Performance Benchmarks to Advance the State of Robotic Hands

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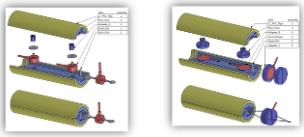
With a growing number of robot hands, there is an increasing need to capture their individual competencies and characteristics under a unified framework. In addition to knowledge of basic hand characteristics such as the number of fingers, degrees of freedom, and degrees of actuation, performance metrics can provide valuable insight into not only the raw traits of the technology, but also their task and function-level performance capabilities. These measures can then be used to help to match capabilities to end-user needs as well as to help provide researchers and developers insight for improving their hardware and software designs.

In order to design relevant performance metrics and methods for characterizing robotic hands, it helps to understand the issues surrounding robotic grasping and manipulation. Regardless of the actual task at hand, any grasping and manipulation problem can be broken down into its first principles, kinematics and kinetics, or more simply, motion and effort. Kinetics are the forces acting on bodies or particles that are responsible for causing their motion. In particular, any kinetic metric or test method will be evaluating force, torques, and any other measure of effort such as electrical current. Kinematics is the geometry of motion of bodies or particles with complete disregard for the forces that cause such motion. Therefore, any kinematic metric or test method will be concerned with evaluating positions, velocities, or accelerations of bodies, parts, or particles, and will typically be in units of length and time. Candidate entities of interest include palms, fingers, points of contact, or parts under grasp. Building test methods from this fundamental point of view will ultimately lead to relevant performance capture, and will span from lower-level capabilities including primitive sensing and control to higher-level capabilities including manipulation, perception, and decision making

We present a framework for robotic hand performance benchmarking [1]. Many of the concepts presented were derived by NIST using a community driven approach using the recently formed IEEE Robotics and Automation Society (RAS) Robotic Hand Grasping and Manipulation (RHGM) Technical Committee (IEEE RAS Technical Committee on Robotic Hand Grasping and Manipulation; http://www.rhgm.org). As shown in Table 1, elemental test methods are used to measure the basic characteristics of a hand and its components. NIST provides supporting documentation that includes test artifact designs and provides example implementations of the methods using equipment within the NIST Dexterous Manipulation Testbed [2].

Table 1 Elemental Test Methods

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

In addition to elemental component based testing, functional testing is needed to objectively assess the performance of a robotic system in completing a task. NIST has been experimenting with test methods that target manufacturing tasks found in assembly operations such as pick-place, insertion, and fastening with system implementations that include robotic hands. The defined test methods include the use statistical methods to discern small changes within a particular robot's performance as well as distinctive changes when comparing two disparate robot systems in their capability to perform the same task.

[1] J. Falco, and K. Van Wyk, "Grasping the Performance: Facilitating Replicable Performance Measures via Benchmarking and Standardized Methodologies, Robotics and Automation Magazine, pp. 125-136, Dec 2015.

[2] NIST Web Site, "Performance Metrics and Benchmarks to Advance the State of Robotic Grasping", https://www.nist.gov/programs-projects/performance-metrics-and-benchmarks-advance-state-robotic-grasping