

Description of Additional Supplementary Files:

File: Supplementary Movie S1

Description: Movie S1 demonstrates the feature-level task, showing how PixelTac performs real-time marker tracking and spatial contact-feature perception. Marker tracking rely on both CPM and MCU for cyclic detection and trajectory localization. Based on explicit marker trajectory, the 2D marker displacement magnitude and marker Gaussian density can be derived, then lead to estimated 3D contact deformation field.

File: Supplementary Movie S2

Description: Movie S2 demonstrates the event-level task, showing how PixelTac captures event maps and temporal contact features during dynamic interactions. Dynamic contact signals are extracted in CPM by comparing current image to previous image at time gap Δt in analogue domain, then converting to event map in digital domain. The red line represents the temporal variation of the event count under various contact stimuli from low to high frequency.

File: Supplementary Movie S3

Description: Movie S3 demonstrates the inference-level task, showing real-time resultant force estimation and force-vector visualisation based on the in-sensor computed features. Resultant force estimation integrates CPM preprocessing of pixel- and feature-level tasks, also with PCA projection and MLP inference at MCU. The force vector illustrates predicted resultant force, and force curve represents the normal and shear force predictions.