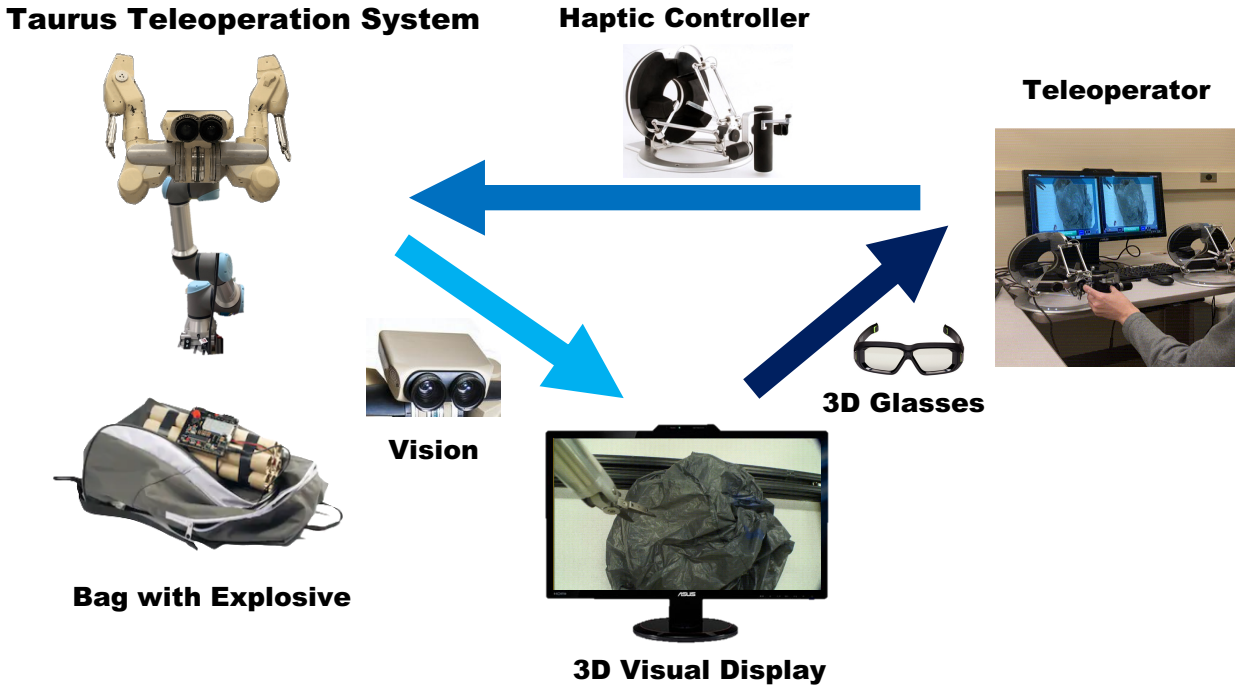
# Fingers See Things Differently (FIST-D): A Robotic Explosive Ordnance Disposal (EOD) based on Augmented Tactile Imaging

Juan Wachs[1], Stephen Beaudoin[1], Hong Z. Tan[1], Bryan Boudouris[1], Wenzhuo Wu[1], Thomas Low[2]

[1]Purdue University, West Lafayette, IN [2]SRI International

## Research Task

Explosive ordnance disposal is among the most hazardous occupations. We mitigate the risk of explosive ordnance disposal by developing a robot that can detect and display concealed improvised explosive devices based on augmented tactile information.




## Key Challenges

- Visualize the concealed objects and plan manipulation policies.
- Develop tactile device with high resolution and contact sensitivity.
- Develop selective polymers to detect explosive residues with high sensitivity.
- Develop a haptic display system to convey the multi-modal information.

## Scientific Impact

- Technology for detecting trace energetics in surface residues could be also applied to detection tasks of other hazardous chemicals.
- The intelligence based on tactile expands the application of robotics to scenarios where optical vision is not applicable.
- The enhanced tactile feedback in teleoperation contributes to the task performance of telesurgery.
- The developed haptic display system could also assist communication for hearing/visually impaired people.

## Broader Impact

- Reduce the risk of EOD teleoperators using enriched perception.
- Incorporating the research outcomes into the coursework of Purdue University.
- The research activities have increased the participation of minorities.

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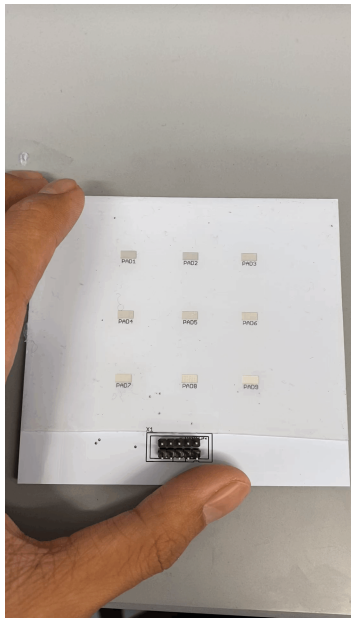
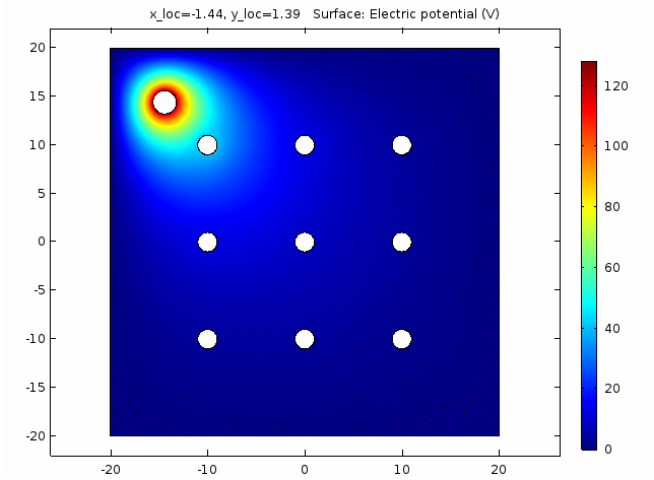
## Technical Solution for Sensing Devices

### 1: Develop Tactile Device for Object Recognition

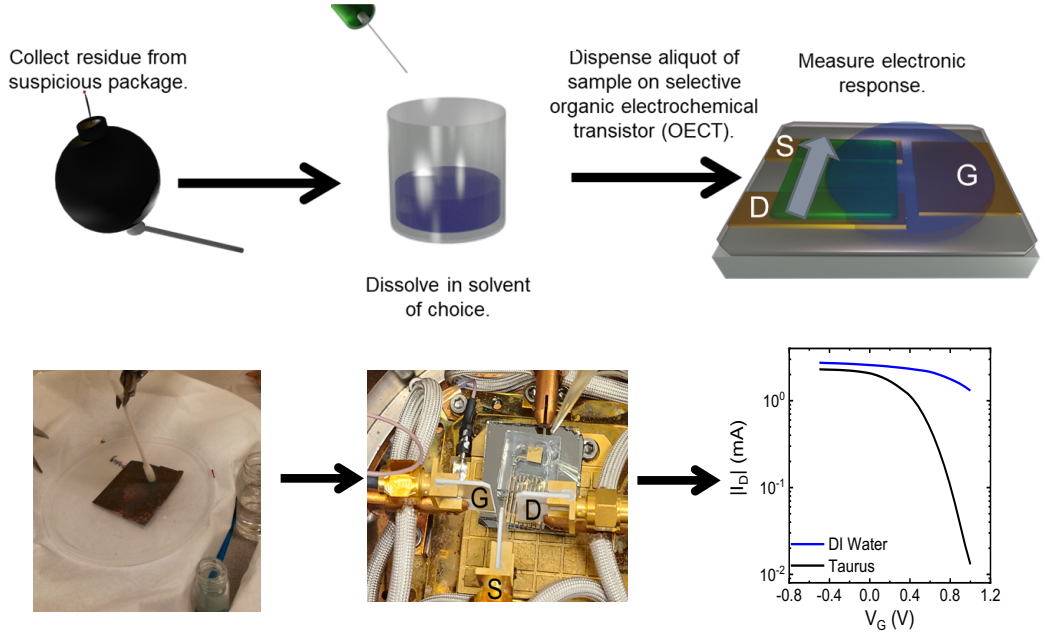


Triboelectric tactile device




FEA simulation of the electric potential

### 2: Develop Sensor for Explosive Recognition




The procedure of explosive recognition based on the developed OECT device

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## 3: Haptic Display System to Multi-modality Information

### User Study on Identification of Tactile Patterns on Both Arms

**User Study on Identification of Tactile Patterns on Both Arms**

Haptic sleeves, each with an array of 12 tactors, are worn on the upper-arm and forearm.

## Research Questions:

- What tactile features are effective at conveying information? We consider the frequency, location, and arm stimulation.
- Can participants selectively attend to one arm when both arms are stimulated?
- Can participants attend to both arms simultaneously?
- Does SOA (signal onset asynchrony) matter?

## Our Findings:

- Two frequencies (low and high) and three locations (distal-dorsal, middle-volar, and proximal-dorsal) can be reliably identified per arm.
- Participants can achieve high accuracy when selectively attending to one arm and ignoring the other.
- Performance drops significantly when participants are asked to attend to signals on both arms.
- Performance with the delayed signal is significantly better.

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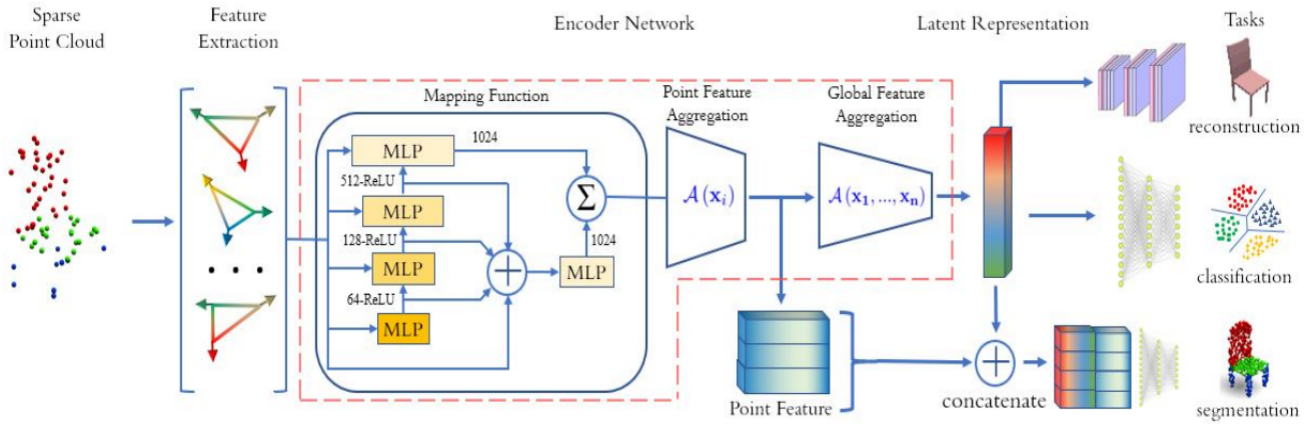
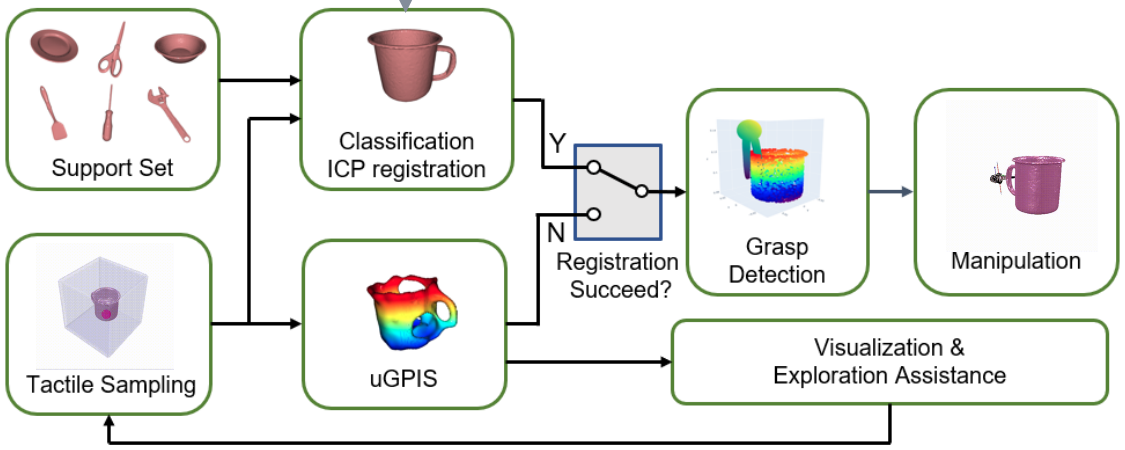
## 4: Object Visualization and Manipulation based on Tactile Data

- How to recognize objects and extract useful features from tactile observations that are naturally sparse, low resolution, and with partial surface coverage?
- How can we (1) visualize the tactile observations in a human understandable manner? (2) plan a manipulation policy based on sparse and discrete tactile point clouds?




We develop a deep neural network (Triangle-Net) that is robust to multifactorial variations including sparsity, noise, scale variance, and arbitrary rotation.




We propose FIST-D, An object-aware framework for generating visualization and manipulation policy based on pure tactile observations.

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## Products

[1] Xiao, Chenxi, and Juan Wachs. "Triangle-Net: Towards Robustness in Point Cloud Learning." *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision*. 2021.

[2] Xiao, Chenxi, Naveen Madapana, and Juan Wachs. "Fingers See Things Differently (FIST-D): An Object Aware Visualization and Manipulation Framework Based on Tactile Observations." *Accepted by IEEE Robotics and Automation Letters (2021)*

[3] Xiao, Chenxi, Naveen Madapana, and Juan Wachs. "One-Shot Image Recognition Using Prototypical Encoders With Reduced Hubness." *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. 2021.*