Soft robots use camera and shadows to sense human touch

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Soft robots may not be in touch with human feelings, but they are getting better at feeling human touch.

Cornell University researchers have created a low-cost method for soft, deformable robots to detect a range of physical interactions, from pats to punches to hugs, without relying on touch at all. Instead, a USB camera located inside the robot captures the shadow movements of hand gestures on the robot's skin and classifies them with machine-learning software.

The group's paper, "ShadowSense: Detecting Human Touch in a Social Robot Using Shadow Image Classification," published in the *Proceedings of the Association for Computing Machinery on Interactive, Mobile, Wearable and Ubiquitous Technologies.* The paper's lead author is doctoral student, Yuhan Hu.

The new ShadowSense technology is the latest project from the Human-Robot Collaboration and Companionship Lab, led by the paper's senior author, Guy Hoffman, associate professor in the

Sibley School of Mechanical and Aerospace Engineering.

The technology originated as part of an effort to develop inflatable robots that could guide people to safety during emergency evacuations. Such a robot would need to be able to communicate with humans in extreme conditions and environments. Imagine a robot physically leading someone down a noisy, smoke-filled corridor by detecting the pressure of the person's hand.

Rather than installing a large number of contact sensors—which would add weight and complex wiring to the robot, and would be difficult to embed in a deforming skin—the team took a counterintuitive approach. In order to gauge touch, they looked to sight.

"By placing a camera inside the robot, we can infer how the person is touching it and what the person's intent is just by looking at the shadow images," Hu said. "We think there is interesting potential there, because there are lots of social robots that are not able to detect touch gestures."

The prototype robot consists of a soft inflatable bladder of nylon skin stretched around a cylindrical skeleton, roughly four feet in height, that is mounted on a mobile base. Under the robot's skin is a USB camera, which connects to a laptop. The researchers developed a neural-network-based algorithm that uses previously recorded training data to distinguish between six touch gestures—touching with a palm, punching, touching with two hands, hugging, pointing and not touching at all—with an accuracy of 87.5 to 96%, depending on the lighting.

The robot can be programmed to respond to certain touches and gestures, such as rolling away or issuing a message through a loudspeaker. And the robot's skin has the potential to be turned into an interactive screen.

By collecting enough data, a robot could be trained to recognize an even wider vocabulary of interactions, custom-tailored to fit the robot's task, Hu said.

The robot doesn't even have to be a robot. ShadowSense technology can be incorporated into other materials, such as balloons, turning them into touch-sensitive devices.

In addition to providing a simple solution to a complicated technical challenge, and making robots more user-friendly to boot, ShadowSense offers a comfort that is increasingly rare in these high-tech times: privacy.

"If the robot can only see you in the form of your shadow, it can detect what you're doing without taking high fidelity images of your appearance," Hu said. "That gives you a physical filter and protection, and provides psychological comfort."

The paper was co-authored by former research intern Sara Maria Bejarano of the University of Los Andes, Colombia.

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