

# Bio-Skin: A Cost-Effective Thermostatic Tactile Sensor with Multi-Modal Force and Temperature Detection

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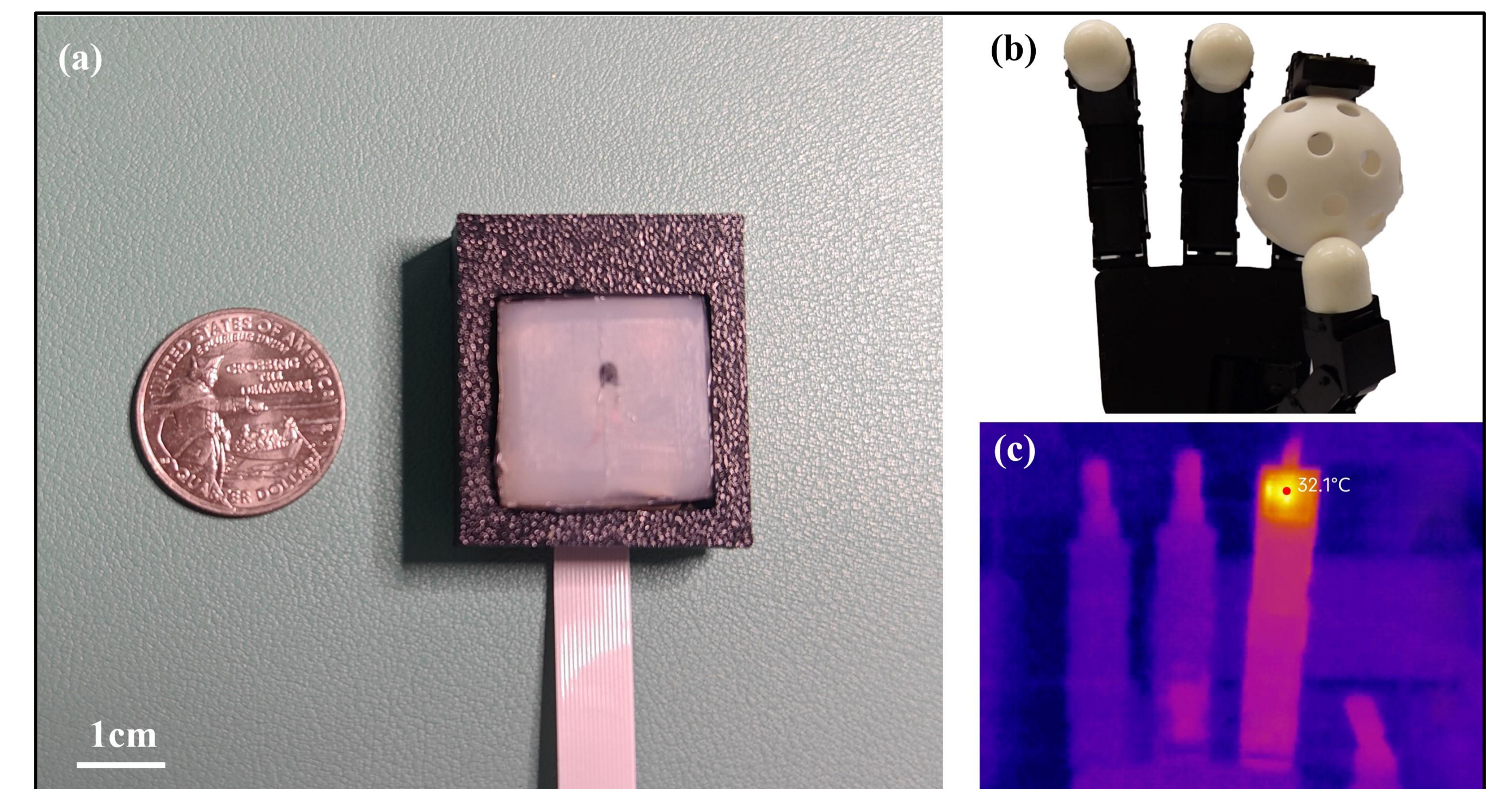
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## Motivations

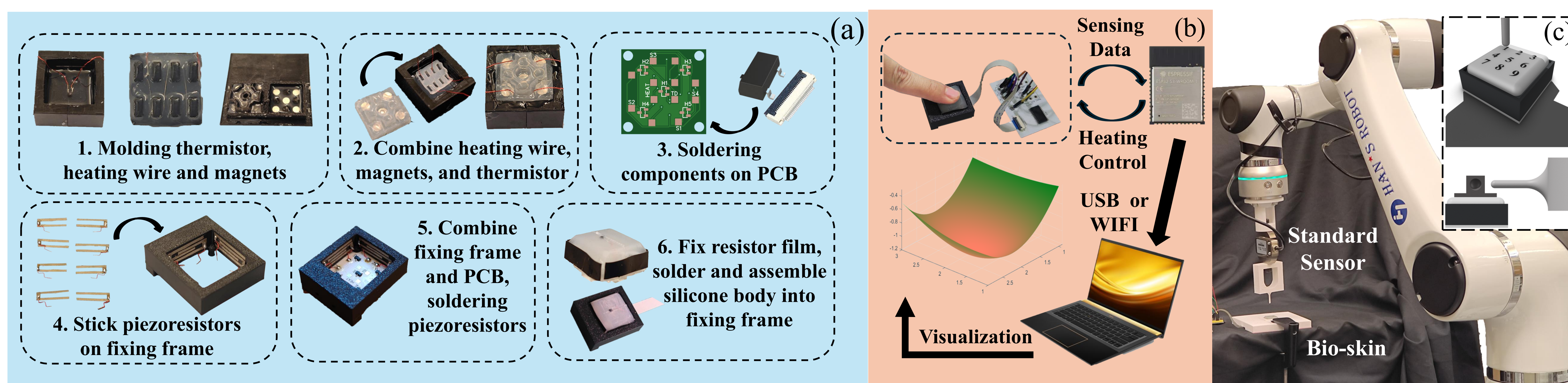
- Humanoid robots require cost-effective, multi-modal tactile sensors with temperature sensing and regulation for safe and adaptive human interaction.
- Current multi-modal sensors often prioritize performance over cost, leading to complex integration and large sensor sizes, limiting widespread adoption.

## Key Contributions

- Cost-Effective Multi-Modal Sensing:** We present a tactile sensor utilizing single-axis Hall-effect sensors for normal force and bar-shape piezoresistors for shear force, significantly reducing costs while offering multi-modal and anti-interference ability.
- Integrated Thermostatic Function:** A thermistor and heating wire are integrated into a silicone body for temperature sensation and thermostatic control, mimicking human skin.
- Bio-Skin's multi-layer design** allows for sequential manufacturing and integration, enabling a fast production pathway.



## Methodology

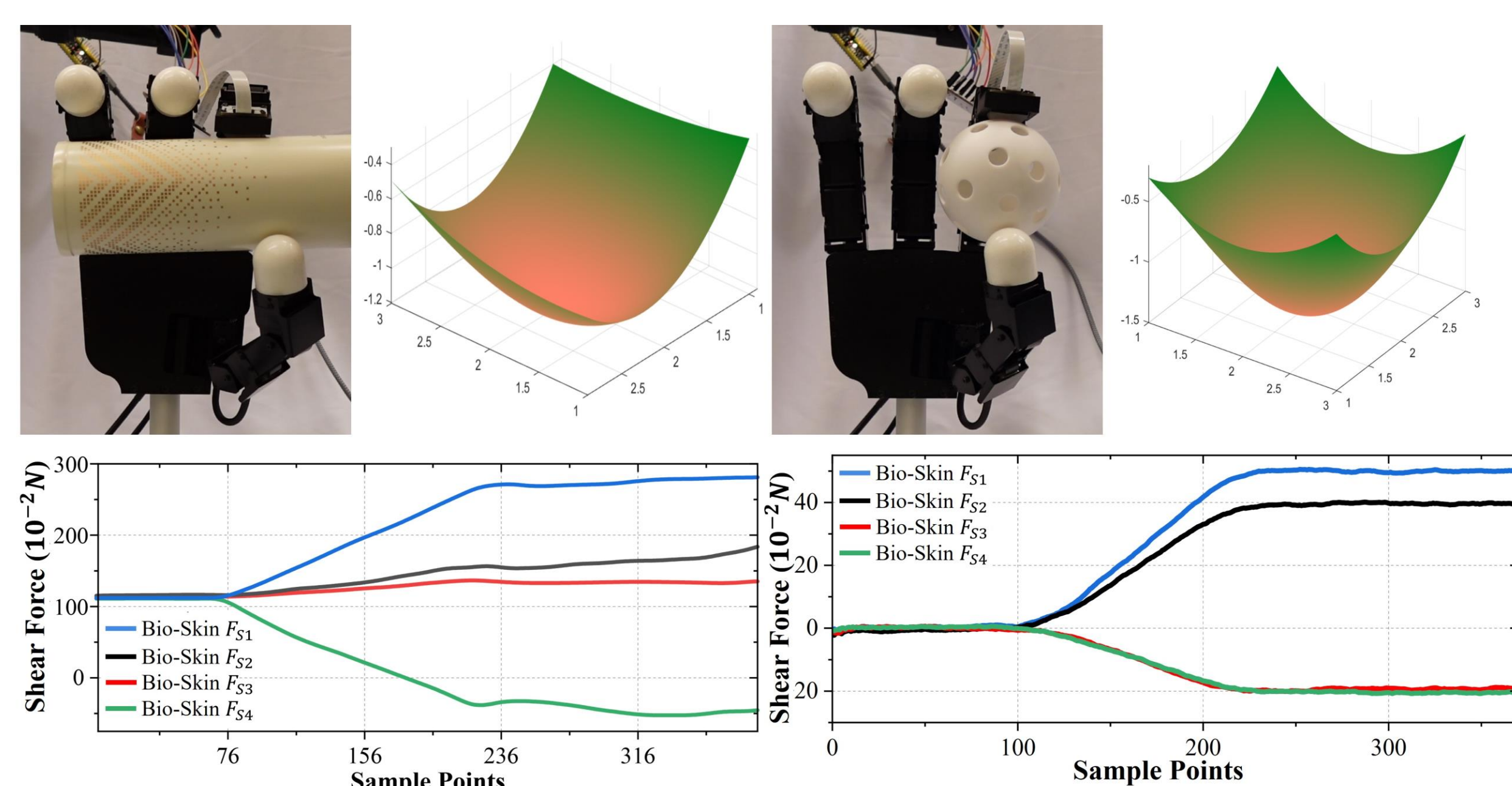


(a) Step-by-step fabrication process of Bio-Skin, including molding, assembly, and integration of key sensing components. (b) System architecture demonstrating real-time sensing, heating control, and data transmission via wired or wireless communication. (c) Calibration setup for collecting data of normal and shear force. Surface of Bio-Skin is divided into 1~9 positions and a direction converter is fixed on Bio-Skin to calibrate shear force.

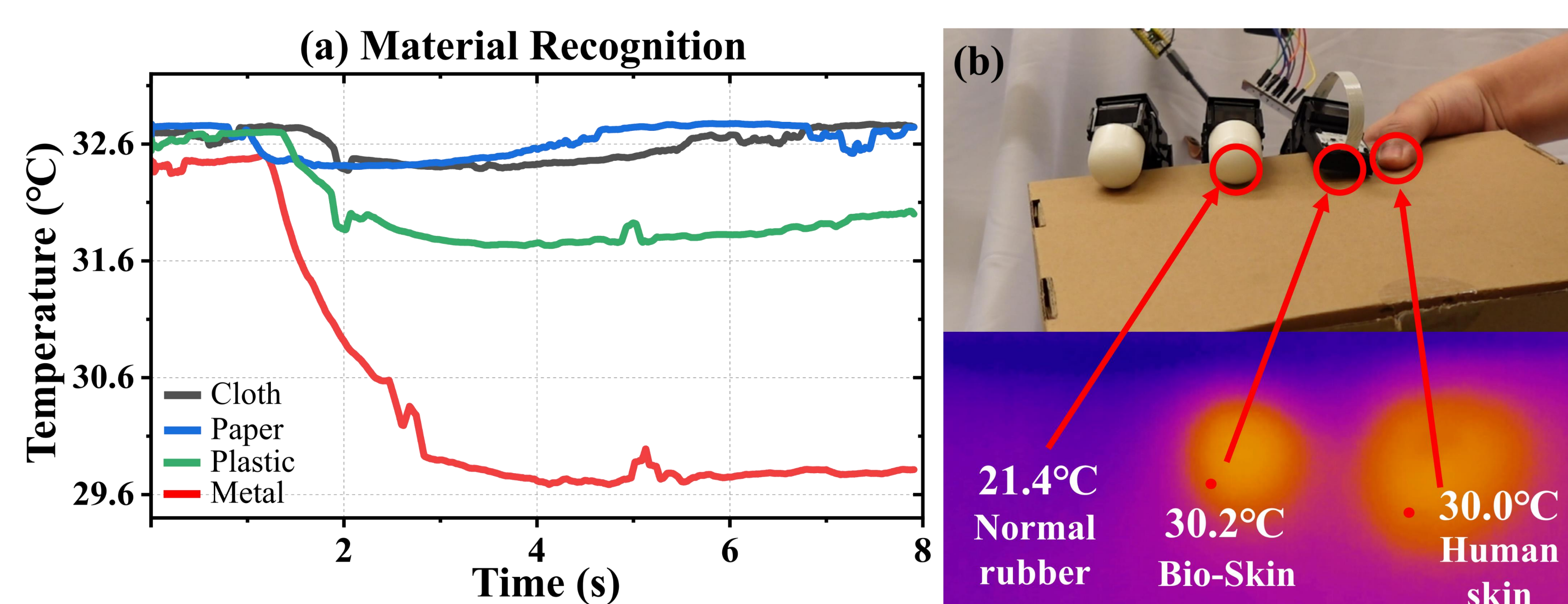
Heating Wire	Controller	Magnet	3D Print
138.80hm/M (\$0.1/each sensor)	ESP32-S3 (\$2.4/each sensor)	Neodymium 5x2mm (\$1/each sensor)	eSun PETG ((\$1/each sensor)
Mux	Silicone Gel	PCB	Thermistor
CD74HC4067M96 (\$0.35/each sensor)	Dragon Skin 10 Fast (\$0.5/each sensor)	JLC PCB (\$2/each sensor)	100kΩ (\$0.2/each sensor)
Hall-effect Sensor	Conductive Film	Other Components	Labor Cost
DRV5056A4QDBZR (\$1.5/each sensor)	Velostat (\$0.1/each sensor)	\$1/each sensor	4~10h (\$60~150/each)

The total material cost for each Bio-Skin sensor is under \$10, excluding labor. This significantly lower cost, at least one-tenth of existing tactile sensors, paves the way for mass production and widespread adoption in humanoid robotics.

## Experimental Results



The force visualization of Allegro Hand fingertip with Bio-Skin while grasping a plastic ball (right) and a metal cup (left), showing distinct normal force distribution and shear force changing.



(a) shows the temperature changing after Bio-Skin touch different materials with temperature regulation on. (b) shows temperature retention by comparing Bio-Skin, human skin and normal rubber.



Paper URL



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