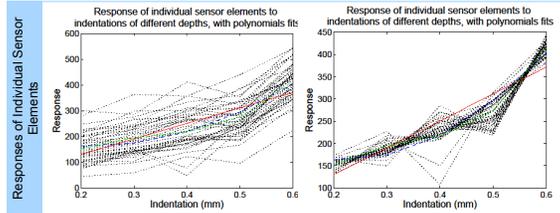


Abstract

The response of a tactile sensor system (consisting of the sensors themselves and the material covering them) was characterized via robotic experiments. A *point spread function* model of this response was developed for typical interaction forces, allowing the use of graphics and imaging techniques respectively for simulating and interpreting tactile sensor readings. This model was implemented in software as a generic artificial tactile sensor simulator, and its accuracy at approximating the output of our test system is demonstrated.

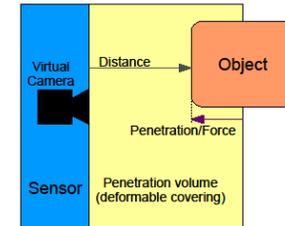
Characterizing Linearity

The covering over each sensing element was indented at 5 depths, in increments of 0.1 mm. A linear fit was applied to each element's response, individually, and used to linearize the output in future experiments.



Simulation Method

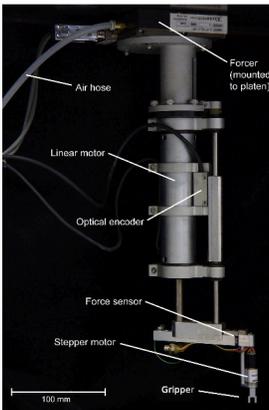
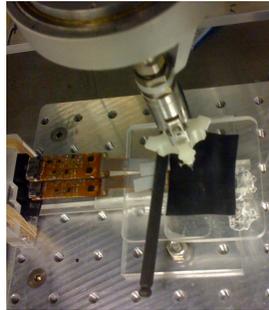
- The sensor is modeled as a camera whose field of view is defined by the material covering it.
- Standard orthographic graphical rendering is used to estimate indentation by objects.



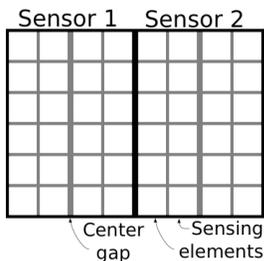
- GLSL shaders are applied to simulate discretization effects, nonuniform response, and point spread.
- This process allows the use of the simulated sensor with any renderable 3D model.

Sensor System and Test Setup

- We used custom-built Digitacts sensors from Pressure Profile Systems. System consisted of two 4x6 sensors, placed side-by-side as shown.
- Output was a 6x8 image with spatial resolution of 2mm.
- The sensors were covered with polyurethane with a durometer rating of 4000 and thicknesses of 0.04", 0.1" or 0.2".
- A robot arm with a cylindrical indenter was used to stimulate each sensor element individually.

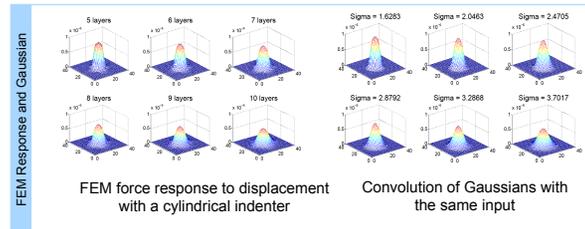
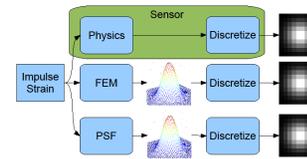


Robot arm used to stimulate the sensors. Figure dapted from [1].

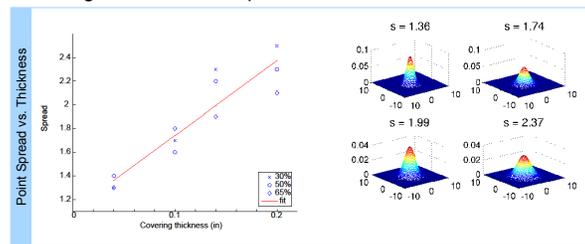


Characterizing Point Spread Function

The effects of the covering were found by finite element modeling to be well-approximated by a Gaussian point spread function.



We fit the parameters of Gaussians to sensor responses at several thicknesses. We found the relationship between covering thickness and spread to be close to linear.



Comparison to Real Sensor

Indenter Used to Compare Simulated Response to Real

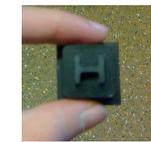
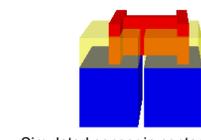


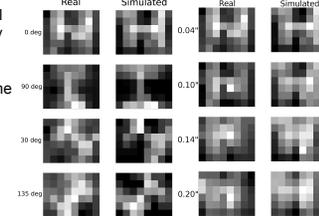
Image of real indenter



Simulated sensor in contact with Simulated indenter

Actual and Simulated Sensor Response to Several Inputs

The simulation model was demonstrated by comparing the actual and simulated responses to the same stimuli, using a real and a simulated version of the same object, applied in different orientations, and with sensor coverings of different thicknesses.



Conclusions

- The response of real tactile sensors can be well-approximated using a point-spread imaging model.
- Tactile sensing can be efficiently simulated by using standard graphical techniques, greatly simplifying the incorporation of tactile sensing models into existing robotic simulation systems.

References and Acknowledgment

- Z. Pezzementi is supported by the Advanced Simulation and Training Fellowship from the Link Foundation.
- This work was supported in part by NSF grants #0722943 and #0748338.
- J. W. Lane, P. J. Fitzgerald, J. M. Yau, I. Pembecki, and S. S. Hsiao. A tactile stimulator for studying passive shape perception. *Journal of Neuroscience Methods*, 2009 (In Press).