A soft touch for robots

A biomimetic sense of touch could ground robots better in the physical world and improve their interactions with humans.

Touch can be defined as contact between two physical bodies. The human sense of touch involves receptors in the skin on the face, fingers, soles of the feet and other areas. Touch is perceived when these receptors are activated by external stimuli. This process can be passive, as when being touched by someone or something; or active, as when moving a hand against a surface to feel the specific texture — when reading Braille with a finger, for example.

Tactile sensing through the skin is complicated, as it does not reflect the transduction of a single physical property into an electronic signal. Instead, touch can detect shape, texture, force, friction, temperature and other properties. Moreover, touch has an active role in the motor system: body parts can move in relation to the tactile properties of a surface or organism, such as grasping a candle or petting a kitten. In humans, touch also has an important role in non-verbal communication, such as in handshakes and hugs.

The possibility to recreate a sense of touch in robots could transform their capabilities, in particular when dealing with complex, unstructured environments and when assisting humans. Key to this aim is the development of accurate tactile sensors and artificial skin, a highly active research topic that is producing many innovative approaches, including machine learning methods to support the processing of raw sensor signals. A challenge for researchers is that artificial skin needs to be soft, stretchable, robust and capable of simultaneously detecting contact location with high resolution and contact intensity with high sensitivity. In a research Article in this issue, Massari et al. contribute to this field by demonstrating artificial skin that is particularly suitable for large areas and curved geometries, so that it can be used to cover robot limbs and bodies, as conceptually shown on the cover of this month's issue.

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Physiologically, the perception of tactile information results from the integration of multiple mechanoreceptor families. Massari et al. take biological inspiration from a type of mechanoreceptor, the slowly adapting type 2 Ruffini corpuscles, which are mimicked with photonic transducers embedded in a soft polymeric matrix — the artificial skin. External tactile stimuli are converted into photonic signals and a deep learning algorithm decodes these signals to infer contact location and magnitude. Such artificial skin enables robots to better sense and respond to touch throughout their bodies, potentially leading to more productive and intuitive interactions with their surroundings and with humans.

Further advances in artificial skin, via soft robotics and biomimetics, could contribute to the development of an early analogue of homeostatic machines. In living organisms, homeostasis involves the regulation of internal processes for self-preservation. Feelings are thought to have a crucial involvement in homeostasis and provide a motivation for adaptive behaviour. A machine analogue of feelings and homeostasis could give robots an internal motivation to evaluate their interactions with the world and perform tasks while avoiding the risk of harm in complex and unpredictable environments. In this approach, artificial skin and tactile sensors would provide an active interface between the internal mechanisms of the machine and the external world. For example, artificial nociceptor devices, robot pain sensation models and reaction controls have been developed for robots to sense stimuli akin to pain and to activate suitable reflex movements. Analogues of feelings in machines are intended to be just that — analogues. However, the design of 'feeling machines', especially with regard to imitating feelings of discomfort, raises ethical questions that need to be discussed.

Other areas of investigation for artificial skin and touch include haptic technologies in which humans interact with smart interfaces that exert small forces to recreate the experience of touch, immersive interactions with robots, virtual reality, neuroprosthetics and robotic body augmentation. Such emerging applications involving artificial touch provide a new frontier for embodied artificial intelligence, an area that may be under-appreciated owing to the successes in the past two decades for non-embodied AI, in particular deep learning. Arguably, creating intelligent, safe and adaptive behaviour for machines in the physical world could be an ultimate challenge in AI. In the near future, the ability of a robot to interact sensitively with its surroundings via a biomimetic sense of touch would support visions for physical intelligence or physical artificial intelligence.

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