DenseTact 2.0: Optical Tactile Sensor for Shape and Force Reconstruction

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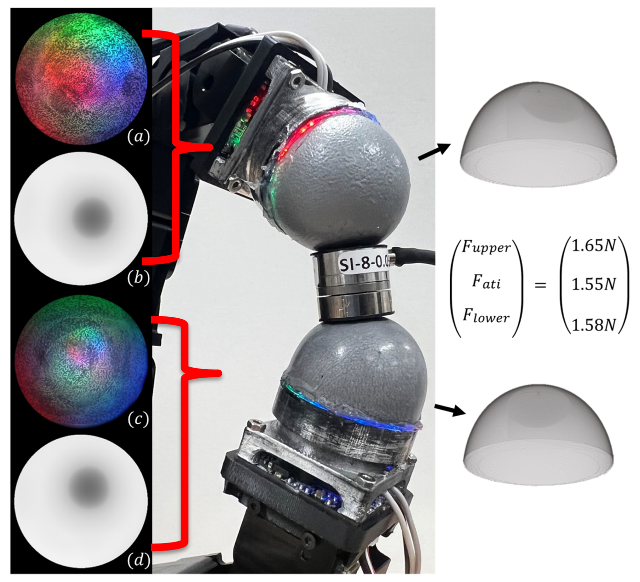
arm.stanford.edu/research/improving-robotic-assistant-dexterity

Motivation and Broader Impact

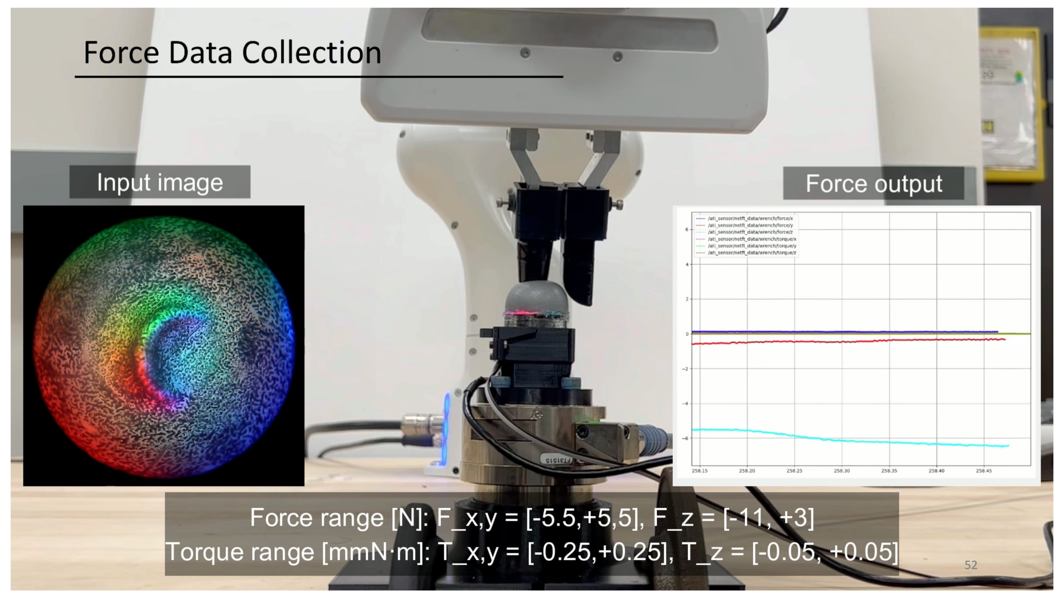
Robots have great ubiquitous potential in domains from generalized industrial assembly to care robots for assisted living. To be effective in these spaces, robots must be able to manipulate objects with dexterity that rivals human performance.

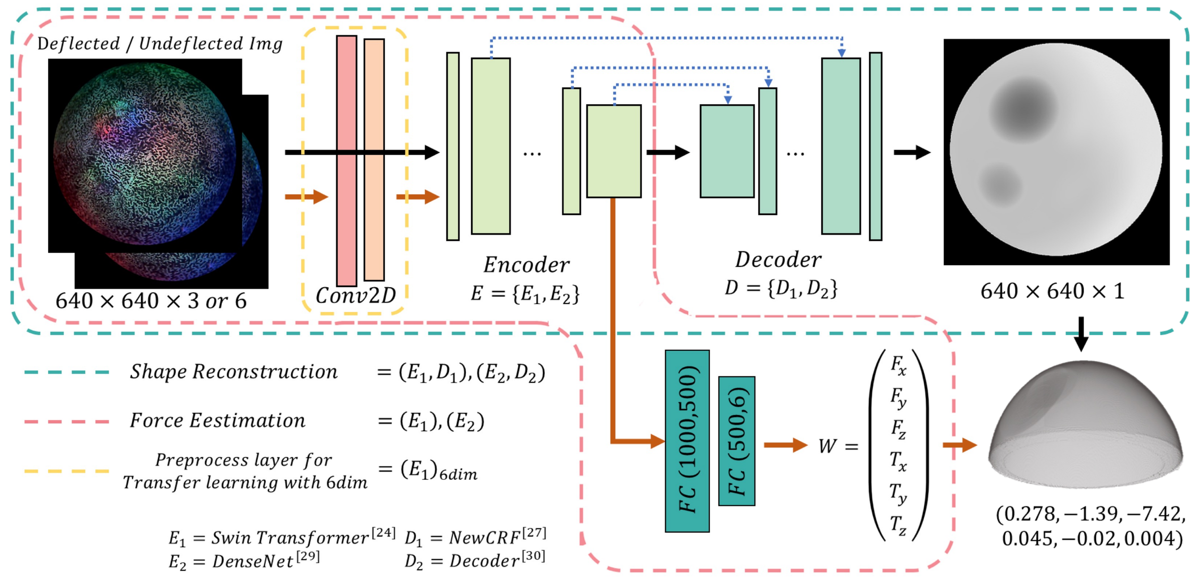
DenseTact2.0 is a calibrated, high-resolution shape and force sensing optical tactile sensor for improved robotic manipulation. This fingertip will enable advanced robotic manipulation strategies in future applications.



Modeling and Calibration

DenseTact2.0's primary contribution is the method of calibrating and learning model of regression for shape reconstruction and wrench estimation. **Shape reconstruction** we press the sensor into an array of known shapes (~30k touches/sensor), we use transfer learning to reduce this to ~4k touches/sensor. **Force Estimation.** We press the sensor with different tips while reading ATI sensor output to map images to wrench. **Model Architecture.** We use an autoencoder as shown, comparing methods SwinTF vs DenseNet (CNN) for estimation.



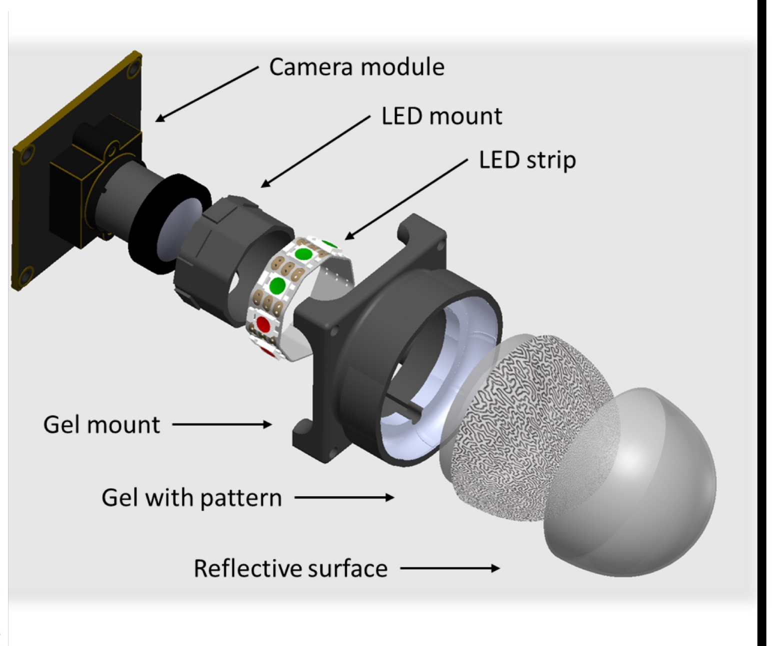


DenseTact 2.0 Design

DenseTact2.0 is the second generation of this sensor which adds 6-axis wrench sensing to the capability of calibrated, high-resolution (pixel resolution) shape reconstruction. The sensor exploded view and comparison to similar sensors is shown below:

Name	Resolution	Force range	Shape
Gelslim 3.0 [11]	640×480	unspecified	full
TaTa [13]	1280×720	$\times$	full
Skin sensor [7]	0.1 mm	$0 \sim 3N, 1$	partial
Softbubble [14]	224×171	$\times$	full
Omnitact [15]	400×400	$\times$	partial
NeuTouch [16]	39	$\times$	$\times$
Romero [17]	640×480	$\times$	full
Optofiber-sensor [18]	61 fibers	$0.03 \sim 8N, 5$	$\times$
GelTip [19]	$\times$	unspecified	partial
Digit [20]	640×480	$\times$	partial
Insight [10]	1640×1232	$0.03 \sim 2N, 5$	partial
DenseTact 1.0 [8]	800×600	$\times$	full
DenseTact 2.0	1024×768	$-11 \sim 3N, 6$	full

TABLE I: **Related Work.** Table shows resolution of sensor, sensing range and dimension of the force, and availability of shape reconstruction. 'Partial' means the sensor does not estimate the depth of the entire sensing area, or estimates only the position of contact.



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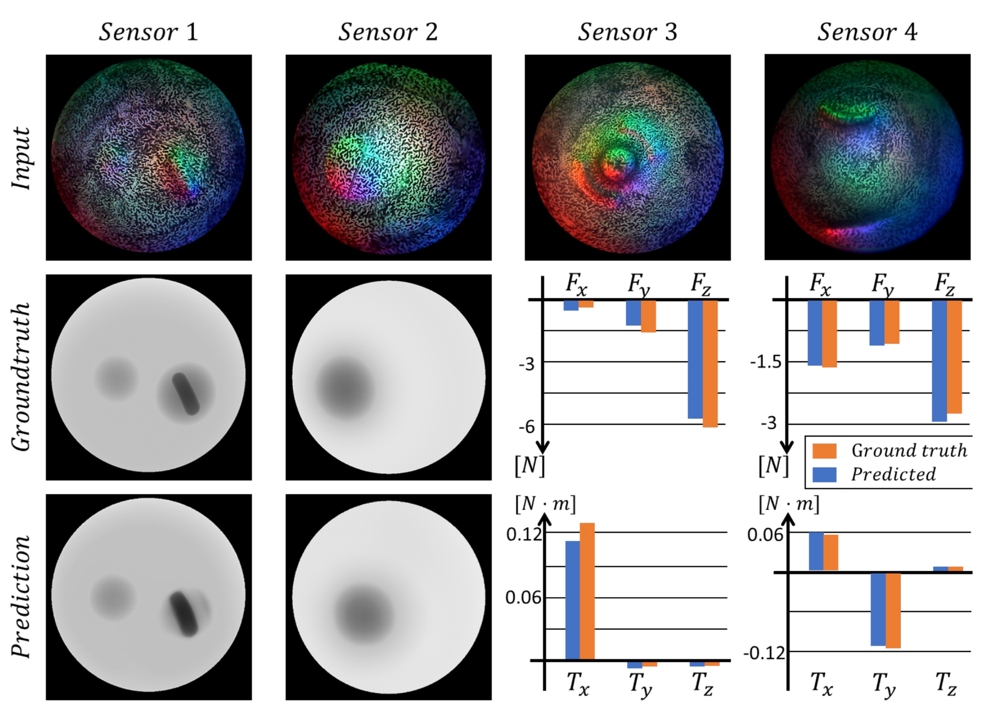
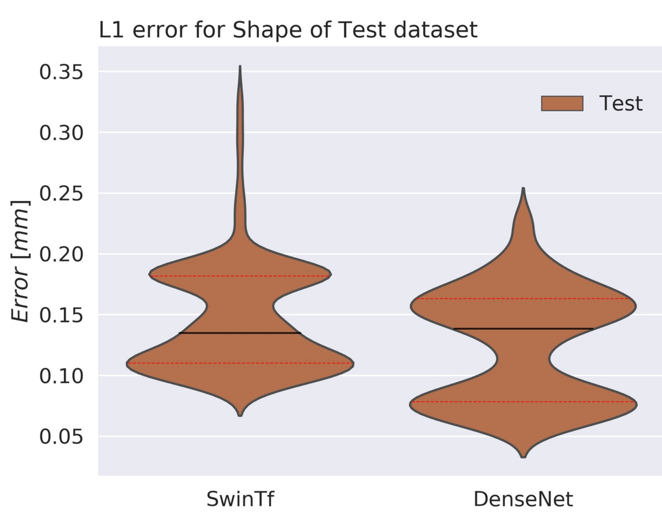
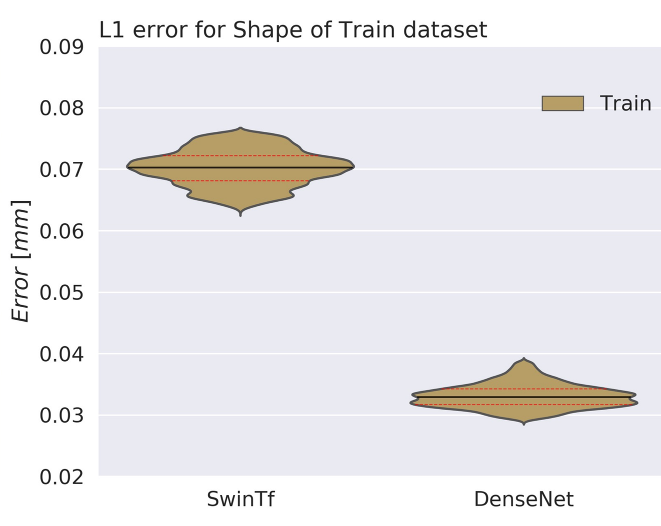
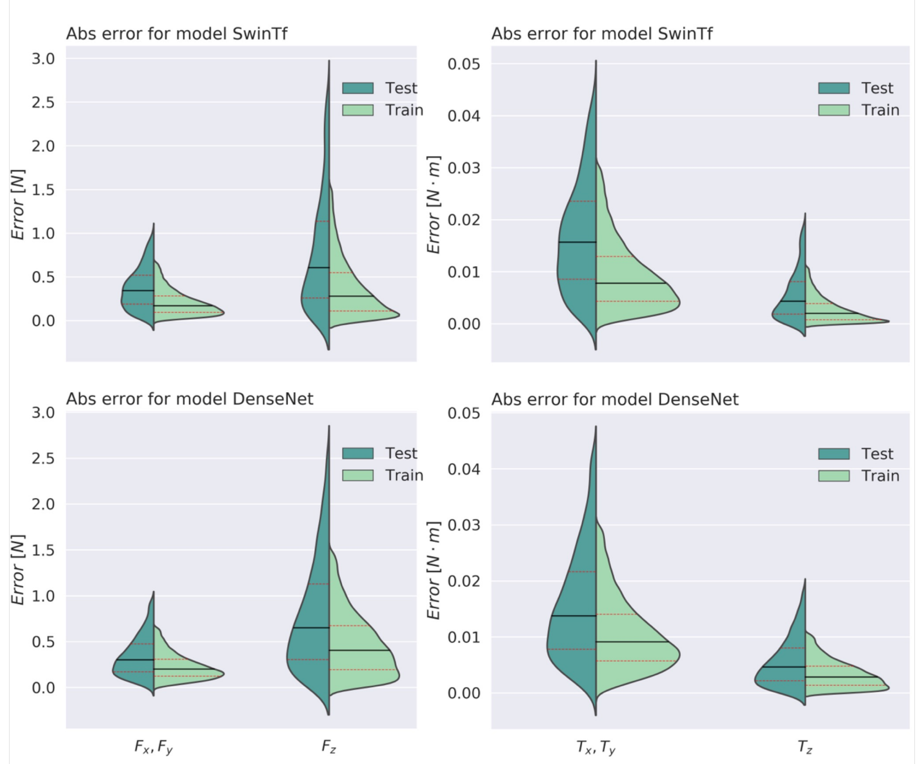
Results

For **shape reconstruction**, we demonstrate an average L_1 loss per pixel of 0.13mm (L_2 of *0.36mm with* DenseNet model, 1000 image hold-out set, 0.78MP camera). For **wrench estimation**, we show an average error of *0.41N for forces*, and *0.387 $N \cdot mm$ for torque*. Transfer learning allows us to use only *12% of the first training iteration dataset size* for both shape and wrench. Bi-modal shape reconstruction distribution is attributed to complex feature detection, with performance bounded under L_1 loss of 0.2mm per pixel.









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