Revolutionizing Robot Tactile Perception by Vibration Injection

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Abstract:
Tactile sensors are essential for robots to acquire dexterity comparable to that of humans. Existing tactile sensors improve performance by mimicking human mechanisms and focus on improving temporal and spatial resolution. However, due to integrated circuits and motion control limitations, robots face significant challenges in acquiring tactile perception in the same framework as humans. In particular, although vibrotactile perception, one of the tactile senses, has excellent engineering features, tactile information can only be extracted through vibrations generated by sliding motion with the object, e.g., tactile exploration and gross slip. This dissertation focuses on the frequency characteristic changes of the soft structure affected by the static contact surface rather than the trajectory of the dynamic sliding motion. Since the stress state of the contact surface that contains tactile information involves the deformation of the entire soft structure of the fingertip through its elasticity, the tactile information is expected to be indirectly expressed as the frequency characteristics of the structure. This dissertation proposes a method to extract tactile information from actively propagated vibrations by utilizing the fact that, unlike humans, robots can apply arbitrary vibrations through actuators regardless of sliding motion. The method enables a new approach to robot tactile perception that does not require sliding motion while maintaining the advantages of vibrotactile perception. Application examples of the proposed method include 1) object recognition without tactile search behavior and 2) incipient slip detection for grip stabilization. These examples show that the proposed method can appropriately extract tactile information from the propagation characteristics of the injected vibration and be as effective as or more effective than the conventional method in the robot task.