The Art of Folding

Origami-Inspired Sensors Offer Precision and Repeatability in Soft Robotics and Medical Applications

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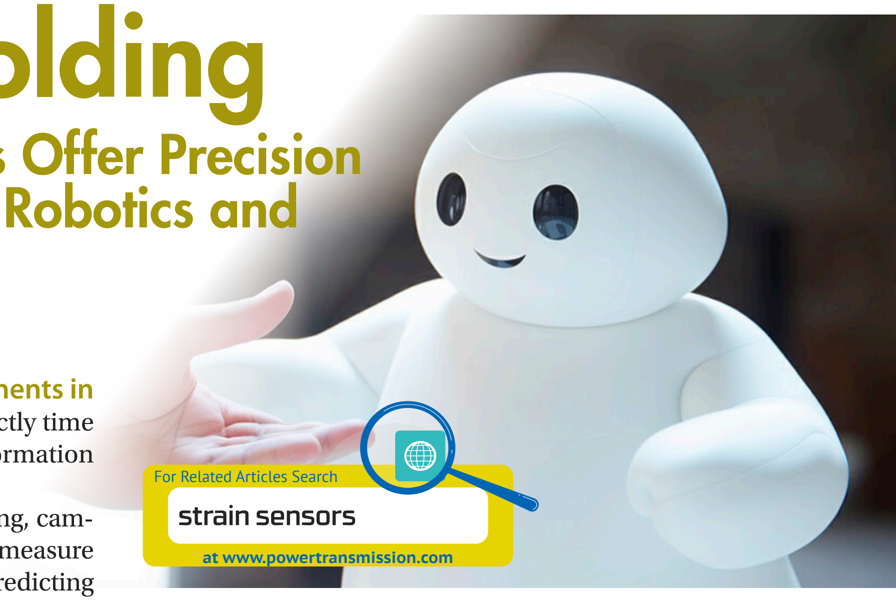

How does one accurately examine the components in a robotic arm or prosthetic leg? There's not exactly time (nor space) to set up multiple cameras to track deformation or changes in shape of soft components.

According to the USC Viterbi School of Engineering, cameras can gather data that enables researchers to measure stretchability and recovery, crucial information for predicting and therefore controlling the motion of the robot. This process, however, rarely works outside the lab. If a robot is navigating the ocean, operating up in space, or enclosed within the human body, a set-up of multiple cameras isn't practical.

Hangbo Zhao, an assistant professor in the Department of Aerospace and Mechanical Engineering and the Alfred E. Mann Department of Biomedical Engineering, recently developed a new sensor design using 3D electrodes inspired by the folding patterns used in origami that can measure a strain range of up to three times higher than a typical sensor.

Zhao said these sensors can be attached to soft bodies in motion—anything from the mechanical tendons of prosthetic legs to the pulsating matter of human internal organs—for the purpose of tracking shape-change and proper functioning, with no cameras required.

"To develop the new sensor, we leveraged our previous work in the design and manufacture of small-scale 3D structures that apply principles of origami," Zhao said in a news article by Matilda Bathurst for USC. "This allows the sensors to be used repeatedly, and to give precise readings even when measuring large and dynamic deformations of soft bodies."

Existing stretchable strain sensors typically use soft materials like rubber—but this type of material can undergo irreversible changes in the material properties through repeated use, producing unreliable metrics when it comes to deformation detection.

But what if the material of the sensor wasn't inherently soft or stretchy? Instead, the 3D structure of the electrodes would convert stretch and release to a process of unfolding and folding.

As the electrodes unfold, the strength of the electrical field is captured. A model developed by the team then converts this reading into a measurement of the deformation. This approach is ideal for responding to large deformations that existing sensors can't identify accurately, through the art of folding.

While the design of the new sensor was originally intended for controlling soft robotics—from delicate robotic grippers to snake-like surveillance devices—they are also ideally suited for innovation in biomedicine.

"We can apply these sensors as wearable or implantable biomedical devices for healthcare monitoring," Zhao explained. "For example, tracking the movement and flexibility of our skin or our joints. There's also high demand for developing implantable sensors that can continuously monitor the functional status of internal organs that undergo cyclic expansion and contraction."

This research resulted in a paper, "High-Stretchability and Low-Hysteresis Strain Sensors Using Origami-Inspired 3D Mesostructures," which was recently published in the journal Science Advances.

The combination of large stretchability, small hysteresis, fast response speed, directional strain response, and small sensor footprint is critical for accurately measuring local strain of large, complex, and multimodal deformations, as found in animals (e.g., octopus arms and elephant trunks), humans (e.g., lungs), and soft robots.

The scalable fabrication process and predictable sensor performance further expand opportunities for practical implementation. Future work may involve 3D electrode designs for increased strain range and gauge factor, as well as enhanced resistance to normal pressure and electromagnetic interference.

These findings suggest potential applications for accurately measuring large and complex deformations of soft bodies in wearable and implantable devices, soft robot proprioception, and human-machine interfaces.

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