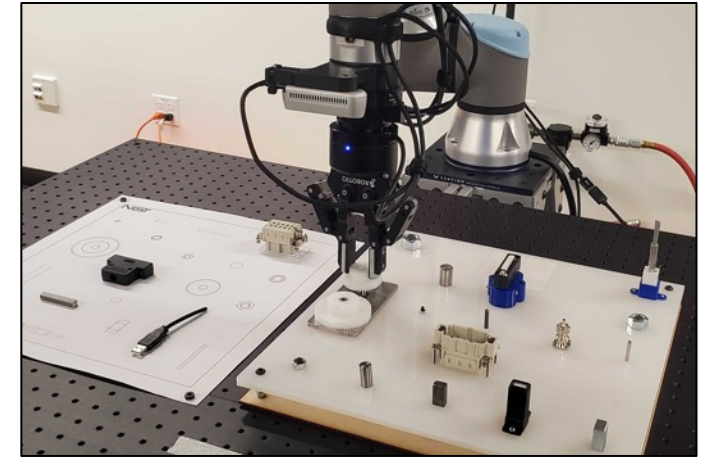
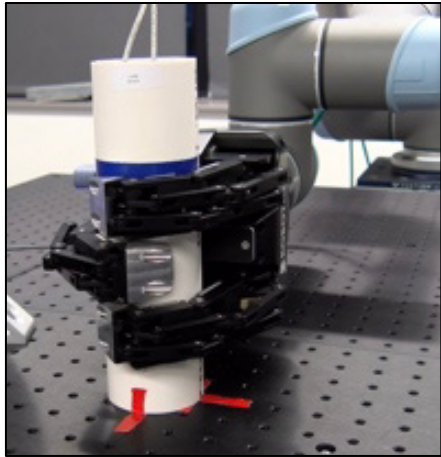


Development and Validation of Robotic Grasping and Manipulation Test Methods



Adam Norton, Associate Director

University Of Massachusetts Lowell

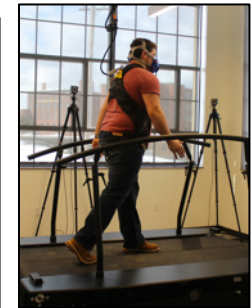
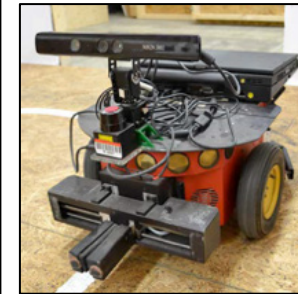
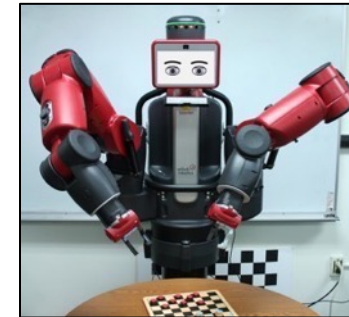
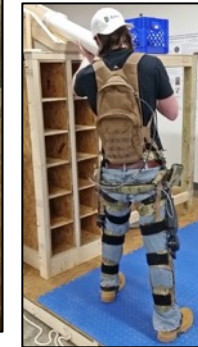
New England Robotics Validation And Experimentation (NERVE) Center

adam_norton@uml.edu

University of Massachusetts Lowell

New England Robotics Validation and Experimentation (NERVE) Center

- The NERVE Center is an interdisciplinary robotics testing, research, and training facility that evaluates robot capabilities, human performance, and human-robot interaction.
- Our mission is to improve the development of robot systems by enabling evaluation across many domains including industrial automation, exoskeletons and wearable robots, and disaster response.
- Test and evaluation services are available on-site, in the field, and remotely; we can provide test apparatuses, sensors, data collection, personnel, logistics, and analysis.
- We participate in the development of consensus standards through ASTM: E54.09 response robots, F45 industrial mobile vehicles, F48 exoskeletons and exosuits.
- **Director:** Holly Yanco
- **Associate Director:** Adam Norton
- **Affiliated Faculty:**
 - Biomedical Engineering: Bryan Buchholz
 - Computer Science: Reza Ahmadzadeh, Holly Yanco
 - Electrical and Computer Engineering: Yan Luo, Paul Robinette, Jay Weitzen, Thanuka Wickramaratne
 - Mechanical Engineering: Yan Gu, Murat Inalpolat, Kshitij Jerath, Kelilah Wolkowicz
 - Physical Therapy and Kinesiology: Pei-Chun Kao, Alexandre Lopes, Yi-Ning Wu
 - Plastics Engineering: Ramaswamy Nagarajan



ARMada Industrial Manipulator Testbed



Omron LD90



ABB YuMi



Agility Robotics
Digit



Fetch Mobile
Manipulator



Kinova Gen3



Kinova JACO²



KUKA LBR iiwa



Rethink Robotics
Sawyer



Universal Robots
UR5e



Yaskawa Motoman
GP7



Omron TM700



OnRobot RG2-FT



Rethink Robotics
Vacuum Gripper



RightHand
Robotics ReFlex
Takktile 2



Robotiq Epick



Robotiq 2-Finger
Adaptive Gripper



Robotiq 3-Finger
Adaptive
Gripper



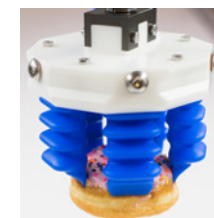
SAKE EZGripper
Gen2



Schunk 2-Finger
Grippers



Schunk 3-Finger
Grippers



Soft Robotics
Gripper



Vaccon
Vacuum
Grippers



Wonik
Robotics
Allegro Hand



Cognex Camera



Asus Xtion Pro



Intel RealSense



OptiTrack V120: Trio



OptiTrack Prime 17w



ATI 6-axis
F/T Sensor



Robotiq F/T
Sensor



OptoForce OMD-
20-SE-40N



Fusion3 F410

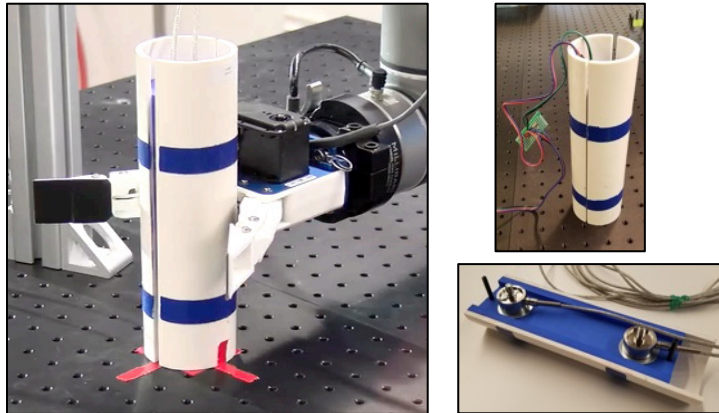


Computer Stations

Manipulation Test Methods, Benchmarks, and Metrics

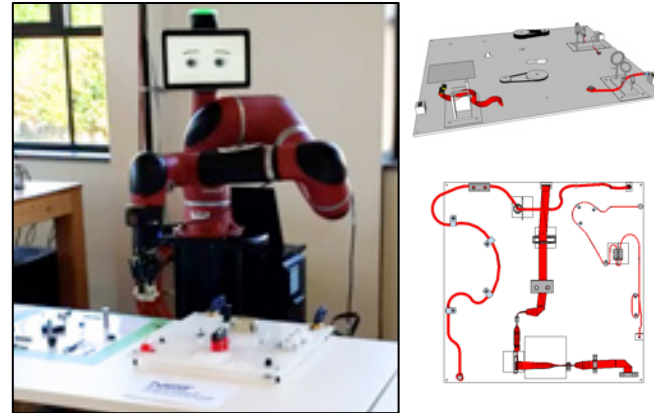


Grasping



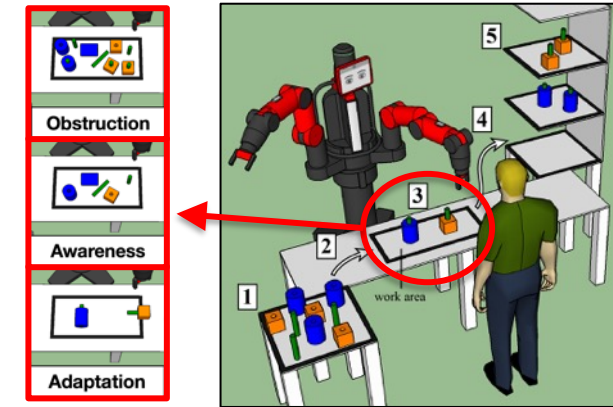
Grasp and finger performance test methods
SAKE Robotics EZ Gripper

Assembly



Manufacturing assembly task boards
Rethink Robotics Sawyer with Robotiq 2-finger

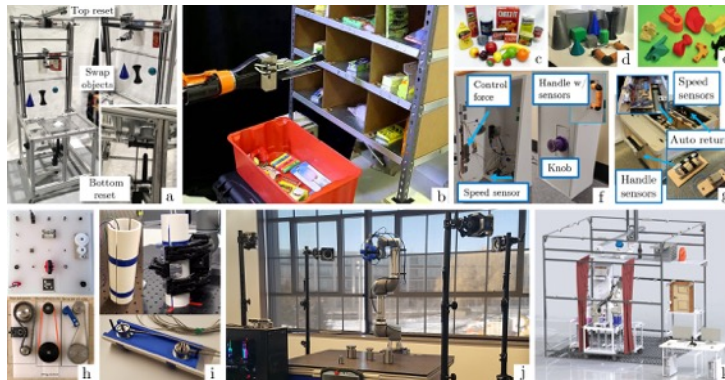
Collaboration



Example HRC scenario: artifact assembly, handoff between agents, transfer, organization



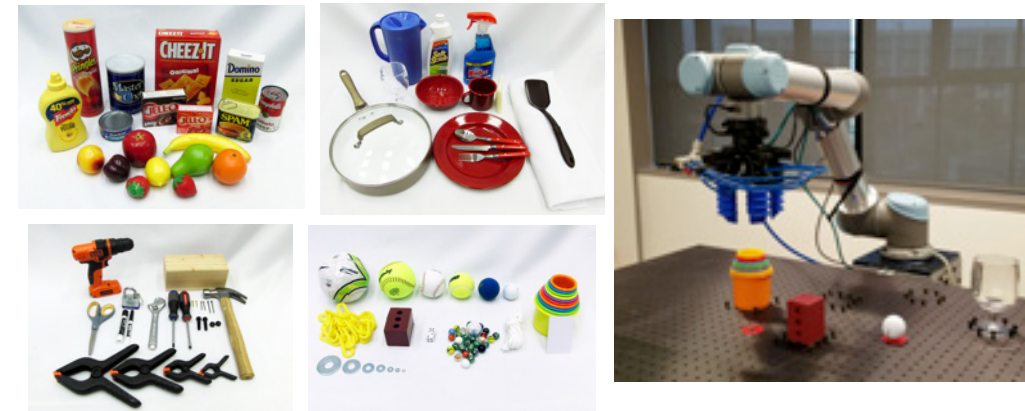
Oregon State University



Remote Experimentation of Manipulation for Online Test and Evaluation (REMOTE)

YCB Object and Model Set

Common objects used for manipulation research

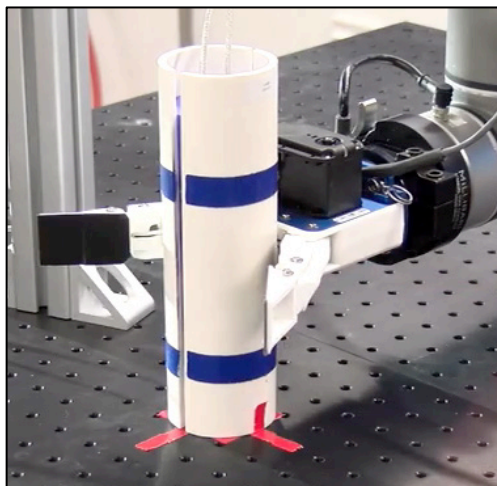


<http://nerve.uml.edu>



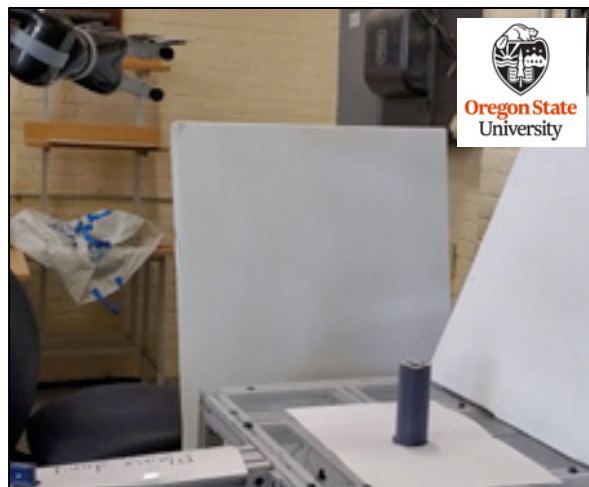
Manipulation Test Methods, Benchmarks, and Metrics

End Effector Capabilities



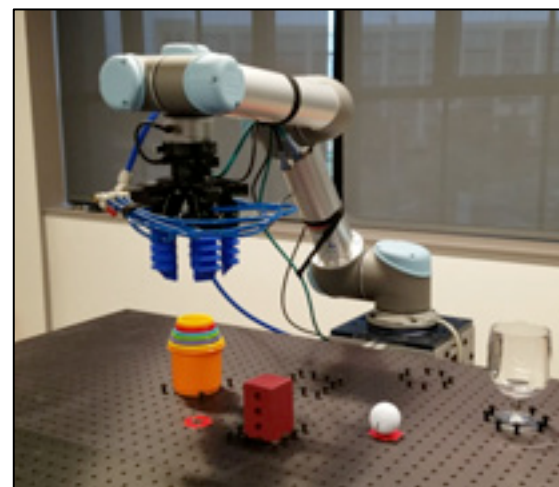
NIST Split Cylinder Artifact

Object Grasping



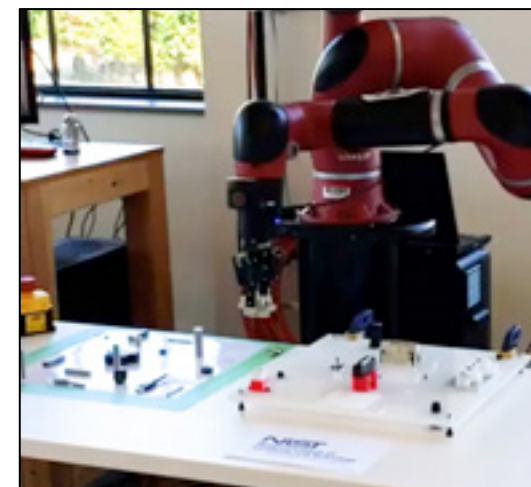
OSU Grasp Reset Mechanism

Object Manipulation



YCB Object Set

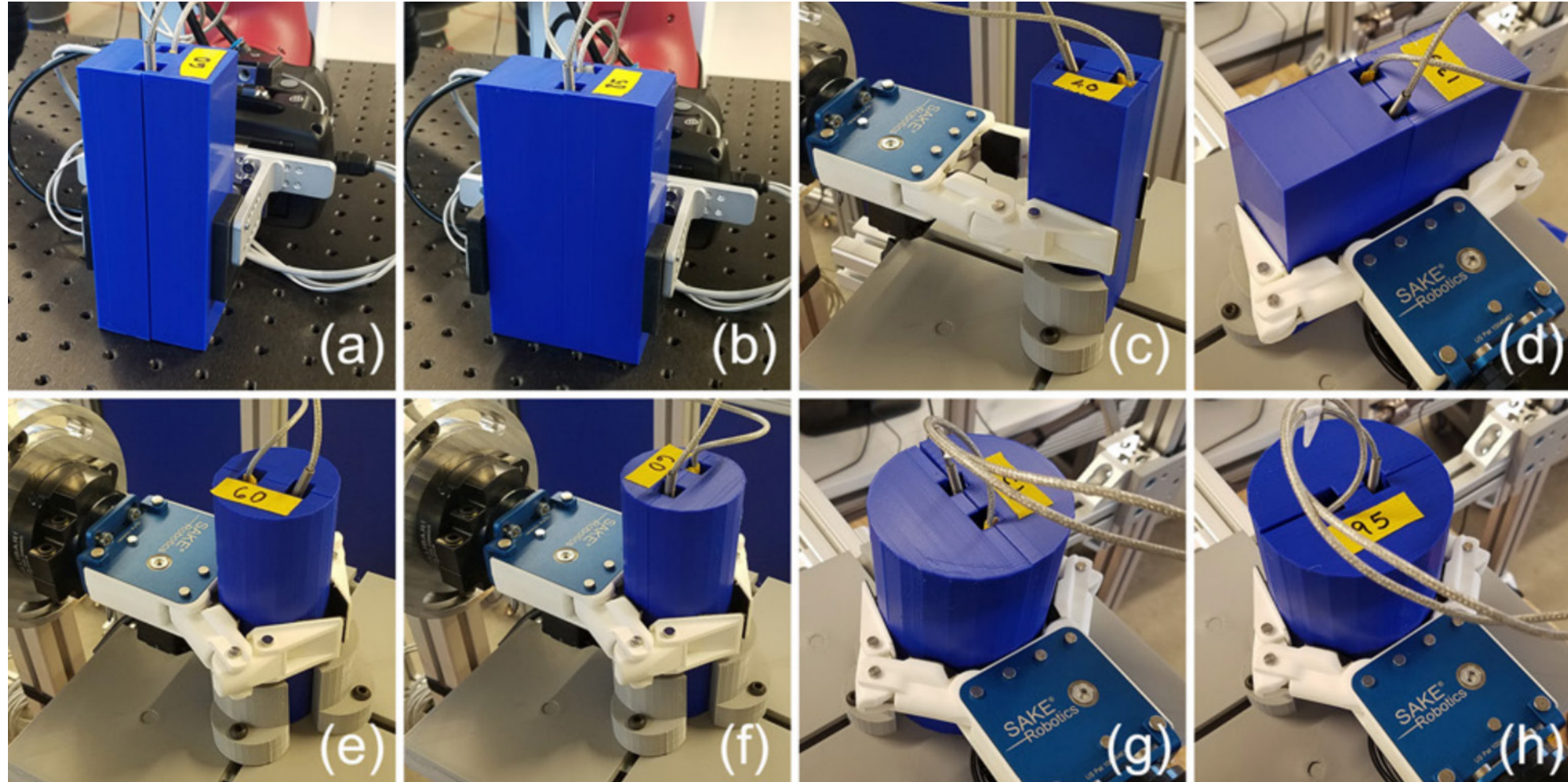
Fine Object Manipulation



NIST Assembly Task Board

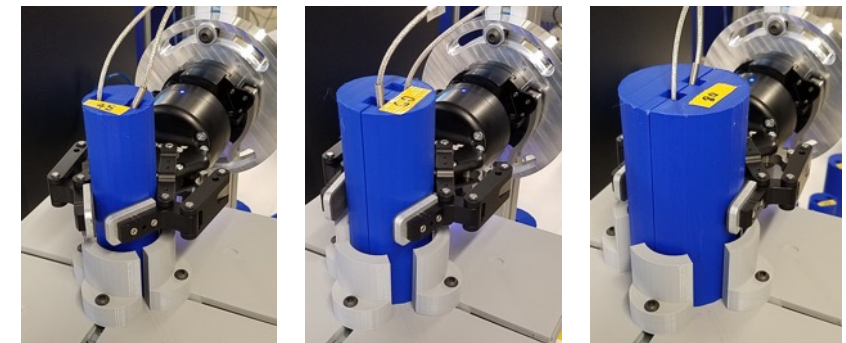
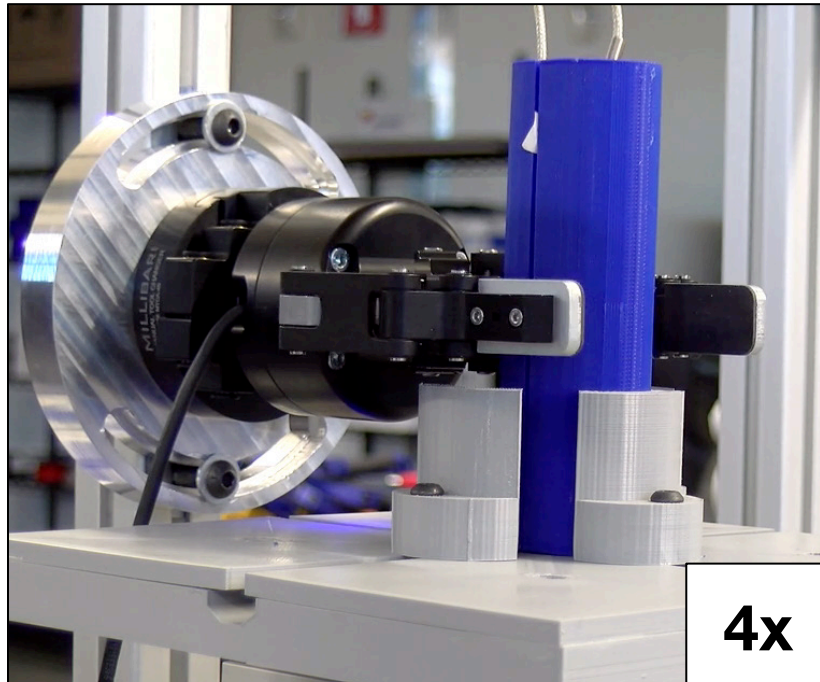
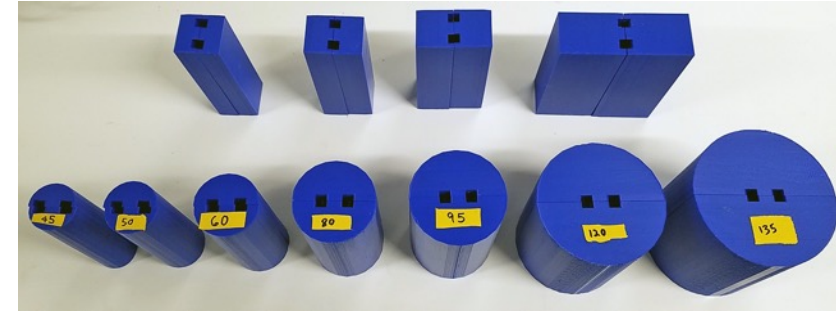
Complexity

Grasp Strength and Grasp Cycle Time

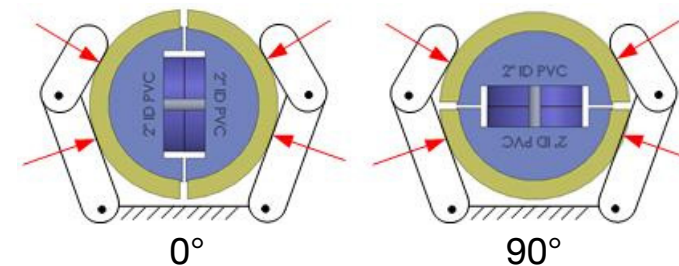


Grasp Strength and Grasp Cycle Time

- Split cylinder or split block artifacts
 - Encompassing/wrap grasps (cylinder artifact)
 - Pinch grasps (block artifact)
- Orientations of grasping forces: 0° or 90°

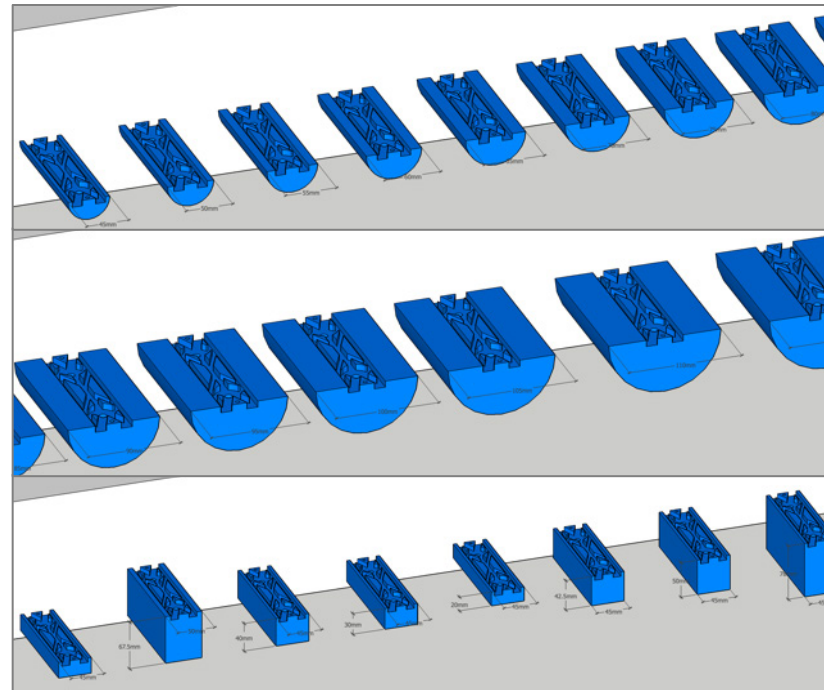


Minimum, median, and maximum grasp sizes



Grasp Strength and Grasp Cycle Time

- Resources:
 - 3D models for artifact cores, versions for dimensions every 5mm
 - Software tools for extracting quasi-static force readings for grasp strength
 - Software tools for extracting grasp cycle time in progress



<https://tinyurl.com/UML-NIST-Manip-Bench>

YCB Object and Model Set

Common objects used for grasping and manipulation research; ~200 kits distributed internationally to date



UPDATES

Object ID 6, Master Chef coffee can



Old



New

Object ID 47, Power Drill



Old



New

Object ID 69, Magazine



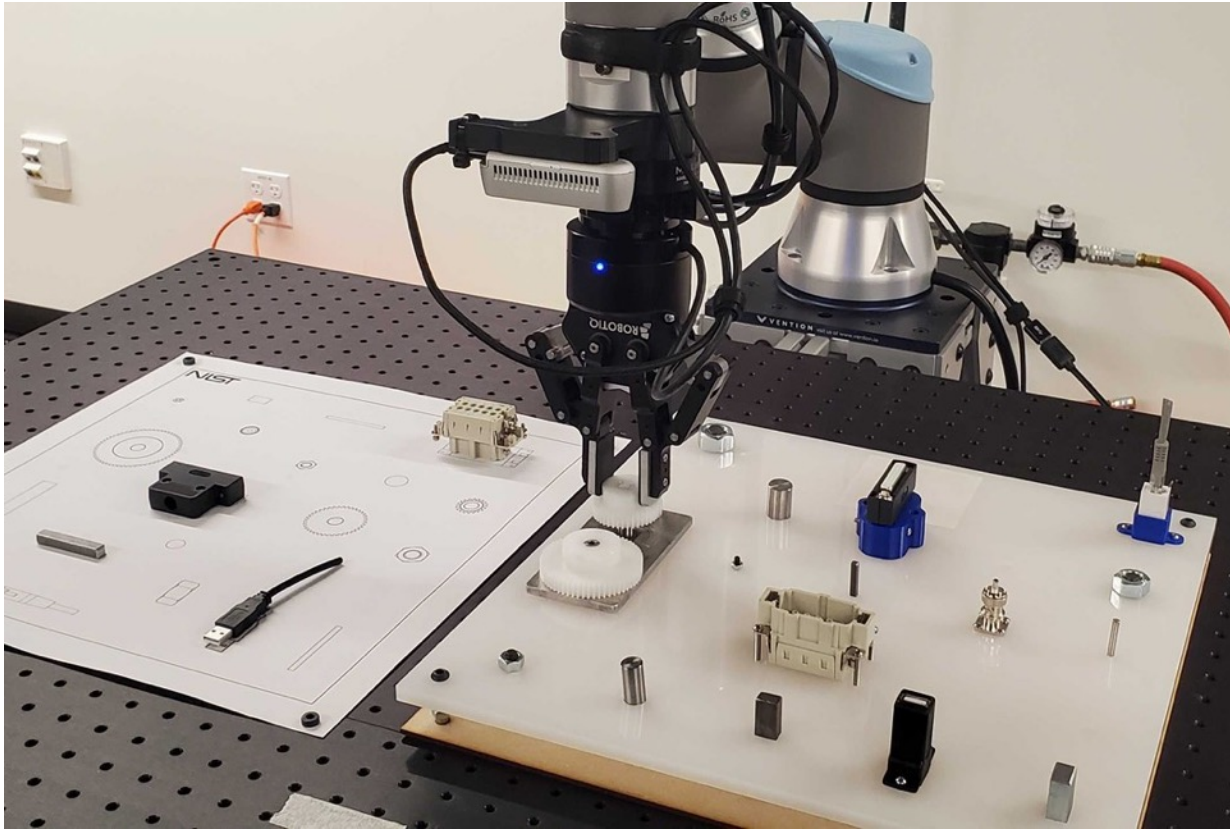
Old



New

More to come!
(unfortunately)

NIST Assembly Task Boards



NIST-ATB #1

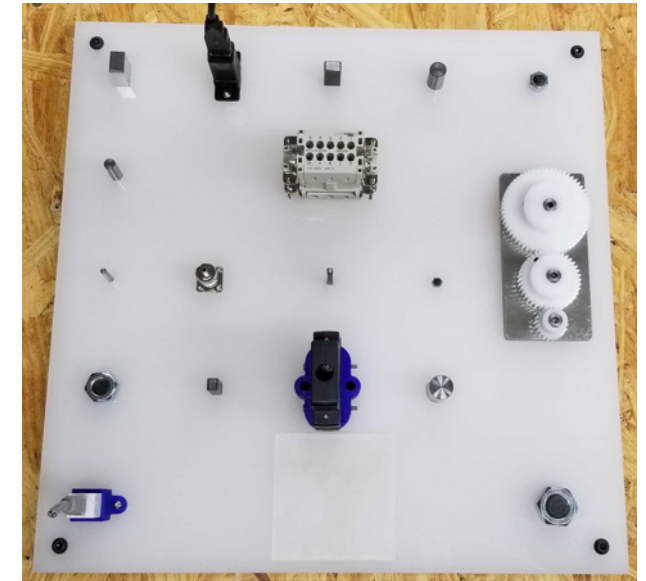


IROS 2020 ATB

NIST Assembly Task Boards

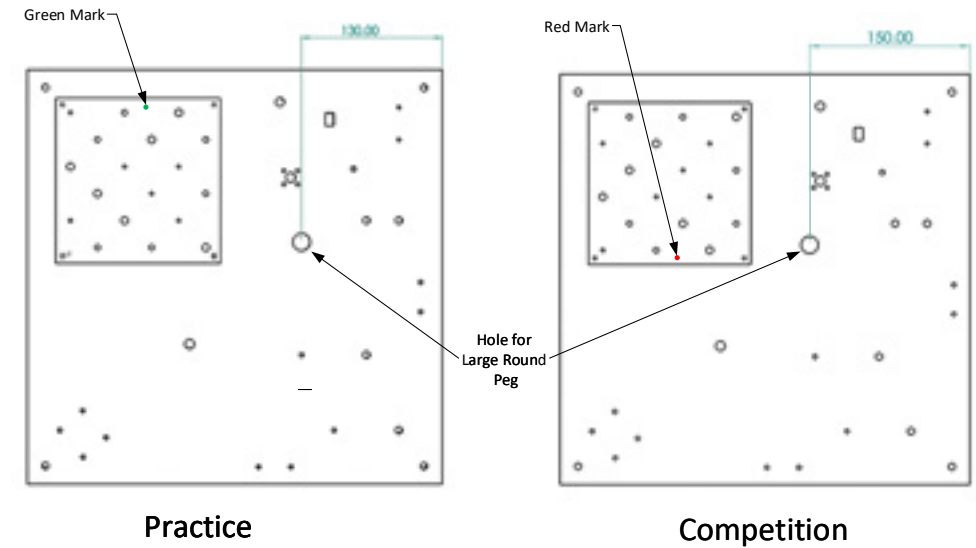
- Robotics: Science and Systems (RSS) 2020 Workshop: Benchmarking Tools for Evaluating Robotic Assembly of Small Parts
 - <https://www.uml.edu/research/nerve/assembly-workshop-rss-2020.aspx>
 - Authors of accepted submissions received a NIST-ATB #1
- IROS 2020 Manipulation Competition: Manufacturing Track
 - <https://www.nist.gov/el/intelligent-systems-division-73500/iros-2020-robotic-grasping-and-manipulation-competition>
 - Competitors received two assembly task boards: one for practice, one for competition, hidden until competition time
 - Variable task placement between practice and competition requires perception

NIST Assembly Task Boards



29 NIST-ATB #1 kits distributed to the United States, United Kingdom, Germany, Italy, New Zealand, Switzerland

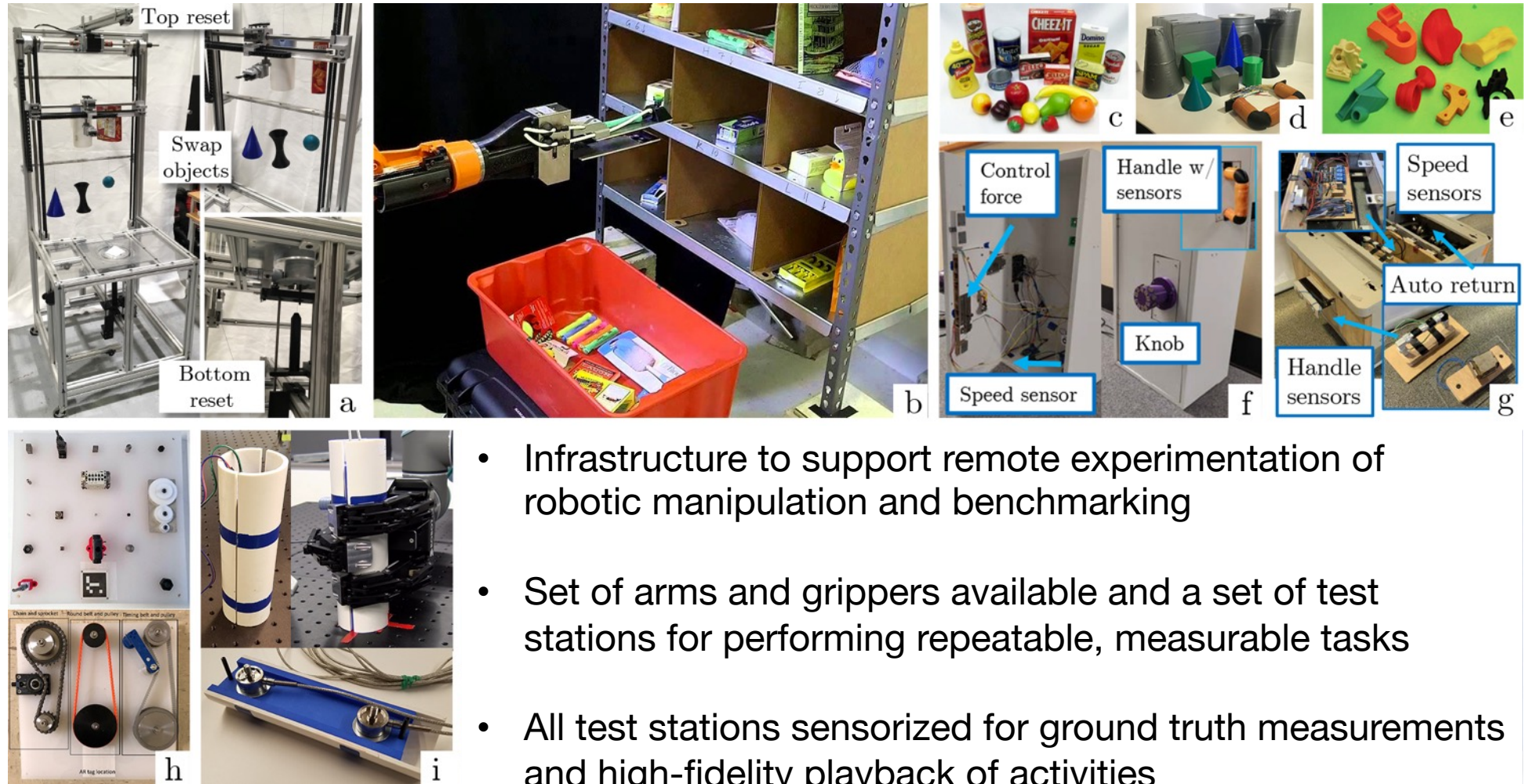
NIST Assembly Task Boards



6 pairs of task boards distributed to the United States, China, Denmark, Germany, Japan, New Zealand



Remote Experimentation of Manipulation for Online Test and Evaluation (REMOTE) Testbed



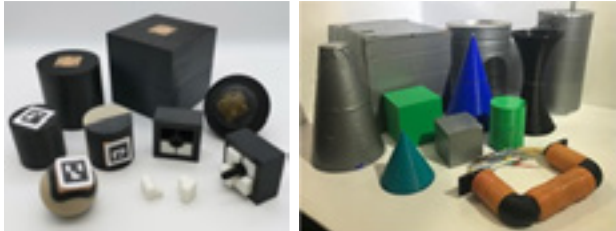
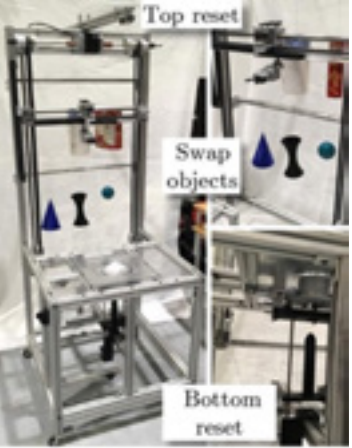
- Infrastructure to support remote experimentation of robotic manipulation and benchmarking
- Set of arms and grippers available and a set of test stations for performing repeatable, measurable tasks
- All test stations sensorized for ground truth measurements and high-fidelity playback of activities



Oregon State University

Remote Experimentation of Manipulation for Online Test and Evaluation (REMOTE) Testbed

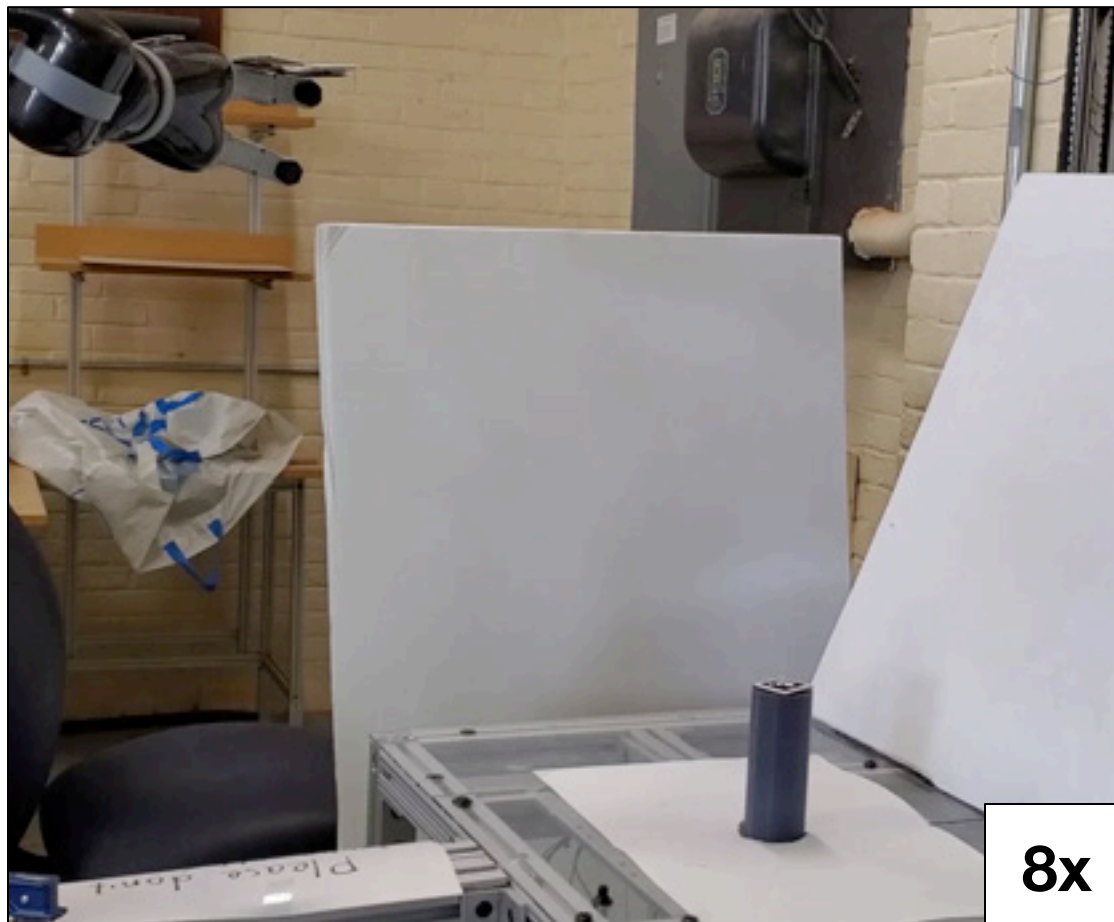
GRASPING



TASKS



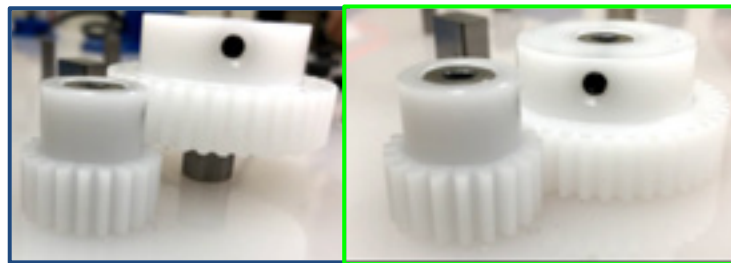
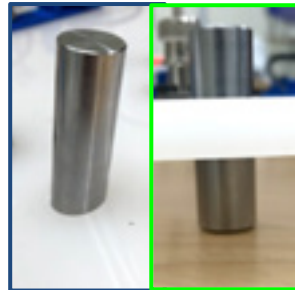
REMOTE: Repeatable Grasp Testing



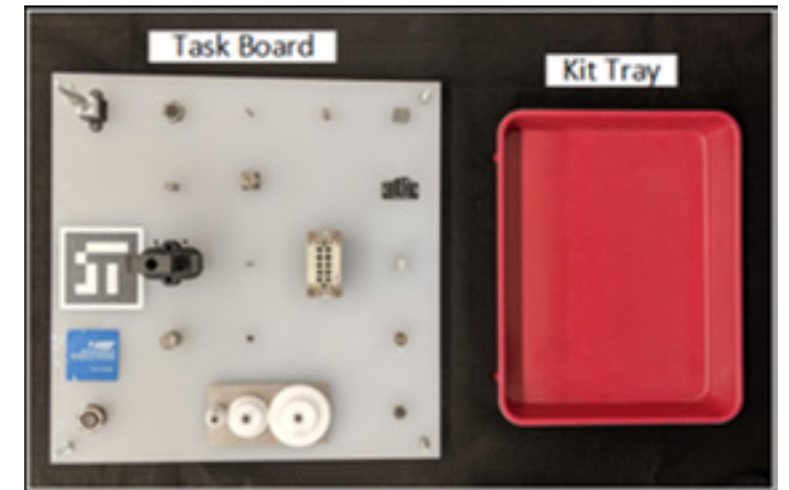
Grasp Reset Mechanism (Oregon State University)

REMOTE: Automatic Evaluation of NIST-ATB #1

- NIST Assembly Task Board #1
- Must be positioned and reset manually
- Developing automated evaluation method utilizing computer vision to compare before and after states



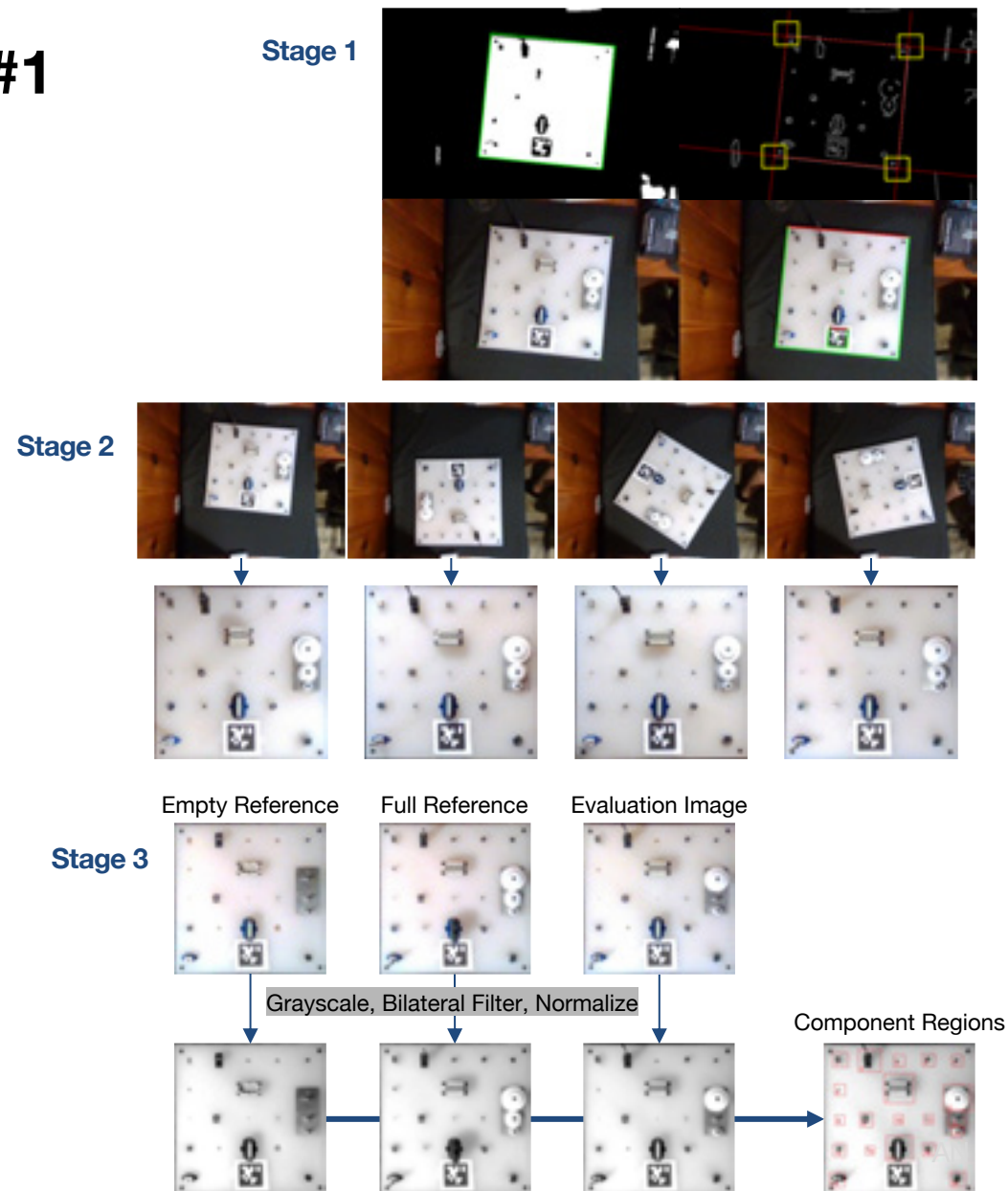
Disassembled



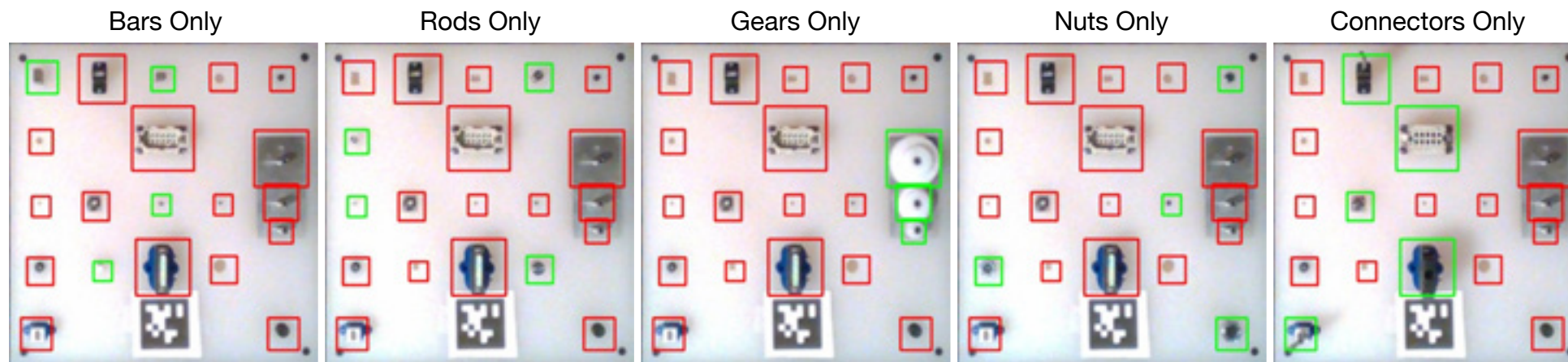
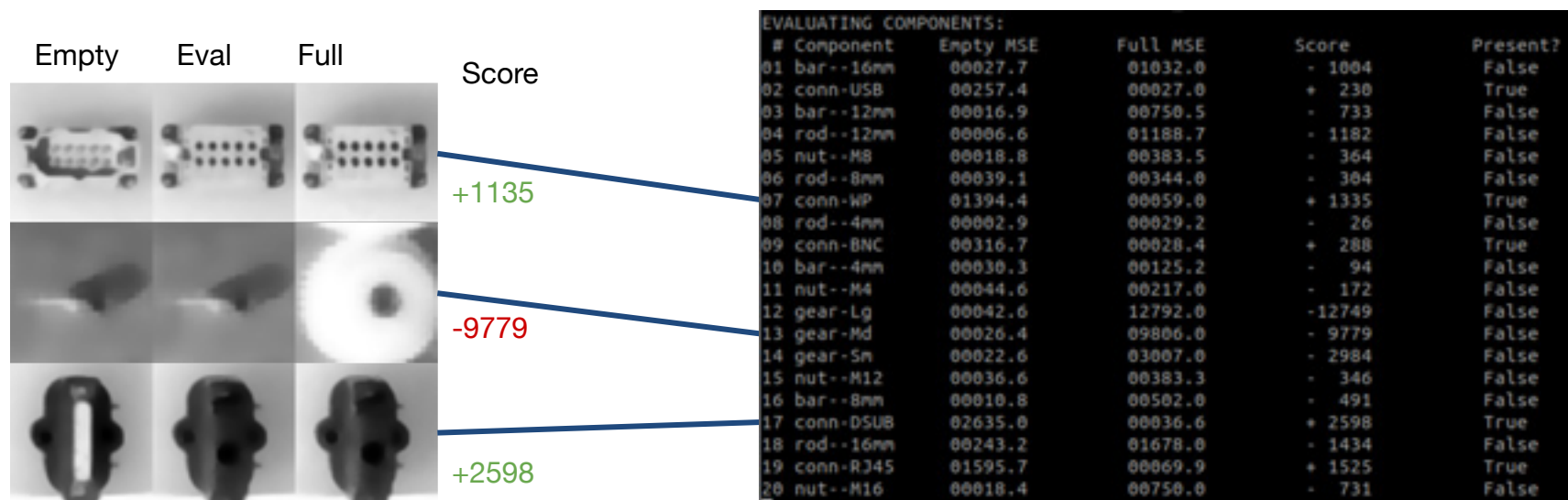
Assembled

REMOTE: Automatic Evaluation of NIST-ATB #1

- Automated evaluation
 - Stage 1: Position invariant task board detection
 - Stage 2: Data collection
 - Stage 3: Component evaluation
- Future Work
 - Adding more cameras for multiple views
 - Measuring agreement between cameras
 - Working towards empty and full conditions; how to treat in between states?
 - Experiment with error states; e.g., misaligned gear placement



REMOTE: Automatic Evaluation of NIST-ATB #1



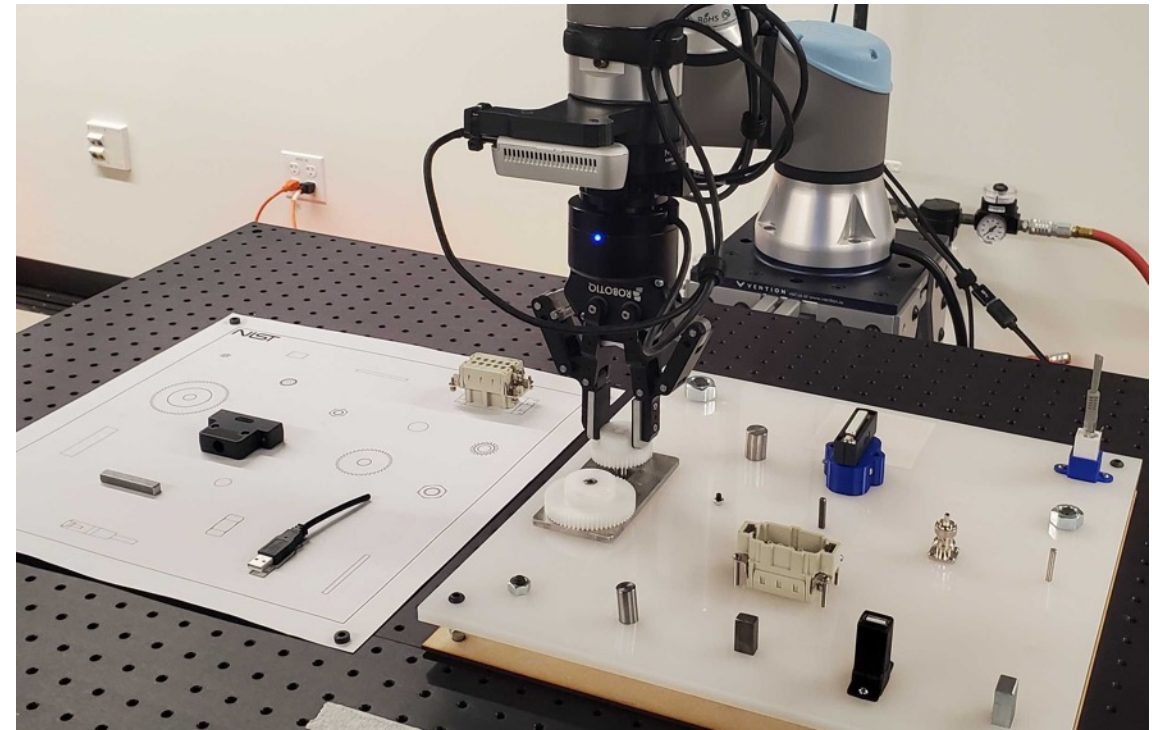
Test Method Validation

- Round robin testing to exercise test methods
 - Repeatability of fabricating the test artifacts and apparatuses
 - Repeatability of results for the same robot in different facilities
 - Evaluating robots available in different facilities
 - Environmental effects of different facilities
- Gathering test data to demonstrate the effectiveness and robustness of the test method, modifying as needed based on these results
- Common practice for other robot test method efforts: response robots, mobile robots, etc.

Benchmarking Tools Available

YCB Object and Model Set

NIST Assembly Task Board #1



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Thank you!

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