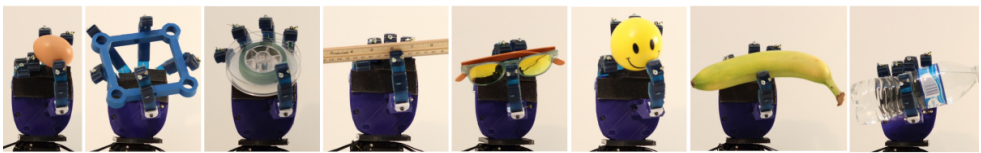
- Dimensions: $L_{\mathrm{H}} = 185$ mm, $B_{\mathrm{H}} = 90$ mm
- Weight: 360 g (net)
- Software: ROS
- Materials: 3D printed ABS, Smooth-On PMC-780
- Availability: Open-source (OpenBionics initiative)



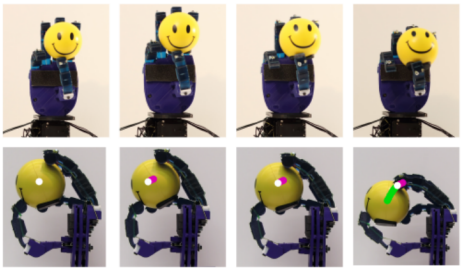
Hand Postures and Gestures



Grapsing of Everyday Life Objects



Equilibrium Point Manipulation



Finger Pivoting and Reorientation

Conclusions and Future Work

Conclusions:

- Design and development of adaptive, anthropomorphic robot hand
- Achieved robust grasping of various everyday life objects
- Performed in-hand manipulation tasks
  - Equilibrium point manipulation
  - Finger pivoting
  - Object reorientation

Future work:

- Employ more sophisticated differential mechanisms for more challenging manipulation tasks (e.g., finger gaiting)
- Development of affordable proprioception for robot hands

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Thank You!