IEEE Standards Study Group:

Standard Metrics and Test Methods for Assessing the Performance of Grasping-Type Robot End-Effectors

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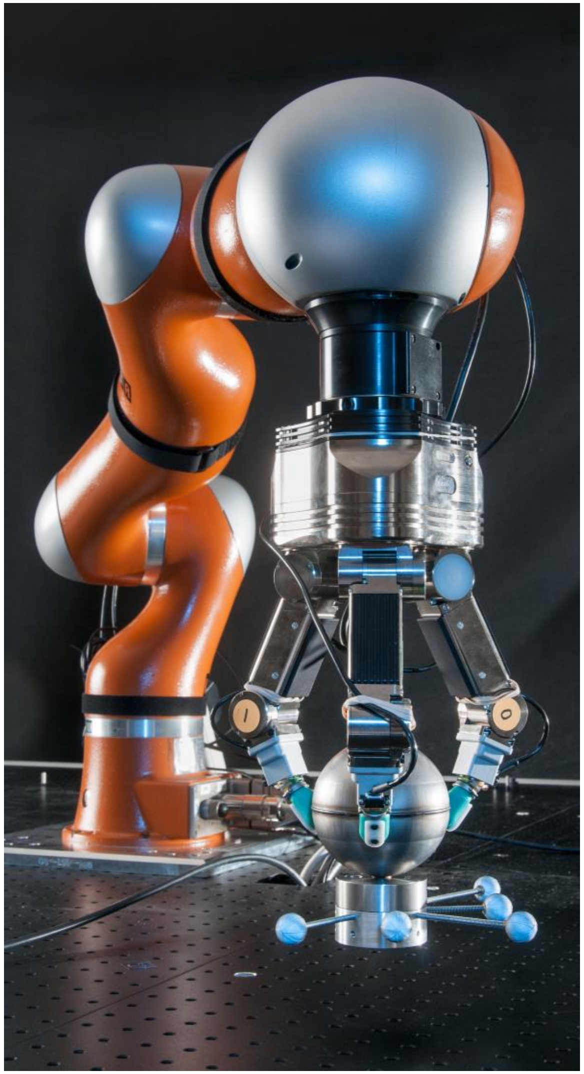
Agenda

- Introductions
- IEEE Study Group – Step 1: Project Authorization Request (PAR).
- NIST– Performance Metrics and Test Methods for Robotic Hands (Joe)
- Round Robin Testing and Test Resources (Adam)
- Discussion: Approach for developing this standard
- Future Grasping and Manipulation Standards Efforts (Berk, Kenny)

IEEE Standards Study Group: **Standard Metrics and Test Methods for Assessing the Performance of Grasping-Type Robot End-Effectors**

Goal: A unified set of metrics and performance tests that the robotics community will use to help advance robot grasp type end-effector technologies through standardized benchmarking with the longer-term use as a standard specification to define the characteristics of commercially available end-effector technologies.

Scope: This standard contains a series of metrics and supporting test methods to perform a characterization of grasping type robot end-effectors. Developing these characterizations will guide in the selection of appropriate designs to support an application and will help to direct research and development advancements. Each test method describes the test setup, artifacts, measurements, and guidance for analysis of the measurements. The metrics provide a common language for comparing different designs and will strengthen the development, and deployment of more-capable grasping-type robot end-effectors toward increasing the flexibility and general-purpose applicability of robots.



URL: https://www.nist.gov/el/intelligent-systems-division-73500/robotic-grasping-and-manipulation-assembly/standards-efforts

Grasping and Manipulation Benchmarks

- Why robotic hands?
- Problem
  - What makes a ‘good’ hand/gripper?
  - Informing consumers
- Goal
  - Feedback for R&D, benchmarking
  - Technical specifications
- Mechanism
  - Metrics and test methods
  - Artifacts and datasets
  - Data analysis guidance




NIST Proposed Metrics and Test Methods

DRAFT **NIST Special Publication 1227**

Performance Metrics and Test Methods for Robotic Hands

Joe Falco
Karl Van Wyk
Elena Messina
Intelligent Systems Division
Engineering Laboratory

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.1227-draft

October 2018

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Undersecretary of Commerce for Standards and Technology

DRAFT **NIST Special Publication 1229**

Proposed Standard Terminology for Robotic Hands and Associated Performance Metrics

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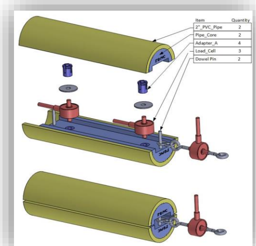
See: https://www.nist.gov/el/intelligent-systems-division-73500/robotic-grasping-and-manipulation-assembly/publications

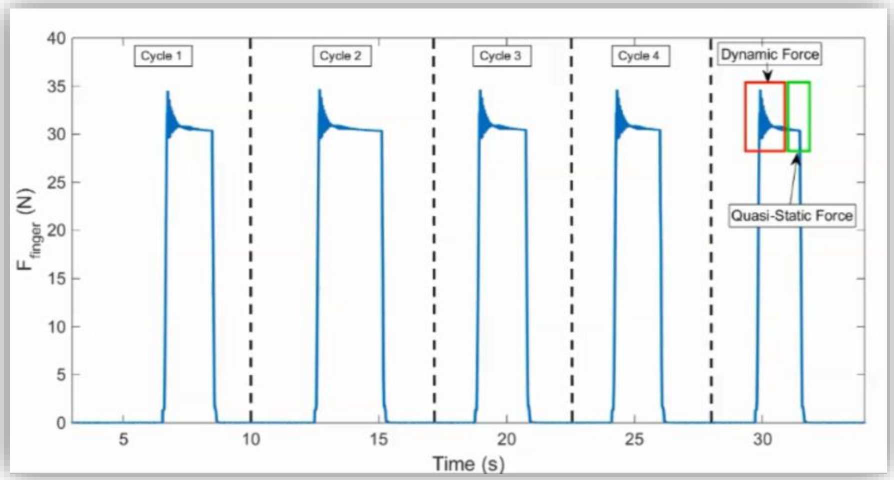
Elemental Performance Measures

Test Method	Example Measurement Instrument
Finger Strength Touch Sensitivity Finger Force Tracking Force Calibration	
Finger Repeatability	
Grasp Strength Slip Resistance Grasp Efficiency Cycle Time	
In-Hand Manipulation Object Pose Estimation	

http://www.nist.gov/el/isd/grasp.cfm

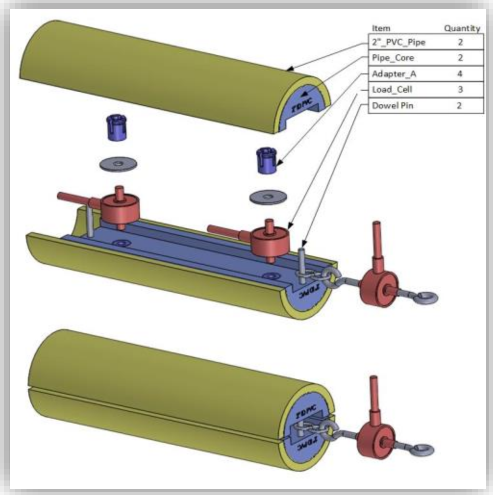
Finger Strength

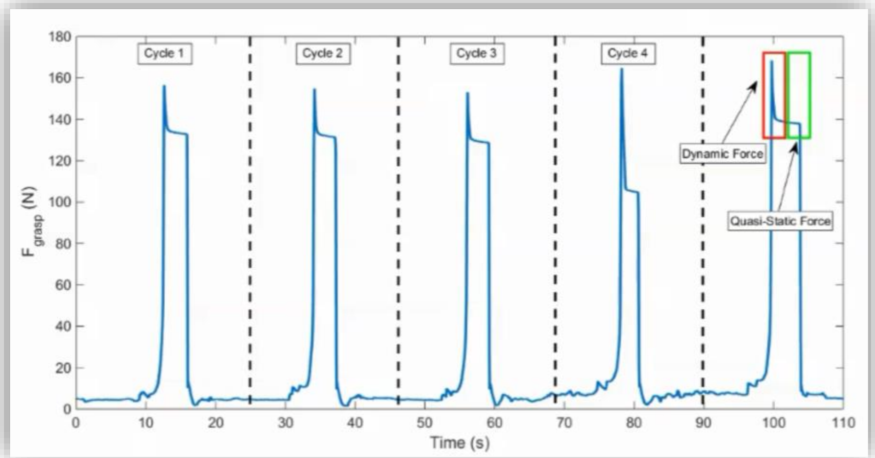
- What: Maximum force a robotic finger can impose on its environment
- How: Measure peak quasi-static forces with load cell at full finger extension
- Why: Strength across fingers can vary, weakest at full extension, positively correlated with payload, guide control



Grasp Strength

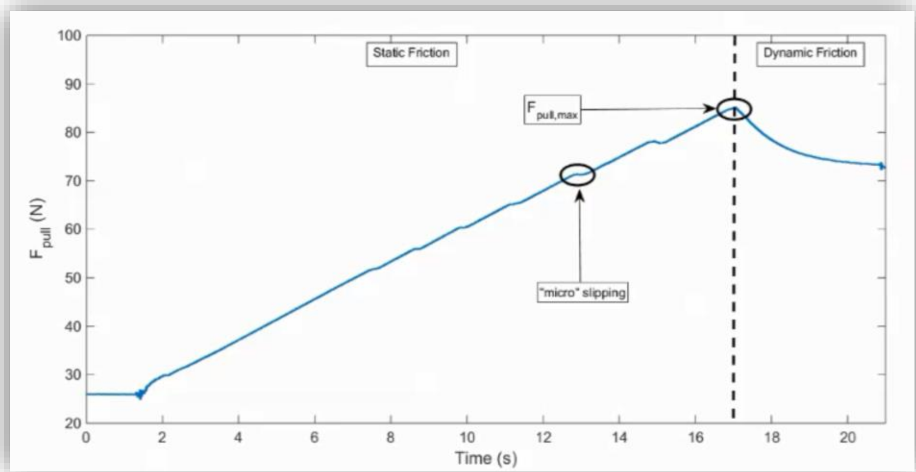
- <u>What:</u> The maximum force a robotic hand can impose on an object
- <u>How:</u> Artifact with intrinsic force sensing
- <u>Why:</u> Estimate payload

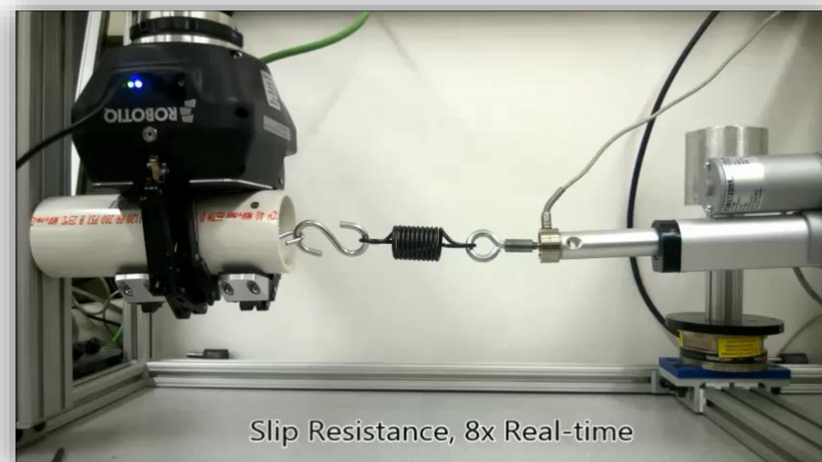




Slip Resistance

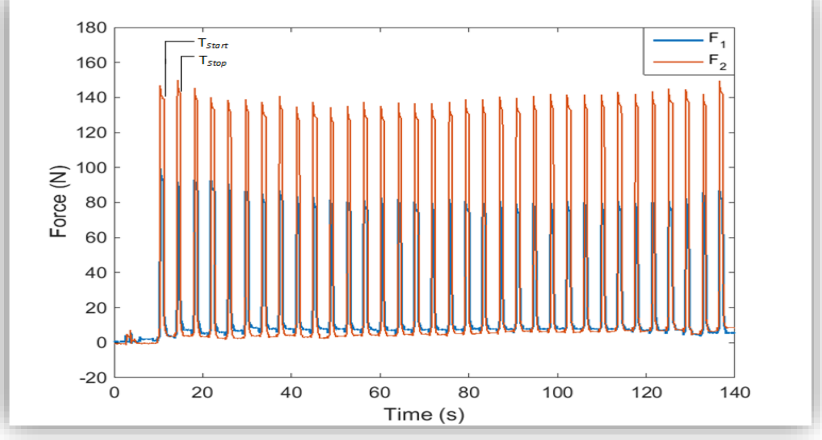
- What: Maximum force hand can sustain in shear
- How: Measure peak force at the onset of gross slipping
- Why: Indicator of minimum payload, indicator of whole-hand friction coefficient, safer to test





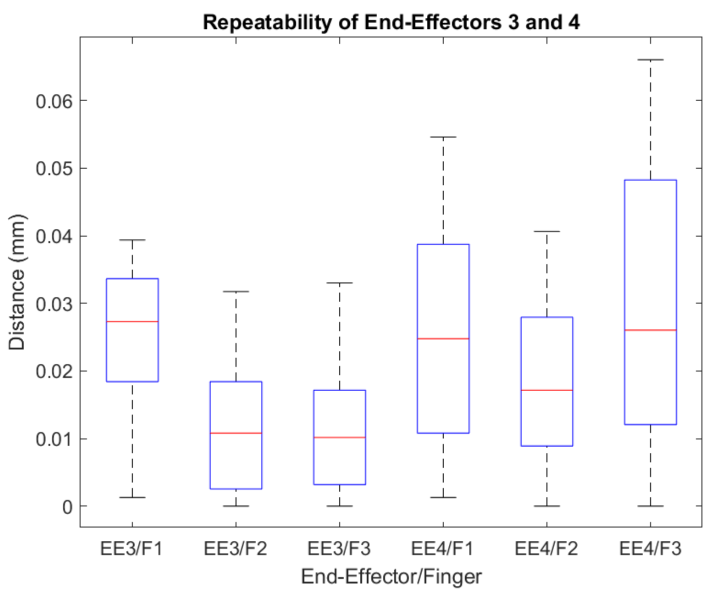
Cycle Time

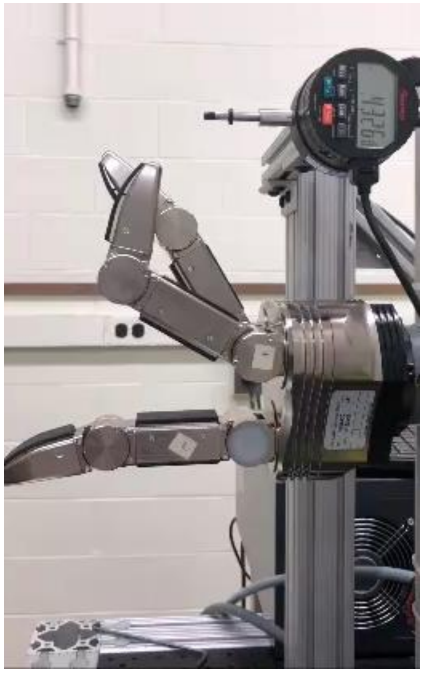
- What: A measure of the minimum time required for a robotic hand to cycle from pre-grasp, to grasp, to pre-grasp
- How: Requires two consecutive cycles with a force sensing object artifact
- Why: estimating productivity, guide controllers and planners



Finger Repeatability

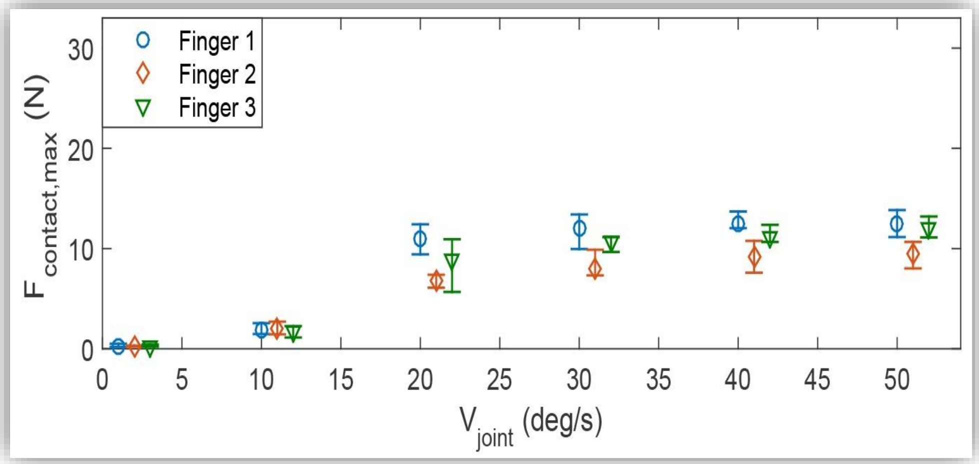
- <u>What:</u> A measure of the difference in pose results when a finger is commanded to a position multiple times from the same direction
- <u>How:</u> Requires two consecutive cycles with a force sensing object artifact
- <u>Why:</u> Ability to re-establish pose

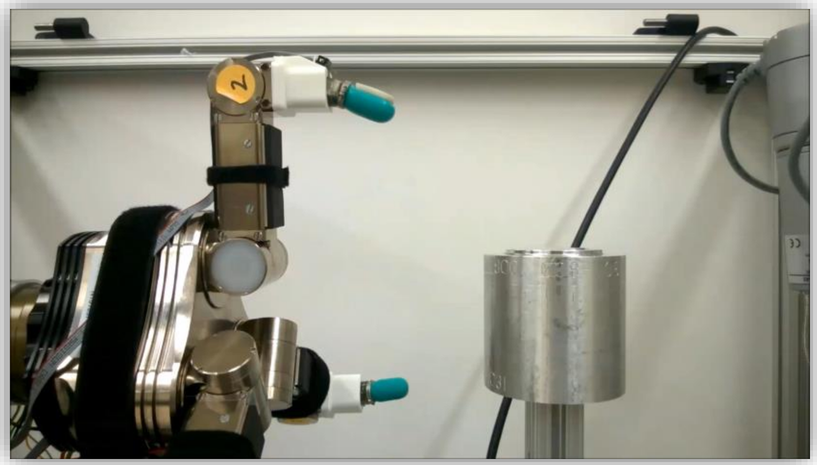




Touch Sensitivity

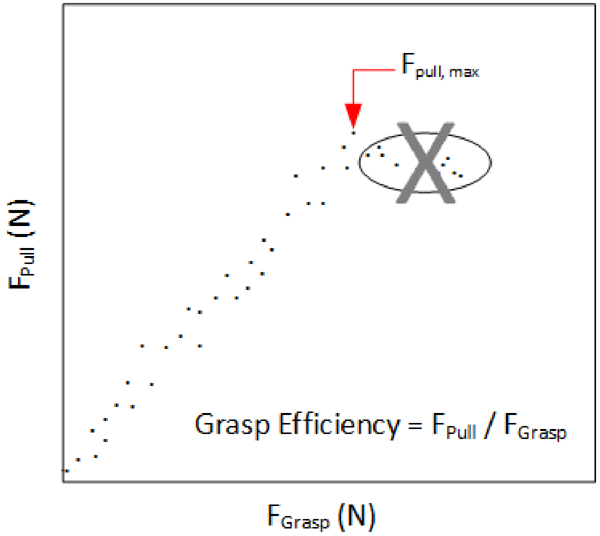
- What: A measure of the smallest, self-registered contact force exerted by a robotic finger on an object
- How: Measure maximum impact force at full finger extension at various joint speeds
- Why: Force dependent on speed, force maximized at full extension, minimize disturbance during object acquisition

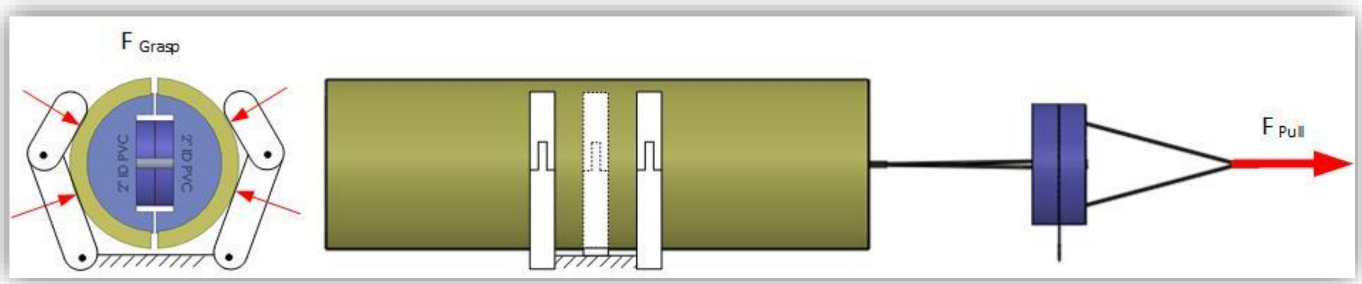




Grasp Efficiency

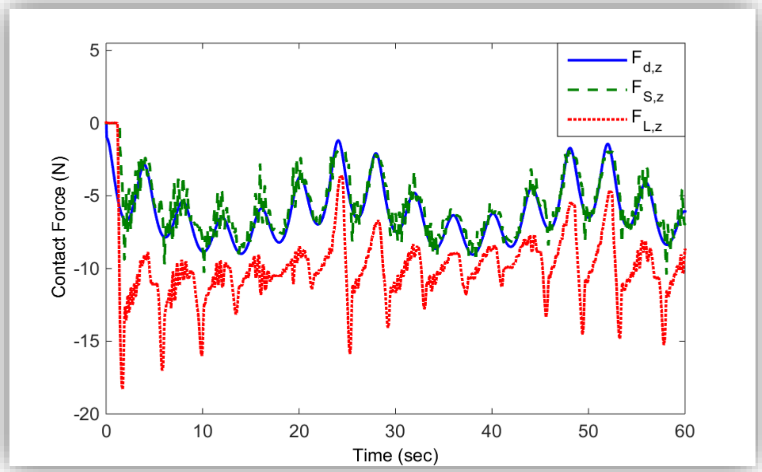
- What: Ability to force-modulate grasp with increasing object disturbance
- How: Computed at each data point collected from initial grasp force until maximum pull force (gross slipping)
- Why: Automated grasping efficiency, minimize power consumption, minimize wear-and-tear





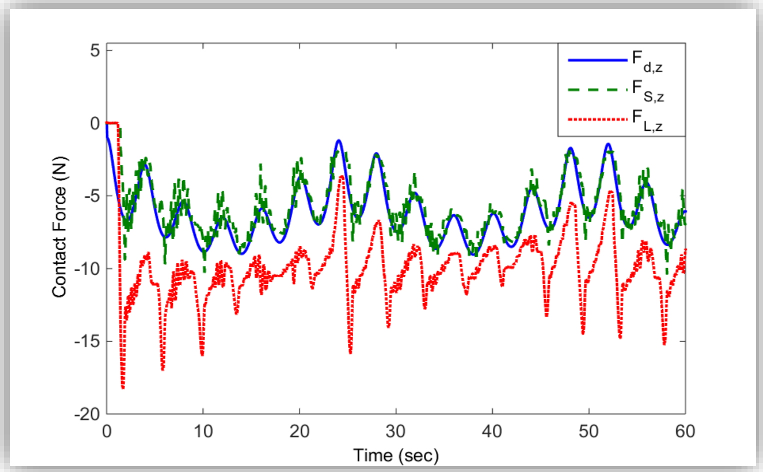
Finger Force Tracking

- What: Finger ability to impose desired contact forces on its environment
- How: Measure disparity between hand-reported forces and reference force-torque transducer
- Why: Prerequisite for force-modulated grasping and manipulation



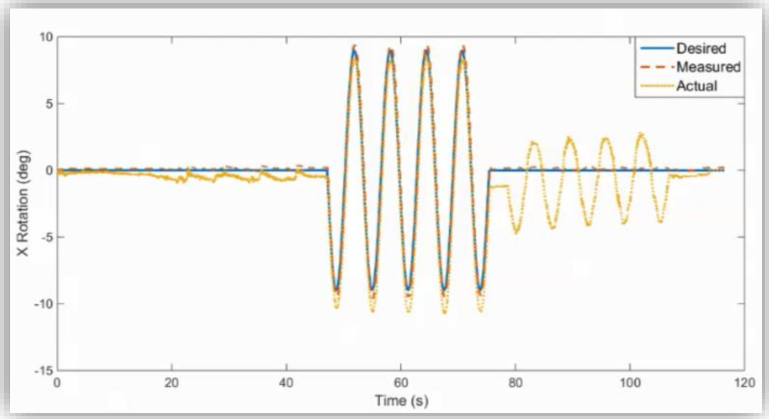
Force Calibration

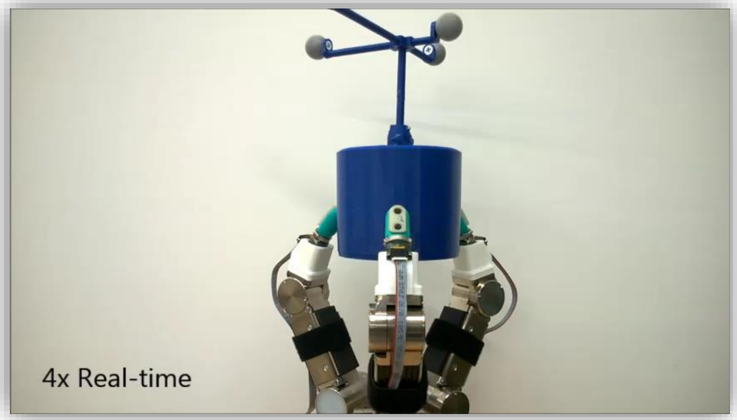
- What: Quantifying force calibration accuracy of onboard tactile sensing
- How: Coupled with finger force tracking test
- Why: Non-removable force sensors, force accuracy often not reported/available, impacts force control strategies



In-Hand Manipulation

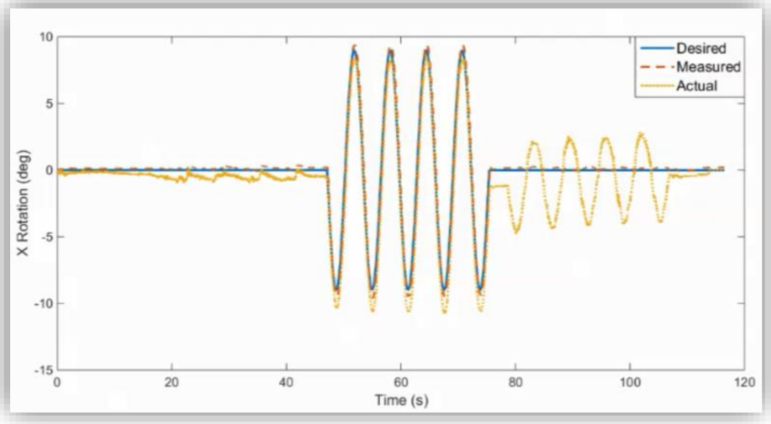
- What: Measure of a robotic hand's ability to control the pose of an object
- How: MoCap system and objects with optical targets
- Why: Quantifies range-of-motion, frequency response, controller accuracy and repeatability, useful for functional-level tasks

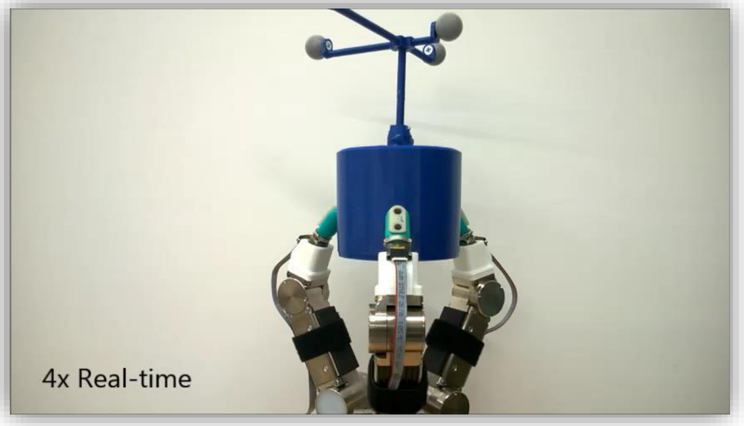




Object Pose Estimation

- What: Measure a robotic hand's ability to estimate the pose of an object (contact or non-contact)
- How: MoCap system and objects with optical targets
- Why: Object pose information can inform task-level operations, objects can move within grasps, visual occlusion





Publications

- J. Falco, D. Hemphill, K. Kimble, E. Messina, A. Norton, R. Ropelato, H. Yanko, “Benchmarking Protocols for Evaluating Grasp Strength, Grasp Cycle Time, Finger Strength, and Finger Repeatability of Robot End-effectors”, IEEE RA-L Special Issue on Benchmarking Protocols in Robotic Manipulation (2020).
- J. Falco, K. Van Wyk, E. Messina, Performance Metrics and Test Methods for Robotic Hands, NIST Special Publication 1227, Oct 2018
- J. Falco, K. Van Wyk, E. Messina, Terminology for Robotic Hands and Associated Performance Metrics, NIST Special Publication 1229, Oct 2018
- J. Falco, K. Van Wyk, S. Liu, S. Carpin, “Robotic Grasping: Facilitating Replicable Performance Measures via Benchmarking and Standardized Methodologies”, *IEEE Robotics and Automation Magazine*, December 2015.
- Stefano Carpin, Shu Liu, Joe Falco, Karl Van Wyk, “Multi-Fingered Robotic Grasping: A Primer,” *arXiv* 1607.06620, online.

Discussion

- Suggestions for additional performance measures / test methods - ongoing
- Start the effort by choosing three existing performance measures
- For each, review suggested revisions to date (rhgm feedback) including implementation by papers that reference NIST work.