VibeCheck: Using Active Acoustic Tactile Sensing for Contact-Rich Manipulation

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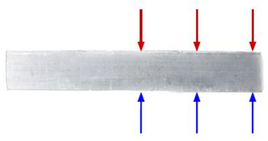
Overview

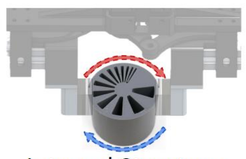
In **VibeCheck**, two piezoelectric fingers send and receive acoustic signals through an object, providing information about resonant frequencies and object state. With this hardware, we demonstrate:

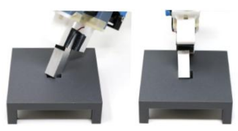
- Object classification
- Grasp position classification
- Internal structure pose estimation
- Extrinsic contact type classification

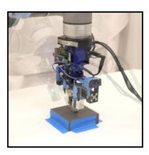
Using our contact type classification model, we demonstrate **peg insertion using only active acoustic sensing.**


Object Type

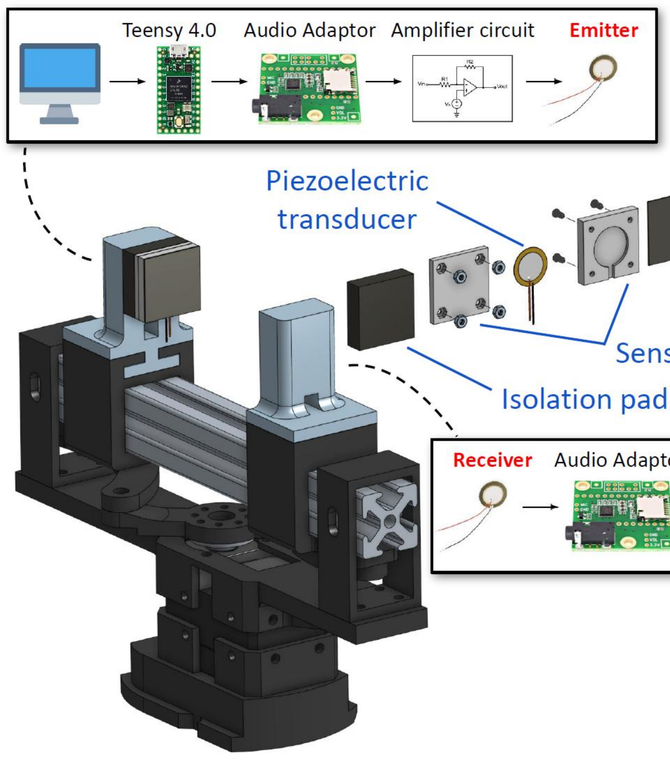

Grasping Position


Internal Structure

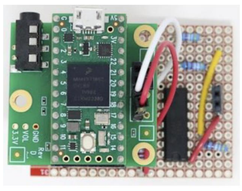

Contact Type -----► Peg Insertion

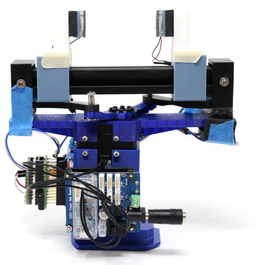


Hardware Design

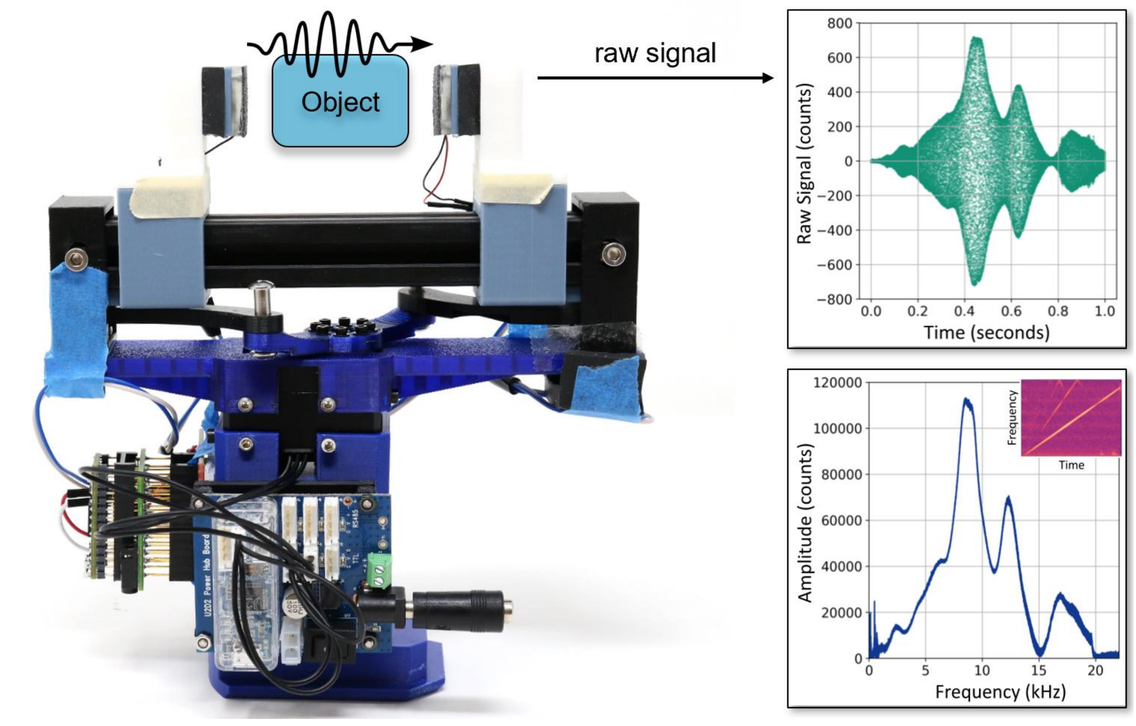



Receiver side


Speaker side

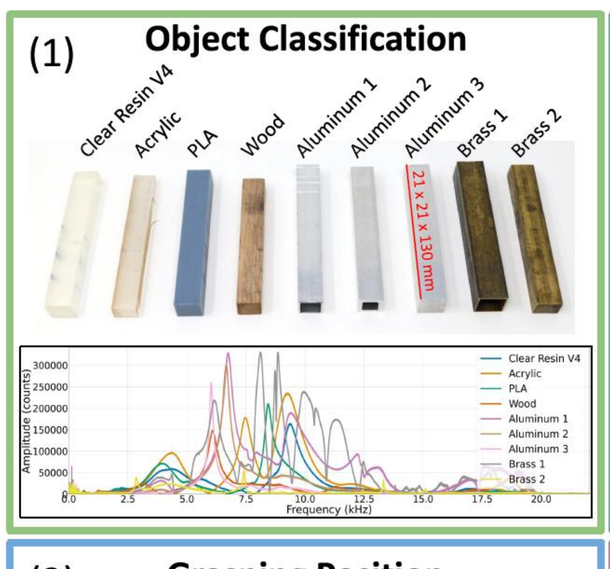

Parallel Gripper Setup

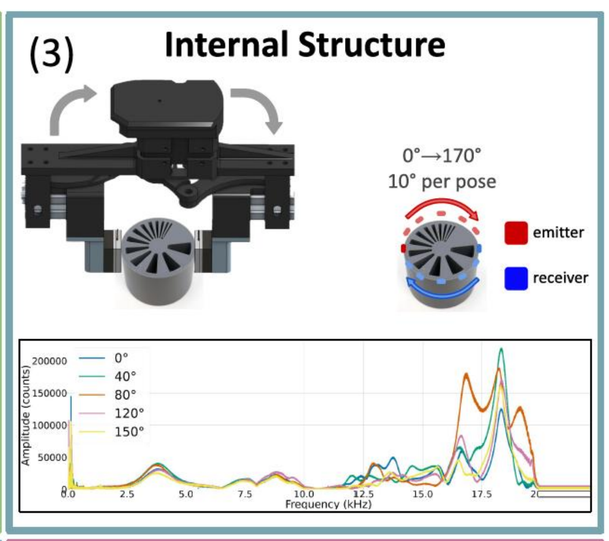
Sensor Signals

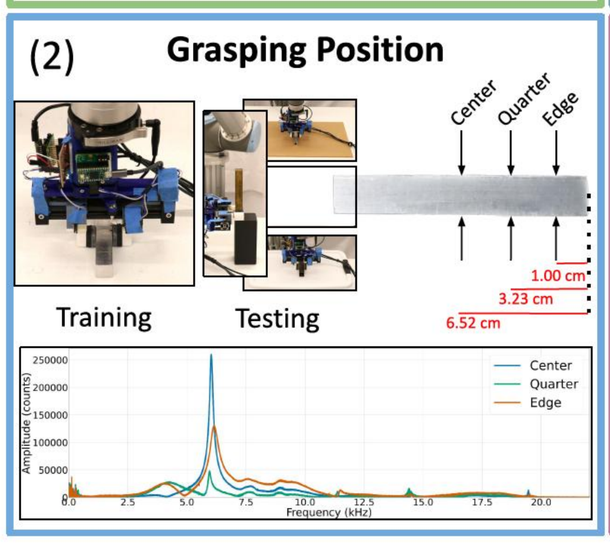


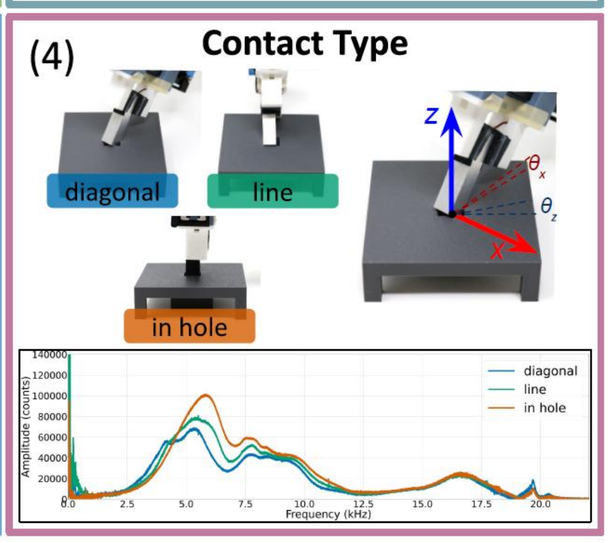
The emitter finger generates a 1-second linear frequency sweep (0.02 – 20 kHz) while the receiver records the transmitted vibration. The response depends on object resonance, material, geometry, and contacts. We transform raw time-domain signals into the frequency domain (FFT), then apply kernel PCA for dimensionality reduction before model training.

Estimating Object State



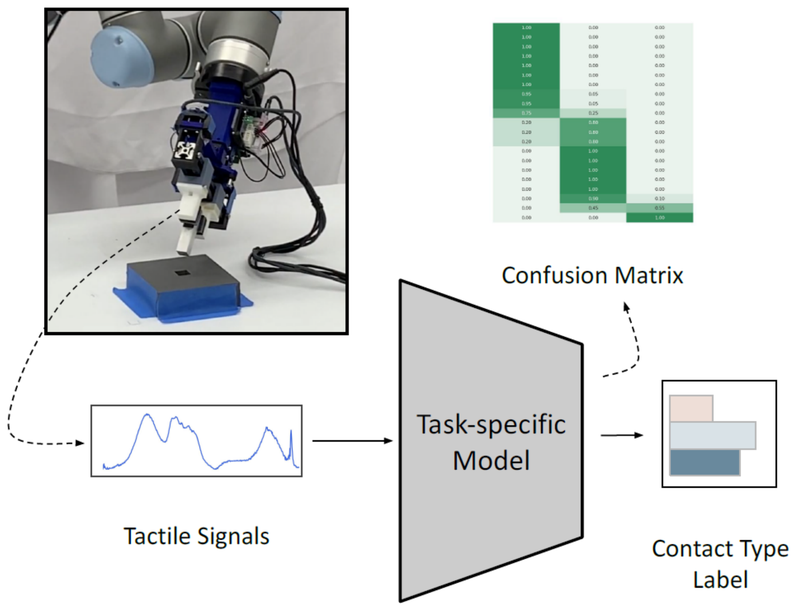




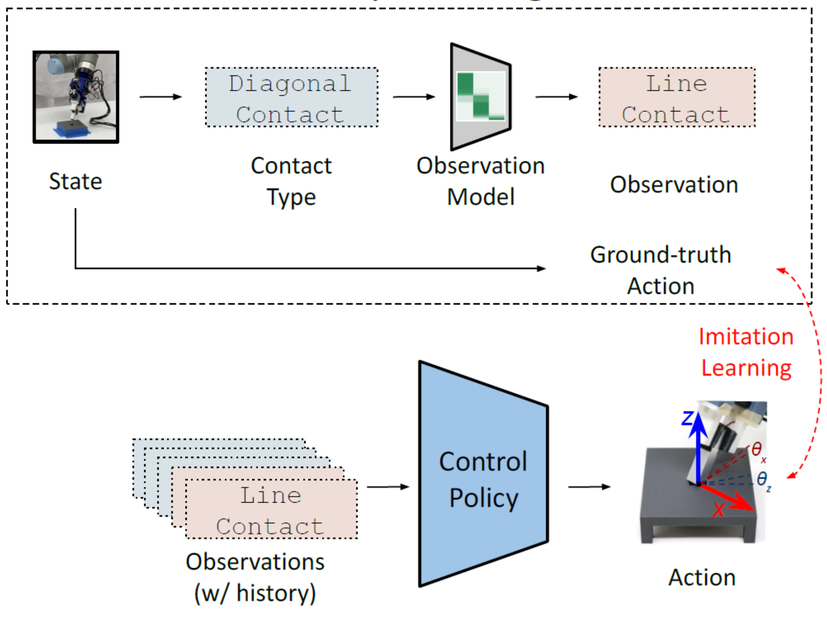


Peg-Insertion Task

Learning task-specific models



Policy learning



We tackle a long-horizon peg-insertion task using the contact type classifier as the sole feedback signal. We build a simulator with ground-truth labels and train an imitation learning policy that incorporates observation history to handle classifier uncertainty. On the robot, the policy learned in simulation achieves 90% success rates for in-distribution starting states and 50% for out-of-distribution.

Acknowledgments

This work was supported by a NASA Space Technology Graduate Research Opportunity. We thank Pedro Piacenza, Trey Smith, Brian Coltin, Peter Ballentine, and Ye Zhang for insightful discussion.