Do-It-Yourself Whole-Body Social-Touch Perception for a NAO Robot

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Motivation

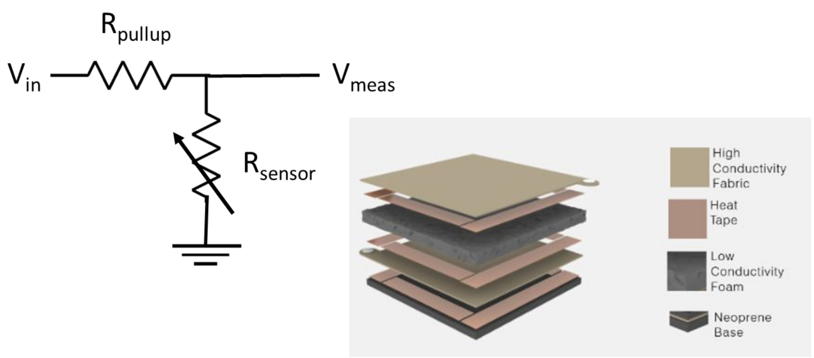
- Social touch is an essential part of our everyday interactions with family, friends, and colleagues.
- Despite its importance, touch perception in social robots is very limited.
- Burns et al. introduced an easy method to add social touch perception to existing robots via external, fabric-based tactile sensors [1].
- We introduce several improvements and additional sensor templates to cover the full body of a NAO robot.

A child gently touches HERA, a NAO robot covered with fabric-based tactile sensors and a soft koala suit [2].

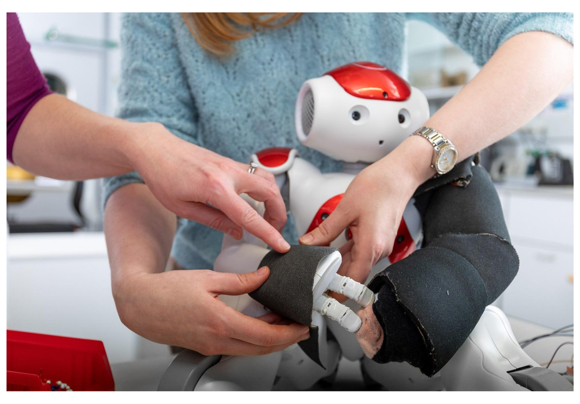
Prior Work: Sensor Fabrication and User Study

Burns et al. introduce fabric-and-foam-based resistive tactile sensors that are easy to make, pleasant to touch, and utilize curved fabrication to match the shapes of existing robots [1].

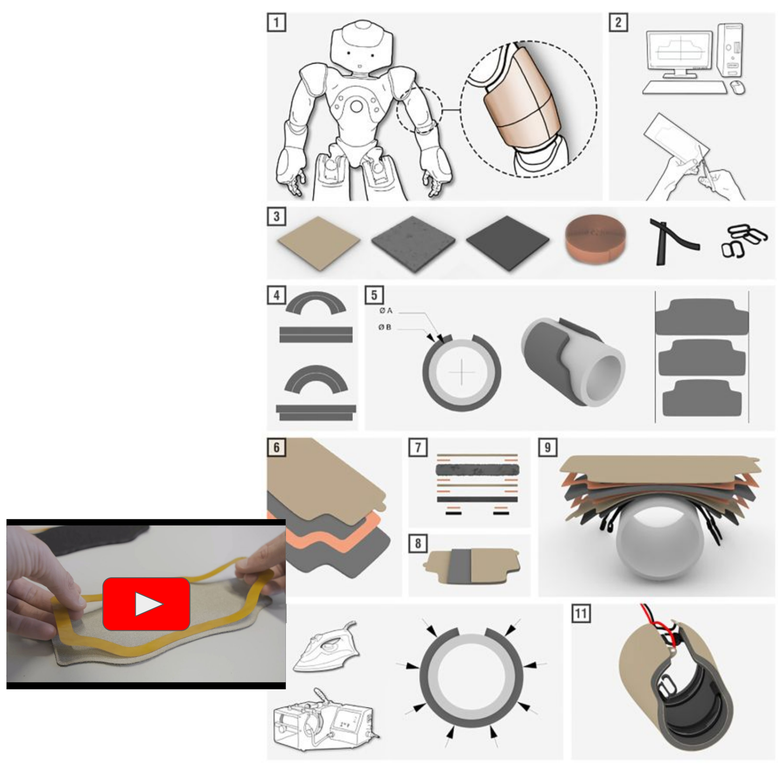
Working Principles: Voltage Divider and Curved Fabrication



Each sensor covers a segment of NAO's arm and operates as a single taxel.



Building a sensor flat and then wrapping it around a surface degrades sensitivity. Instead, the sensor is fabricated along a curvature matching that of the robot's body part.



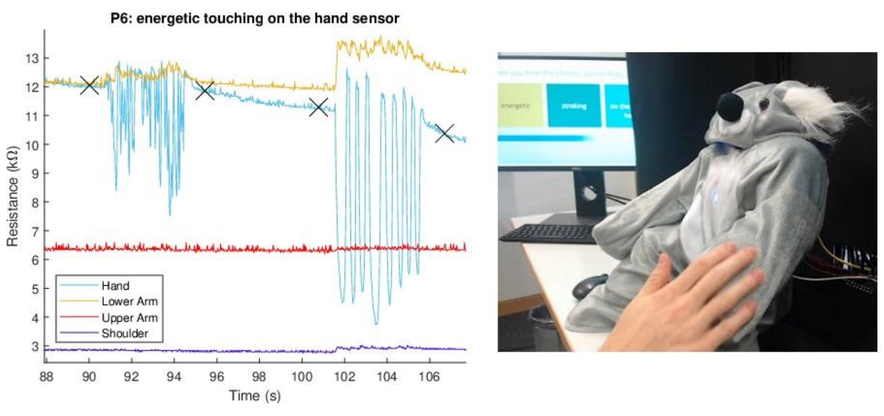
An illustrated guide and step-by-step video for sensor fabrication can be found in the paper and supplementary materials [1].

Study Design

15 participants*
4 sensors across NAO's arm
5 social-touch gestures
2 force intensities
3 repetitions for each five-second trial

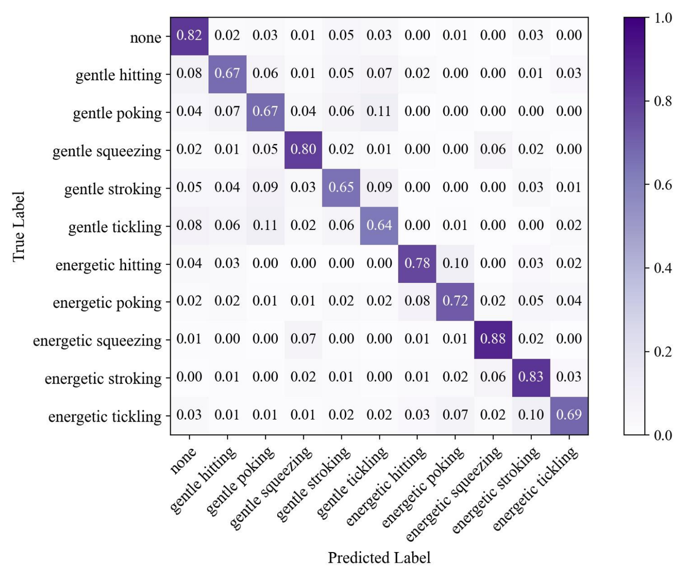
*15 adult participants (Age = 32 ± 5), 7 female and 8 male, from 10 different home countries and ranging in experience with robots.

Dataset of 1800 Touches [3]



In this example, the participant performed an **energetic tickling** gesture on the robot's hand between 90 and 96 s and performed **energetic stroking** on the same body part between 101 and 107 s.

Classification Results



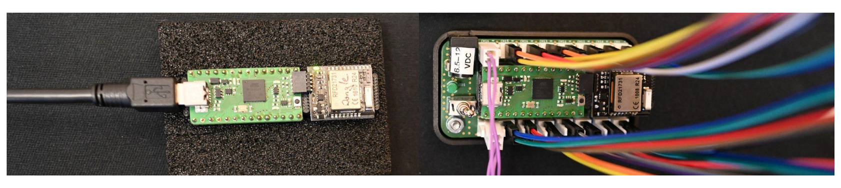
Confusion matrix for classifying combined gesture and force intensity.

Using a gesture-classification algorithm based on a random forest, the combined gesture and force intensity were classified with an average accuracy of 74.1%. Burns et al. also report individual classification accuracies for sensor location, gesture, and force.

Our Improvements: New Hardware, Fabrication Step, and Patterns

Hardware Comparison

Prior Work by Burns et al. [1]	Our Improvements
4 sensors across the NAO's arm	12 additional sensors for 16 total patterns and full-body coverage
Arduino Uno	Custom microcontroller
4 analog inputs	16 analog inputs
40 Hz sampling rate	400 Hz sampling rate (10x faster)
Wired data streaming	Wireless data streaming



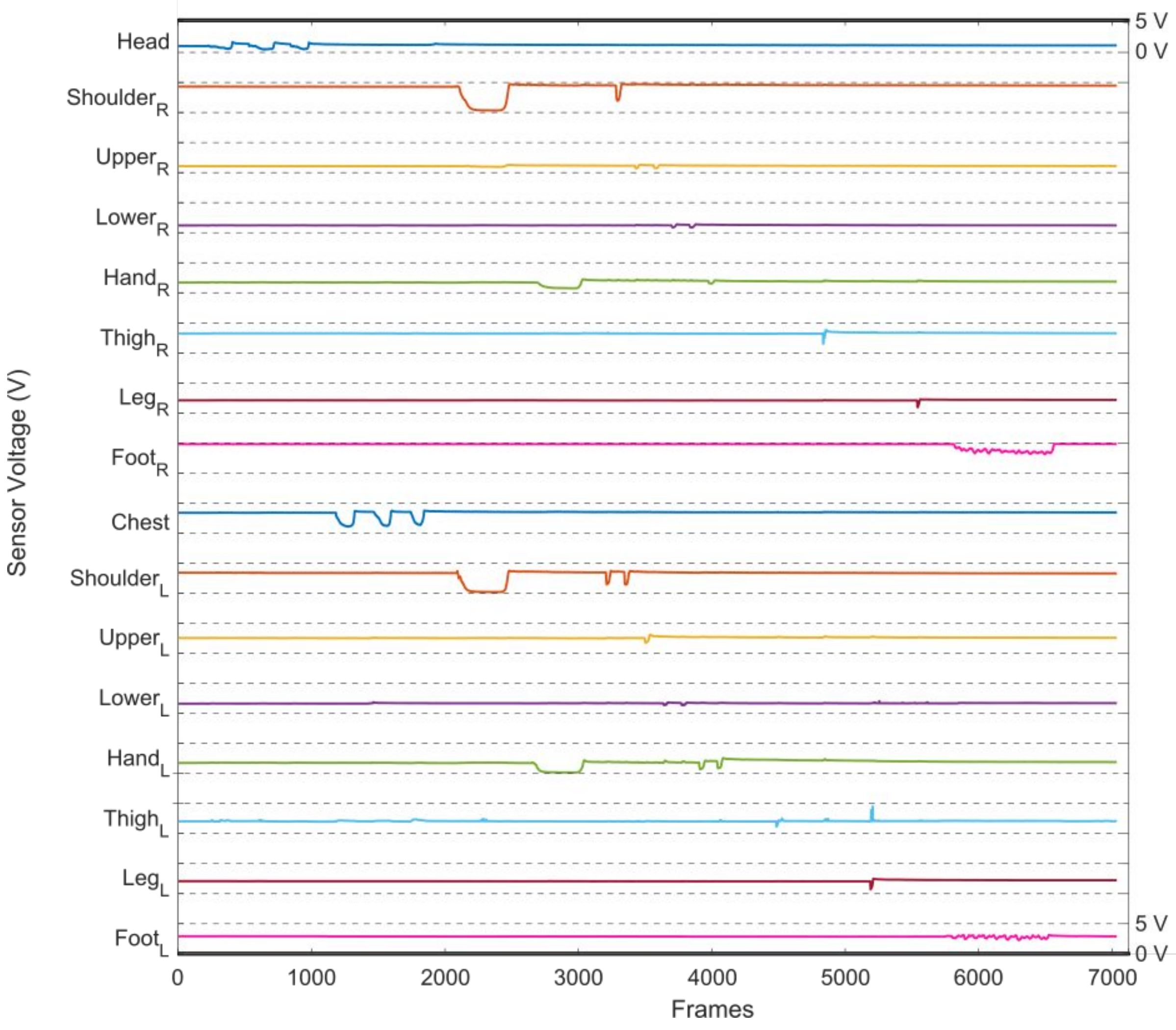
Left: NAO wearing the twelve new sensors we created, along with the original four patterns by Burns et al. Right: The custom receiver and sender components of our microcontroller, which has several hardware upgrades and allows for wireless data transmission.

Fabrication Improvement: Silicone-sealed Sensor Edges

- Prevents electrical interference from neighboring sensors
- Reduces delamination and sensor motion
- Soft silicone ensures sensors still pleasant to touch

New Sensor Patterns

We iteratively designed and built additional sensors to cover NAO's entire body. Scan the QR code to visit the pattern database [4]. Patterns are available in multiple file formats.



Sample touch interactions measured as time-series voltage data across all 16 channels. The user performs stroking on the robot's head, squeezing its shoulders and hands, poking the arms, hitting the legs, and tickling its feet.

References and Acknowledgements

[1] Rachael Bevill Burns, Hyosang Lee, Hasti Seifi, Robert Faulkner, and Katherine J. Kuchenbecker. Endowing a NAO robot with practical social-touch perception. *Frontiers in Robotics and AI*, 9(840335):1-17, 2022. DOI:10.3389/frobt.2022.840335

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[3] Rachael Bevill Burns, Hyosang Lee, Hasti Seifi, Robert Faulkner, and Katherine J. Kuchenbecker. User study dataset for endowing a NAO robot with practical social-touch perception. *Edmond*, Dataset, V1. 2022. DOI: 10.17617/3.6w

[4] Rachael Bevill Burns, Hyosang Lee, Hasti Seifi, Robert Faulkner, and Katherine J. Kuchenbecker. Sensor patterns for endowing a NAO robot with practical social-touch perception. *Edmond*, Dataset, V1. 2022. DOI: 10.17617/3.6x

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