Empowering Robotics in Manufacturing Through Measurement Science

By Jeremy A. Marvel and Elena R. Messina

The U.S. National Institute of Standards and Technology (NIST) is dedicated to advancing measurement science, technology, and standards, thus promoting innovation and industry competitiveness. In particular, the Robot Systems for Smart Manufacturing (RSSM) program within NIST's Engineering Laboratory focuses on advancing measurement science for industrial robot systems, specifically to address issues that may hinder ease of adoption and advances in the performance of robotic technologies.

Robotic systems are an essential tool for strengthening manufacturing competitiveness in our rapidly changing global economy. Automating the dull, dirty, and dangerous aspects of manufacturing drives growth through greater responsiveness to market needs and innovative product offerings while enabling workforce development and advancement. The flexibility and reusability of robotic systems are proving valuable to both large manufacturers and small enterprises that must respond nimbly to customer's needs.

The RSSM program consists of several projects targeting different measurement science challenges related to robotic systems. These projects focus on topics including the following:

- evaluating robot system performance such as mobility, dexterous grasping, sensing, and safety
- assessing and assuring robots' ability to work collaboratively with humans and with other robots
- measuring the capacity for adapting to uncertainty and change
- facilitating easier integration and improved interoperability of robots in smart manufacturing work cells.

These projects also focus on advancing the state of practice of robot applications in manufacturing environments, with a particular interest in overcoming the barriers that currently prevent small and medium-sized manufacturers from leveraging rwobots in their day-to-day operations.

However, NIST's efforts would be for naught without inputs from both industry and academia to guide and validate the measurement science. There are a number of means through which interested academic and industry parties may collaborate with researchers in the RSSM program. While many interactions occur through ongoing participation in standards organizations and technical societies (including efforts under the IEEE Robotics and Automation Society, such as the Standard Ontology for Robotics and Automation and the Robotic Hand Grasping and Manipulation metrics working group), NIST offers mechanisms for formal partnerships, including grants, contracts, cooperative research and development agreements, and small business innovation research awards. Undergraduate and graduate internships are available for current students, as are postdoctoral research awards (student and postdoctoral fellow positions require U.S. citizenship).

Informal interactions, including input on relevant metrics and comments on draft test methods, are welcome, as is participation in NIST-organized competitions (e.g., the Agile Robotics for Industrial Automation Competition and the manufacturing track of the Robotic Grasping and Manipulation Competition). More information on NIST, the RSSM program, and ongoing research project efforts can be found at https://www.nist.gov/programs-projects/robotic-systems-smart-manufacturing-program.

Despite several decades of continuous advance and successful deployments, many robots remain expensive, dangerous machines that are difficult to integrate, use, and retask. Sensing technologies for process flow and safety have increased in resolution and bandwidth, yet reliably understanding the environment remains a limiting factor for autonomy of operation and resiliency to change. Robot mobility has extended the reach and capabilities of automation to the far corners of the factory floor, yet safety and localization concerns still plague automatic-guided vehicles and mobile robots (i.e., wheeled or legged platforms with autonomy to navigate independently to achieve goals and avoid obstacles).

Innovative designs are flourishing for grasping technologies, including mechanisms that mimic human hands; however, very few are finding their way onto shop floors due to a lack of understanding of their capabilities and how to best apply them. Recent advances in collaborative robot standards have empowered the removal of barriers that

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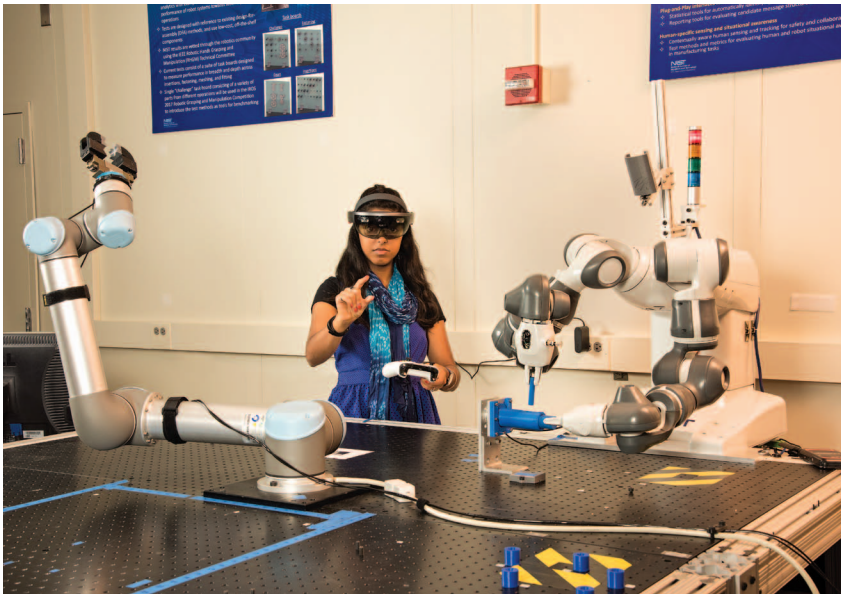

Figure 1. Shelly Bagchi, a robotics engineer at NIST, engages in robot–human interaction.

separate workers and machines, yet there is still no means by which human–robot collaborations (Figure 1) can be assured to be safe or effective.

Ultimately, what is lacking is measurement science: test methods, metrics, and measurement tools by which systems of seemingly identical specifications may be measured, evaluated, and compared in a repeatable and meaningful way. As the technologies and their applications advance, measurement science needs to keep up. There is a measurable gap between the cutting edge and the state of practice, largely due to the lack of measurement science to verify and validate emerging novel research and thus reduce the risk of adoption. While manufacturers may be aware of current trends in robotic research, they are disinclined to pursue incorporating them into their product lines until the technology can be unequivocally demonstrated to be fully functional and robust against uncertainty.

Even with hardened, commercially available technologies, end users are frequently left to their own resources to determine whether a given system, ostensibly a solution for their automation needs, will actually perform as expected. Without clear feedback mechanisms in place to guide performance evaluation, optimizing sensor and robot parameters is too often a matter of trial and error and luck. Validated measurement science establishes a common basis for communicating performance requirements and provides the means by which those requirements may be verified. As new technologies and solutions emerge, measurement science will be increasingly used to assess and assure performance using traceable metrics and repeatable test methods. Similarly, concrete performance targets and benchmarks direct innovation, continuous performance gains, and technology evolution toward addressing existing capability gaps in robotic systems. The RSSM program aims to provide the measurement science needed to enable all manufacturers to characterize and understand the performance of robotics systems within their facilities.