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# Integrative Tactile Skin Using Computation

Combining Sensory Design and Machine Learning

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University of Stuttgart  
Institute of Smart Sensors



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**Intelligent Systems**

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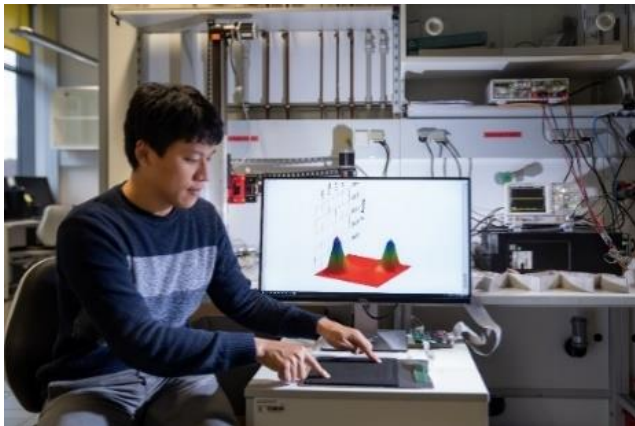


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July 21, 2022

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# Who Am I



## Hyosang Lee

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Keywords for interests: Robotics, Tactile Sensing and Perception, Physical Human-Robot Interaction

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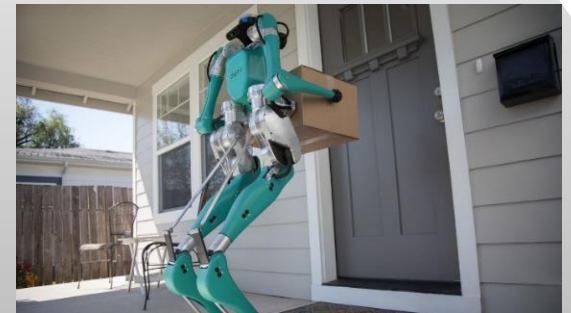
# Importance of Tactile Skin



Human-Robot Collaboration



Physical Human-Robot Interaction

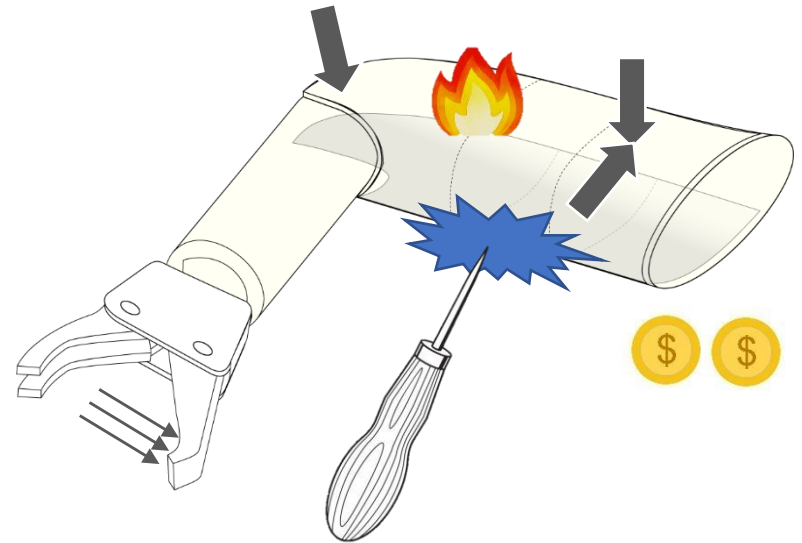


Outdoor Operation

Autonomous operations in contact-rich environments

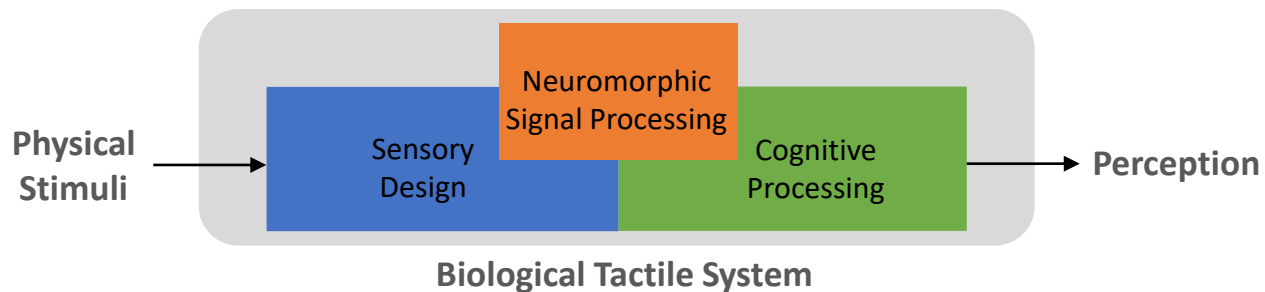
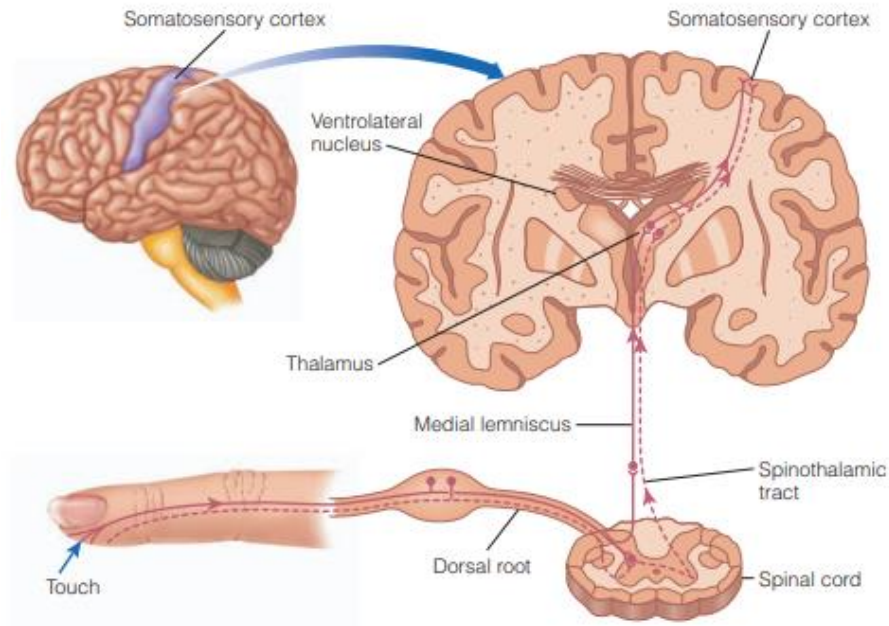
# Requirements for Tactile Skins

- **Multi-contact**
- **Multi-directional (normal, shear)**
- **Multi-modal (pressure, vibration, temperature)**
- **Scalable: fingertip to whole-body**
- **Robust and repairable**
- **Economical**



**Challenges on system level integration**

# Biological Skin's Tactile Perception System



## Coupling of sensory organ and cognitive system

# Lesson from Biological Tactile System

Conventional approach



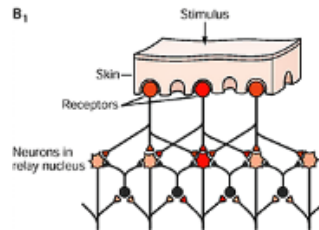
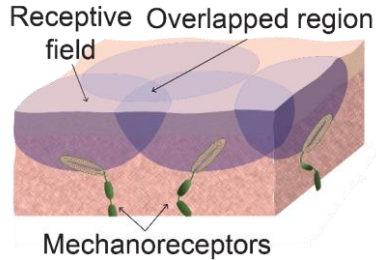
Bio-inspired approach



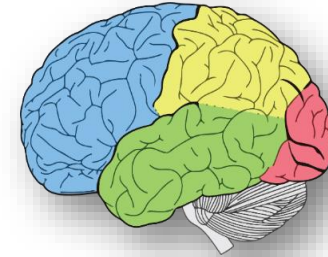
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Rooms for additional functionalities

Computation can **reduce hardware-level burden** and enable integration of multiple functions

# Recent Work: Biomimetic Tactile Perception System



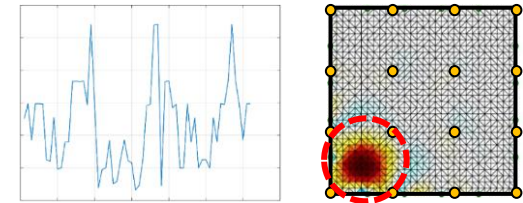
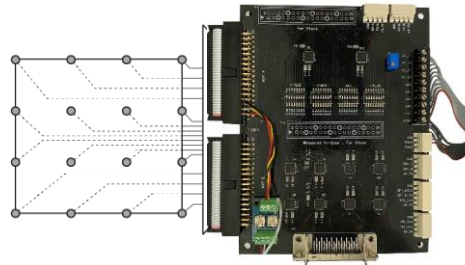
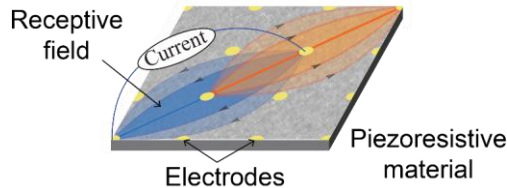
Learning from experience



Overlapping receptive field design

Signal processing

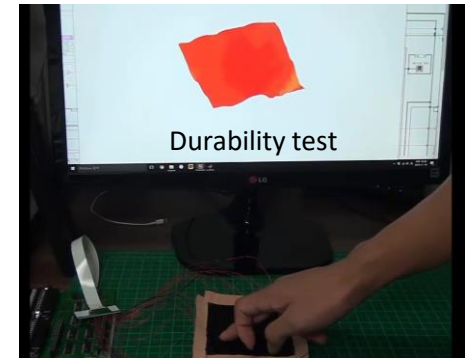
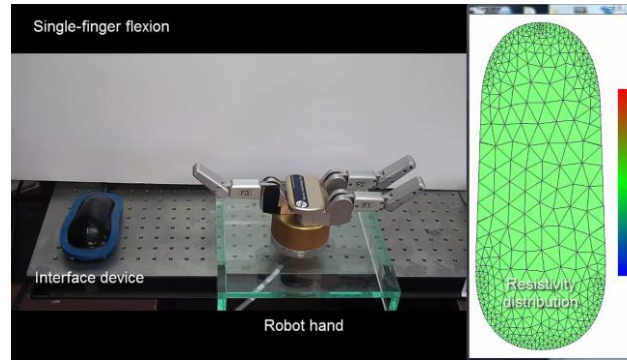
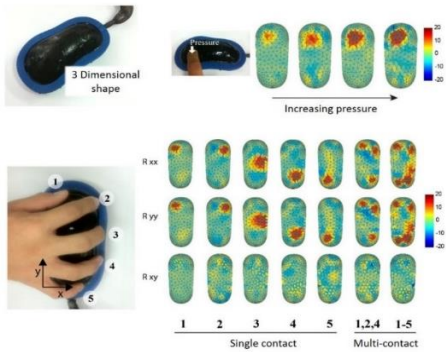
Inference



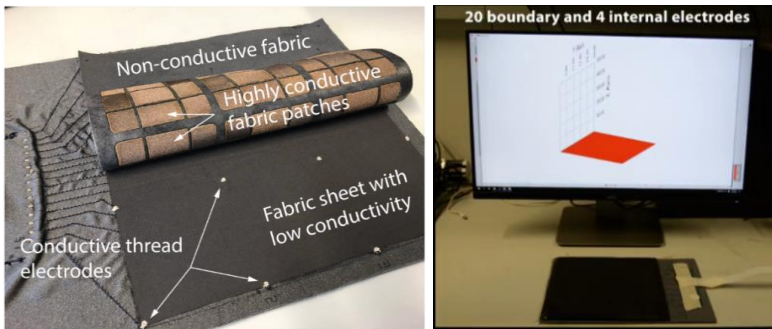
Computation from physics model and data

**Computation** enables the sensory design to have **only a few point electrodes**

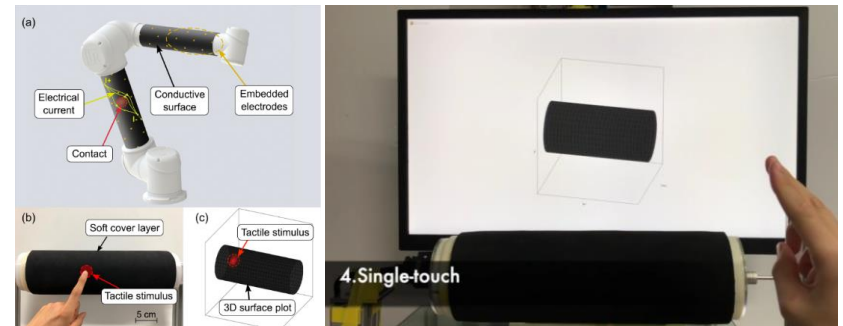
# Demonstrations



Soft tactile skin using conductive polymer

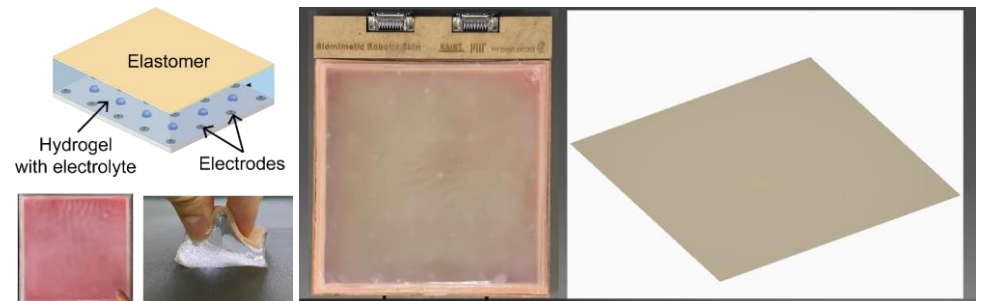


Wearable tactile skin using conductive textile



3-D geometry cover using conductive spray

## Tactile skins with **functional materials** and **geometry**

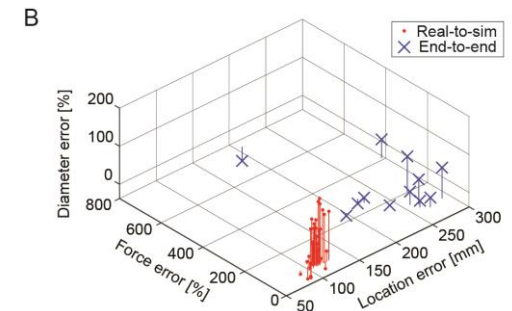
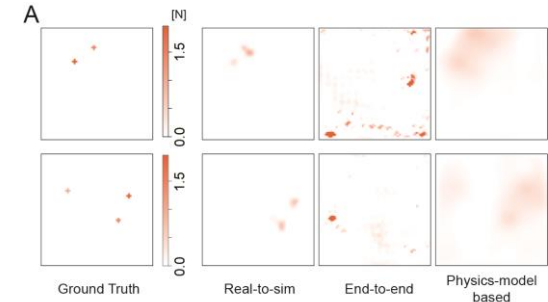
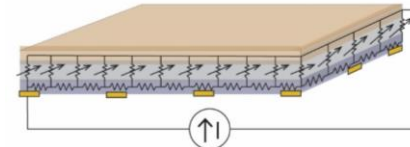
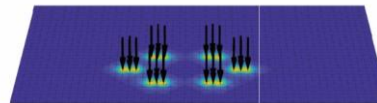
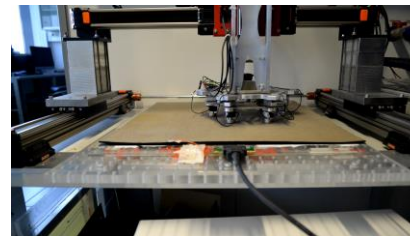
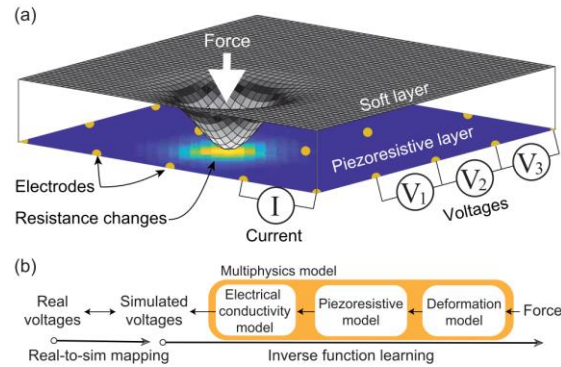


Tactile skin using hydrogel



# Recent Work: DNN for Tactile Perception

- Data-driven approach to learn voltage to force mapping
- Combining real and simulation data to overcome data-deficiency
- DNN achieved accurate and stable reconstruction than physics-model approach



Combining tactile skin and machine learning is promising for high-performance tactile perception

# Summary and Future Directions

- Tactile skin needs to **fulfill various functional-level and integration-level requirements** for future applications
- **Combining sensory design and computation** is promising to achieve **integrative tactile skin**
- Potential future directions related to ML
  - Evolutionary tactile skin optimizing sensory design and computation
  - Integration with motion and multi-modal sensors
  - Neuro-morphic signal compression and processing

**Welcome your opinions and discussion!**