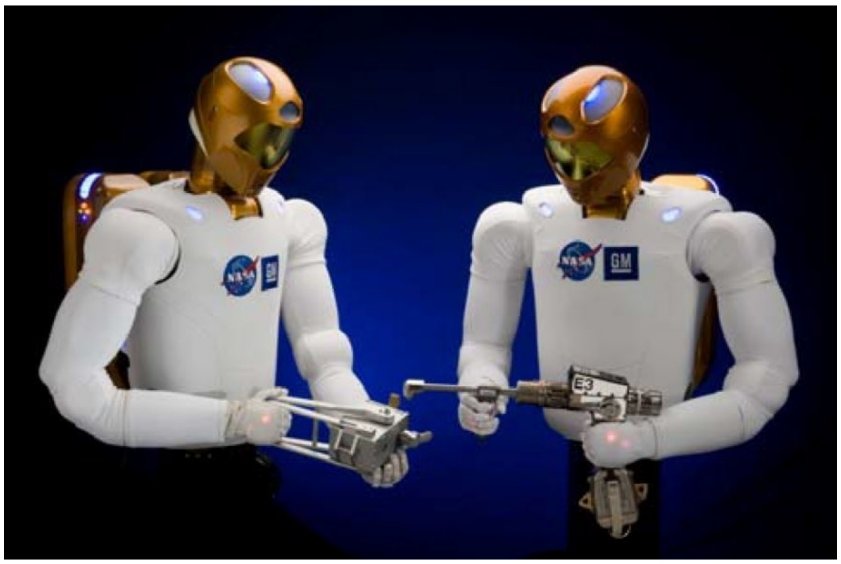


National Aeronautics and Space Administration

# TECHNOLOGY SOLUTION

## Robotics, Automation and Control

# Advanced Robotic Sensing Technologies

Cutting-edge systems for humanoid robotics

NASA and General Motors, two organizations at the forefront of autonomous robotics, have collaborated to develop Robonaut 2 (R2) – a state-of-the-art, dexterous, humanoid robot capable of performing tasks in an automated fashion (or via teleoperation). The technology developed throughout the project represents the cutting edge of autonomous, humanoid robotics. These technologies are available for licensing, both in a modular fashion or as an integrated system, to enhance your robotic products. Please see the Related Links section below for information on additional R2 robotics technologies, including those related to hands, arms, and interface/control systems.

Designing a humanoid robot with human-like sensory and perception systems requires an extensive sensor suite (R2 has over 350 integrated sensors). Several novel sensors were developed to accomplish this goal, including a flexible perception system, tendon tension sensor, contact state estimation sensor, and load sensors in the fingers that give R2 its tactile sense (i.e., sense of “touch”).

### BENEFITS

- High performance visual perception system: R2's visual perception system uses machine vision cameras, processors, and algorithms to perform autonomous localization, tracking, and measurement of objects in its field of view. A particle filter-based contact estimation sensor enables R2 to track hand-object states.
- Tendon tension sensing: Novel tendon tension sensors provide an indication of the external loads experienced by robotic fingers, enabling fine force control.
- Tactile sensing: A unique 6 DoF force torque sensor is placed at each phalange in R2's fingers to measure external contact forces, shear forces, and slippage - granting the robot a human-like sense of "touch."
- Workspace safety: A novel safety monitoring system, which satisfies the stringent requirements of the International Space Station (ISS), was developed to ensure humans can work in proximity of, or interact with, humanoid robots in a safe manner.

## THE TECHNOLOGY

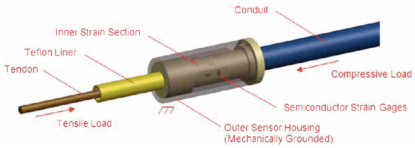
Visual Perception System: Key to enabling humanoid robotics to perform dexterous tasks, R2's visual perception system (U.S. Patent No. 8,244,402) – comprised of machine vision cameras, processors, and novel algorithms – allows robots to find, track, and measure objects automatically in their field of view.

Tendon Tension Sensor: Unique tendon tensions sensors (U.S. Patent Nos. 8,371,177 & 8,056,423) are embedded in R2's palms to enable granular force control of the fingers via a redundant network of tendons. R2's tendons are coupled to, and used to actuate, the robot's finger joints. Thus, tendon tension measurements provided by the sensor allow for the external loads experienced by its robotic fingers to be derived.

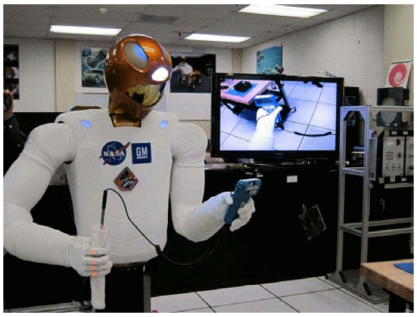
Tactile System: R2's hands feature an innovative tactile system that grant the robot a sense of touch (e.g., measurement of external contact forces, shear force, and slippage of objects held in the hand) – an important requirement for robots designed to perform complex tasks in an automated fashion. The tactile system is enabled by novel six degree of freedom (DoF) force torque sensors (U.S. Patent No. 7,784,363), which are integrated into the fingers at each phalange (14 per hand). A calibration system (U.S. Patent No. 8,265,792) ensures the sensors maintain high accuracy throughout operation.

Contact State Estimation: A contact state estimation sensor (U.S. Patent No. 8,280,837), based on the use of a particle filter, enables R2 to perceive the location, orientation, and shape of objects when in contact with the robot's hands (i.e., tracks hand-object state). The contact state estimation system leverages a novel motion model, which characterizes the motion of a robotic hand as it moves relative to an object of interest.

Series Elastic Actuator (SEA) Sensing: R2's SEAs achieve fine torque sensing at each of its joints without sacrificing strength or payload capacity. The robot uses two 19-bit absolute angular position sensors, calibrated using a novel technique (U.S. Patent No. 8,250,901), to measure the deflection of each spring in real time.




A high-level diagram of R2's tendon tension sensors.



R2's sensing and perception systems allow it to perform "human" tasks, such as reading a flow meter.

## APPLICATIONS

The technology has several potential applications:

- Robotic systems
- Space exploration
- Industrial manufacturing & maintenance
- Personal assistance & caregiving
- Emergency services & operations in hazardous environments
- Automation of repetitive tasks

## PUBLICATIONS

Patent No: 8,244,402; 8371177; 8056423; 8280837; 7784363; 8,265,792; 8,250,901; 8,442,684; 8,525,460; 8,412,378; D628,609

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NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

MSC-24747-1, MSC-24571-1, MSC-24685-1, MSC-24688-1, MSC-24689-1, MSC-24817-1, MSC-24743-1, MSC-24742-1, MSC-24755-1, MSC-24926-1, MSC-TOPS-104

## More Information

National Aeronautics and Space Administration

**Agency Licensing Concierge**

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