How do robots feel in space?

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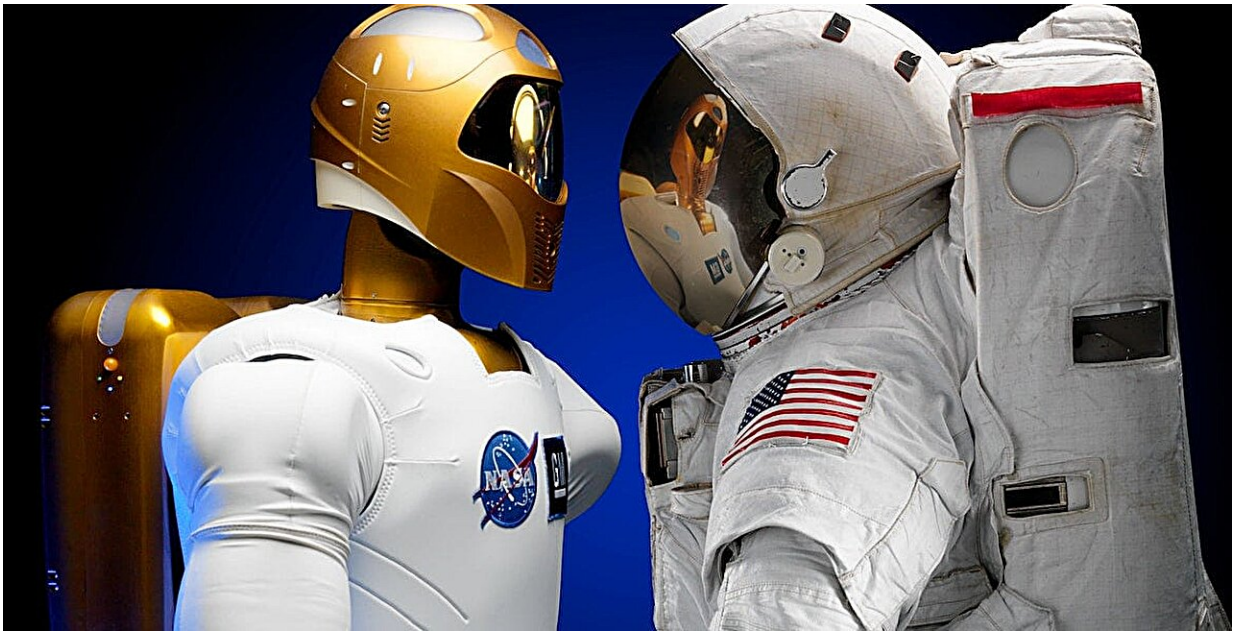

Robonaut, one of NASA's humanoid robots, and an astronaut suit. Credit: NASA

How do robots feel in space? This is both a practical and possibly an existential question. Still, today, we'll focus on the practical side by looking at a review paper from Hadi Jahanshahi and Zheng Zhu of York University in Canada that discusses different tactile sensor types and their advantages and disadvantages for use in space.

The review paper, published in the *Chinese Journal of Aeronautics*, can be divided into two major categories: the challenges of the space

environment and a deep dive into individual sensor modalities. In addition, the authors discuss current material science research on how each of these sensor types might be improved in the near future and lay out a paradigm for selecting the right type of sensor for your space application.

To make the right selection, it's best to know the environment your application will be going into. Space has environmental conditions that are never naturally seen on Earth, such as microgravity, extreme radiation, and massive temperature swings. Each of these can impact sensors, and some will have a larger impact on certain types of sensors than others.

Those types of sensors include four that warranted a deeper dive: resistive, capacitive, piezoelectric, and optical. Other, more advanced sensors, such as quantum tunneling composites or barometric pressure sensors, are mentioned, but they are still either early in the development cycle for use in the harsh environment of space or not well suited for those applications.

Resistive pressure sensors are some of the most commonly used on Earth. They're simple, robust, and work under even the harshest conditions, including space. However, they suffer from both limited sensitivity and resolution. This is exacerbated at extreme temperatures, as the sensors report different resistance changes, leading to different outputs for the same force at various temperatures. They are most useful for extremely harsh environments that don't require a lot of precision, such as docking implements.

Capacitive sensors are commonly used in smartphones and have almost become ubiquitous over the last twenty years. They are extremely sensitive and particularly useful for touchscreen interfaces if a robot has to interact with a human. However, they are also extremely

environmentally sensitive and can be falsely triggered based on general proximity to objects. Helping a robot get into close proximity to something without actually touching it is its forte.

Piezoelectric sensors are commonly used in consumer applications but have a wide range of uses in industrial settings. They are very good at quickly detecting vibration, which is especially useful in dynamic environments like proximate spacecraft. However, they are expensive, and over time, they can lose their signal strength, which, though it can be compensated for, requires expensive computational algorithms to do so. They are most useful for monitoring dynamic vibrations in a robot's hull or housing, especially at high frequencies.

Optical sensors, such as the proximity infrared sensor that turns on lights when someone enters a room, are useful in various precision applications. They allow a robot to estimate how close another object is to them, similar to how a robotic car would do on Earth. Despite being expensive and difficult to integrate, they are also effective at withstanding electromagnetic interference (EMI).

As robots become more common in space, especially as they interact with their environment and other robots more frequently, tactile sensors will become an increasingly important part of their repertoire. However, these valuable sensors already have many applications on Earth. While the space environment might be harsher, the space exploration industry would indirectly benefit from sensors developed initially for extreme applications on Earth. As robots continue to find their way into the solar system, they might even find time to think about how they truly feel about being the vanguard of human exploration.

More information: Hadi Jahanshahi et al, A comprehensive review of tactile sensing technologies in space robotics, *Chinese Journal of Aeronautics* (2025). DOI: 10.1016/j.cja.2025.103423

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