WaveTouch:

Active Tactile Sensing Using Vibro-Feedback for Classification of Variable Stiffness and Infill Density Objects

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Abstract

The perception and recognition of surroundings are essential for robotic manipulation tasks such as rolling motion, palpation, and force control. We introduce a novel tactile sensor utilizing **active vibro-feedback** to classify object properties during gripping that opens perspectives for effective object handling.

This approach can be especially beneficial for object manipulation with **deficient vision systems**. Our experiments demonstrate the efficacy of our approach in distinguishing **variable levels of elasticity and porosity (infill) based on vibration absorption and amplification patterns.**

Why vibrations?

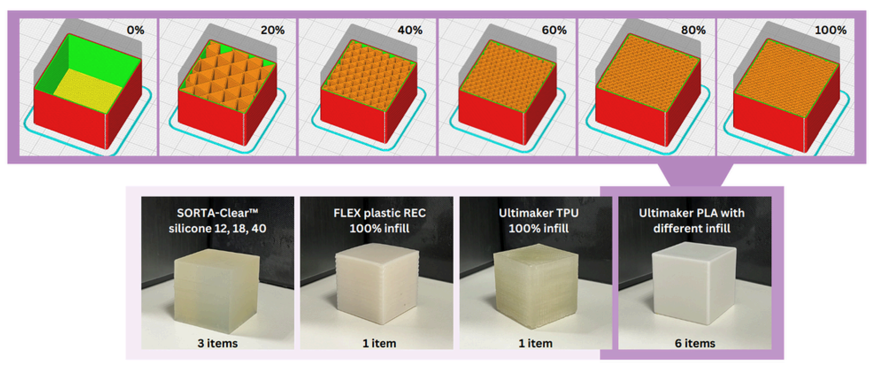
Vibrations play a crucial role in tactile sensing, as evidenced by human tactile perception, such as detecting slippage through changes in vibration patterns. Inspired by this, our study explores active vibration sensors for object property classification. This technique could significantly enhance manipulation tasks by reducing sensor wear and potential damage to objects.

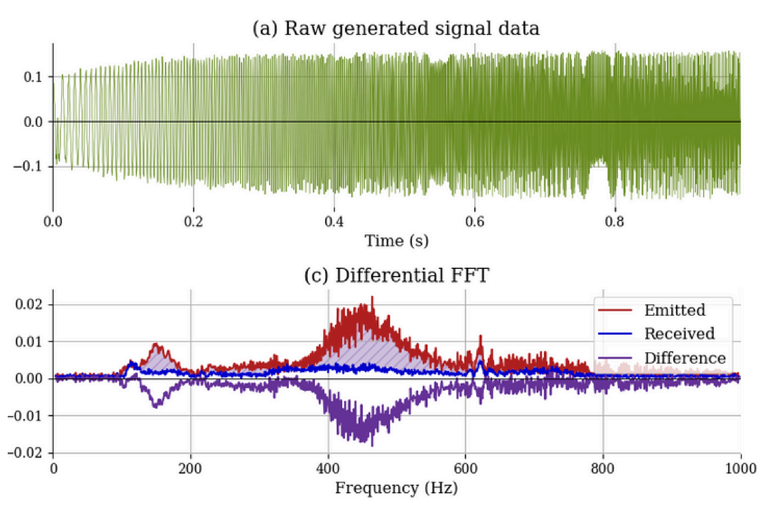
Experiments

A **static force of 1N** was applied to each test cube, and a **chirp signal (100-800 Hz)** was generated and propagated through the cube. The accelerometers recorded the signals for analysis. FFT data from 50 trials were denoised using a uniform filter with a 50Hz window.

TEST OBJECTS:

- **SORTA-Clear™ Silicone Rubber:** Different grades (12, 18, 40) representing varying stiffness levels.
- **FLEX Plastic REC:** Flexible plastic material.
- **Ultimaker TPU:** Thermoplastic polyurethane with elastic properties.
- **Ultimaker PLA:** Polylactic acid with varying infill densities (0%, 20%, 40%, 60%, 80%, 100%)

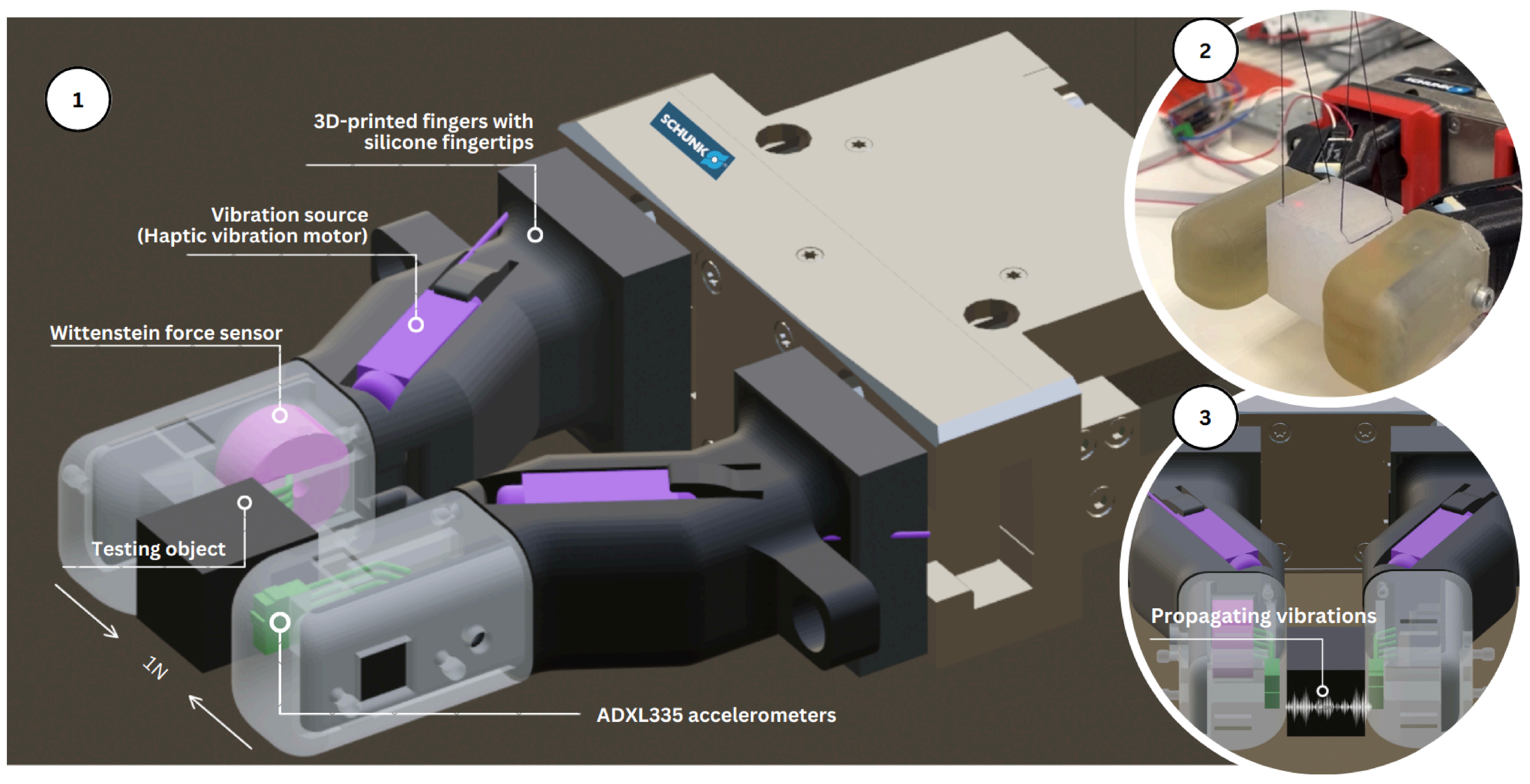




Hardware

We utilized a Schunk ENG 100 robotic gripper with 3D-printed plastic fingers and silicone tips. One finger was equipped with a haptic motor (Haptuator Mark II) and ADXL335 accelerometers to emit and receive vibrations. A Wittenstein HEX-21 F/T sensor was used for force control.

The STM32F4 microcontroller generated a chirp signal to the haptuator, recorded by the right accelerometer, and propagated through the cube to the left accelerometer.

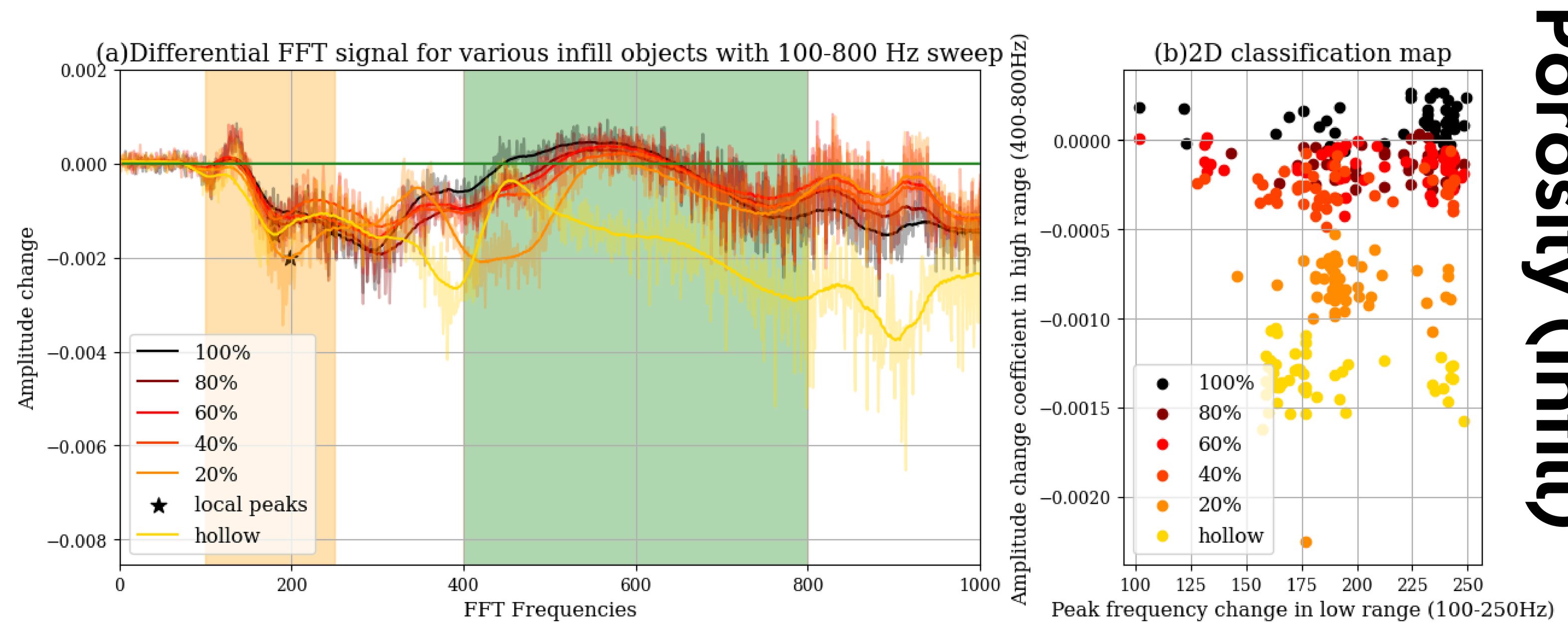


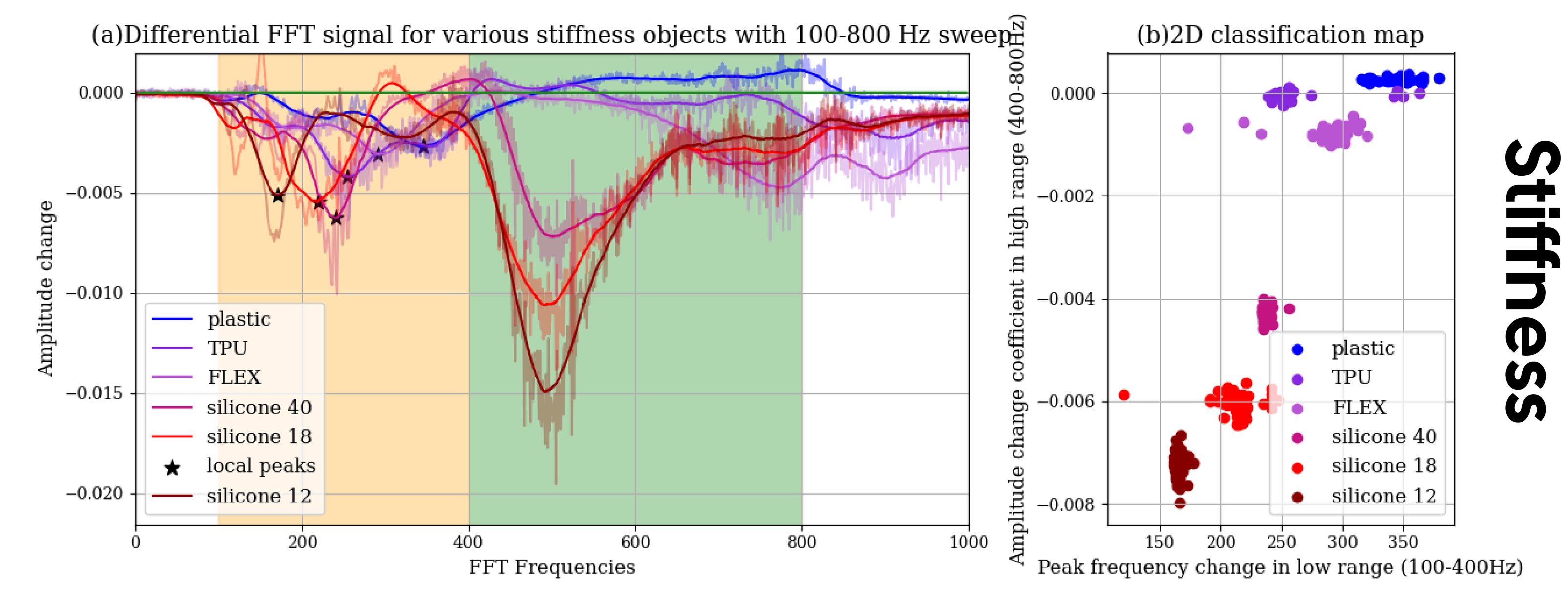
[1] D. Sandykbayeva, Z. Kappassov, and B. Orazbayev, "VibroTouch: Active tactile sensor for contact detection and force sensing via vibrations," Sensors, vol. 22, no. 17, p. 6456, Aug. 2022. doi:10.3390/s22176456

Results

The final features used for classification are low-range peak changes and high-range trends.

- **Stiffness:** The high-range trends have been shown to exhibit increasing signal absorption with increasing object elasticity. For the low-range frequencies, peak changes on the contrary are happening at decreasing frequencies with increasing elasticity.
- **Infill:** The hollow subjects showed significant absorption of the emitted signal, while more solid cubes demonstrated less absorption and even amplification in the higher frequency range (450-600Hz)





Key Insights & Future Work

Our research confirms that active vibro-feedback can effectively classify objects by their stiffness and infill density, enhancing tactile sensing capabilities in robotics.

- **Hollow subjects:** High signal absorption
- **Solid subjects:** Signal amplification at 450-600Hz
- **Soft objects:** 30-50% peak amplitude absorption
- **Rigid objects:** Peak amplitude amplification

Future work will focus on refining force control mechanisms, improving classification algorithms, and exploring additional object properties.