Evaluation Strategies of Adaptive, Anthropomorphic Robot Hand for Dexterous In-Hand Manipulation: Early Results

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Research Interests

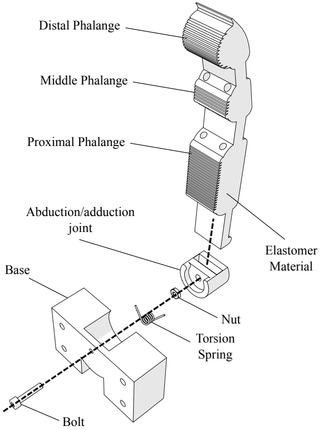
- Design and development of anthropomorphic, adaptive robot hands
- Robust grasping with various everyday life objects
- Dexterous in-hand manipulation
- Model-free continuous time Q-learning
- Manipulation planning based on learning techniques

Objectives

1. Design minimal actuation mechanism to combine various motions
2. Develop an adaptive, anthropomorphic robot hand
3. Employ less number of actuators to reduce complexity, weight, and fabrication cost
4. Facilitate the execution of various grasping tasks
5. Execute complex in-hand manipulation tasks
   - Rolling with a single finger
   - Finger interdigitation
   - Equilibrium point manipulation
   - Finger pivoting
   - Finger gaiting

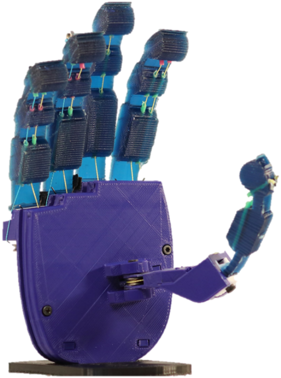
Monolithic Finger Design

- Monolithic finger design
- Portions with reduced width implement flexure joints
- Three phalanges and three joints
- Two individual tendon-routing systems
- Modular design



Adaptive Anthropomorphic Robot Hand

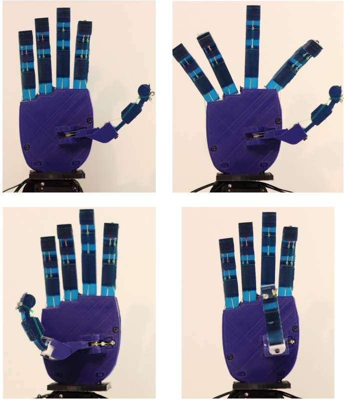
- Based on my hand dimensions
- Exclusively off-the-shelf materials
- Utilized two parallel differential mechanisms
- Employed 4 actuators
- An actuator for finger flexion
- An actuator for finger abduction
- Two actuators for thumb opposition and flexion



Robot Hand Characteristics

Dimensions	HL = 185 mm, HB = 90 mm
Weight	650 gr, with motors
Motors	4 Dynamixel RX-28, 2.8 Nm at 12V
Software	ROS
Materials	3D printed ABS; Smooth-On PMC-780 (urethane rubber)
Availability	Open-source
Cost	$ 1,000
Motions	Thumb: CW & CCW A/A, F/E; Index: CW A/A, F/E; Middle: F/E; Ring: CCW A/A, F/E; Pinky: CCW A/A, F/E

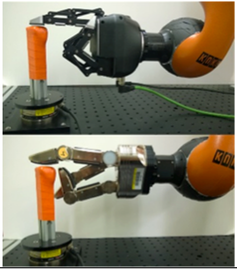
Hand Configurations

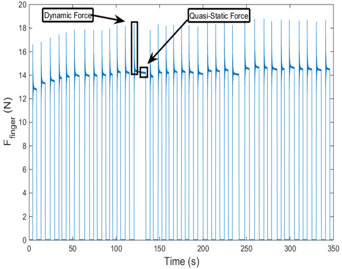


Finger Strength

Definition: Finger strength is a kinetic measure of the maximum force a robotic finger can impose on its environment[1].

- Gather the finger force exertion capabilities
- Employ either a three-axis or a single-axis load cell





[1] From NIST document: `Finger-Stergth-V1-0-2.docx`

Implementation Issues with Adaptive Fingers

- The suggested area above the load cell is too small
- The finger is highly adaptable and slips
- In the document a procedure is described to obtain the maximum finger force
- More interested for the worst case scenario
- For in-hand manipulation other configurations are equally important, i.e. abduction

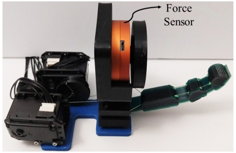
Force Exertion Capabilities

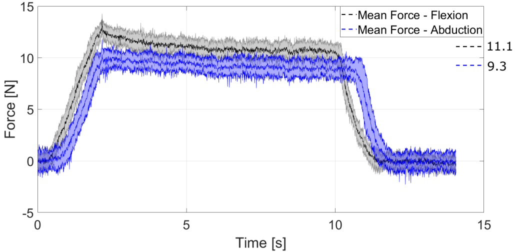
Force experiments

- Used the FSE1001 force sensor (Variense)
- Conducted 30 trials

Results

- Exclusively flexion (black, shaded gray)
- Flexion at maximum abduction angle (blue, shaded blue)
- Force reduction due to friction losses
- Similar force exertion capabilities

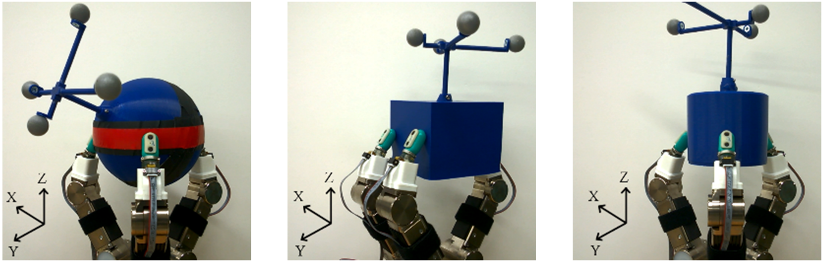




In-Hand Manipulation

Definition: In-hand manipulation is a kinematic measure of how well a robotic hand can control the pose of an object[2].

- Obtain the pose of the object in Cartesian coordinates
- Employ a reference motion capture system (MOCAP)



[2] From NIST document: `Manipulation_v1-0.docx`

Implementation Issues for In-Hand Manipulation

- MOCAP systems are from expensive ($$$$) to very expensive ($$$$$)
- Difficult to attach markers for some tasks that require small objects, e.g, finger pivoting
- The manipulability depends on the object shape and size, e.g., finger gaiting
- Bounds of in-hand manipulation is another measure, e.g., object rolling
- Palm exploitation may assist the manipulation task

In-Hand Manipulation Approach

Suggested Solution:

- Employ a Kinect camera (or similar RGB-D) with simple markers for small objects
- Embed IMU or 3-axis gyroscope sensors to the larger objects

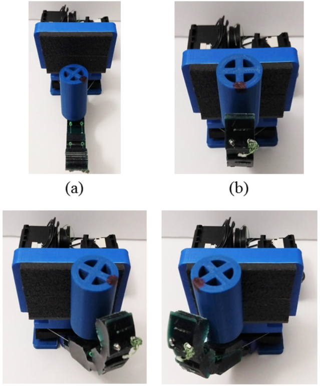
Manipulation measures:

- Equilibrium point manipulation [mm] - Translation and rotation; without regrasping
- Object rolling [degrees] - Rotation and translation; without regrasping
- Object rotation [degrees] - Rotation; without regrasping
- Object sliding [mm] - Translation; with external finger or exploit environment
- Finger pivoting [degrees] - Rotation; with external finger or exploit environment
- Finger Gaiting [contacts/rotation] - Rotation; with regrasping

Finger Gaiting

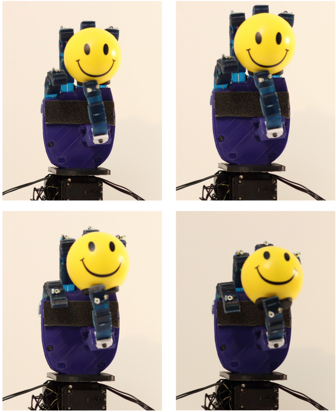
- Shape of the object is critical
  - Objects with flat surfaces are the easier objects
  - Cylindrical objects are more challenging
  - Spheres are the most difficult objects to gait
- Palm exploitation simplifies the task
- Object compliance is important
- Highly deformable objects are easier to gait

Object Rolling with a Single Finger



(a) (b) (c) (d)

Equilibrium Point Manipulation



Conclusions

- The NIST grasping metrics is a very good initiative and can be really useful
- Can be improved in the sense of:
  - More affordable
  - Provide assembly guide with at least:
    1. BoM with representative links of vendor
    2. Drawings, if not CAD files
    3. Assembly guide
- Provide post-experiment software
- Create a repository towards creating a dataset from various labs or companies

Proud to use LaTeX and Beamer

Thank You!