Simulation-driven vision-based tactile sensor design

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Sensor design challenges

- Gaussian curvature sensing: Improved contact area
- Use lighting for better illumination of all sensing surface
- Larger contact area
- Wider range of contact locations
- No way to explore new sensor designs

Our approach: sensor simulation framework

- Challenge 1: Specular-Diffuse-Specular (SDS) path
  - Sampling SDS paths require MCMC techniques which exploit previously found paths to generate new paths
- Challenge 2: Probability of sampling longer paths is low and minimum length of useful light path in our sensor is 5

Our approach: simulation model calibration

- High fidelity simulation requires accurate simulation model
- Calibration of light model and coating material BRDF turned out to be critical models for simulation

Results: Analysis of key design space choices on the sensor performance

- Why: Provides high level intuitions on what are the key parameters to optimize and identify parameter ranges to set for optimization
- What: Perturb parameter and perform design evaluation using RGB2Normal score function

Effect of varying thickness of hard base (t1) and soft sensing volume (t2)

- Thinner soft sensing (PDMS) volume leads to better sensing performance. It is due to light entering and leaving the region with minimum distortion.

Effect of index of refraction of hard base (n1) and soft sensing volume (n2)

- Higher contrast in IDRs between 2 sensor materials (hard base and soft sensing volume) leads to better sensor performance.

Note: Matching IDR is a non-physical case and has been removed from the results

Effect of variation of innermost (Epoxy) sensor surface shape

- Epoxy surface which is flatter at the top to have higher performance consistently and better illumination of indented sensor surface.