ASSISTIVE FEEDING USING FINGERTIP TACTILE SENSORS WITH RICH HAPTIC FEEDBACK

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BACKGROUND

- Assistive Dextrous Arm (ADA), a Personal Robotics Lab project: making a way to feed those who can't feed themselves, with a robotic arm
- ADA uses custom fork with built-in force-torque (F/T) sensor to detect food, but would like to generalize to use any fork


Image: PRL

Why is force-sensitivity necessary?

- Control forces while skewering to account for food compliance and deformability
- Detect bite acquisition from plate
- Detect and safely stop during bite transfer to mouth

Why are are force-sensitive *fingers* necessary?

- Fingers can allow a wide variety items to be picked up, instead of relying on a custom utensil
- Force sensitive finger wires do not get in the way and can be integrated with existing computer
- Force sensitive fingers can be less expensive than an F/T sensor

DESIGN PROCESS

Above:

First GelSight prototype

Below:

What GelSight sees when sensing a force

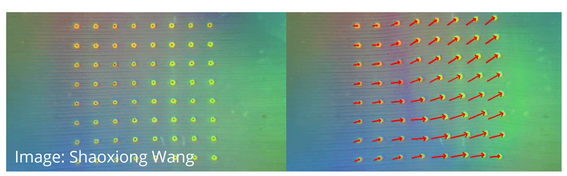
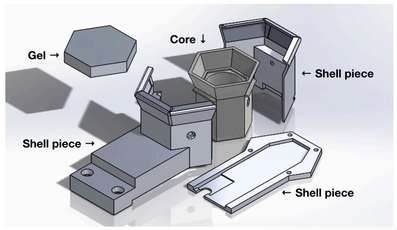


Image: Shaoxiong Wang

Chosen design: GelSight

- Created in the Adelson Lab at the Massachusetts Institute of Technology
- Chosen due to simplicity, sensitivity, and robustness
- How it works:
  - Grid of dots on silicone, covered with gray layer
  - Internally illuminated
  - Internal camera records dot displacement
  - Dot displacement is converted to force

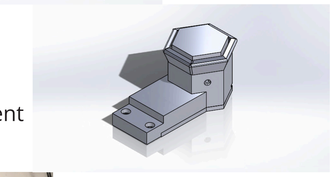


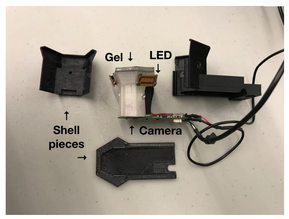
Below and left:

CAD model of original GelSight with exploded view showing 3D printed parts and gel

Below:

Teardown of GelSight protoype, showing 3D printed shell, translucent core, and electronics





- Gel is attached to hexagonal acrylic plate and glued to core
- Three LEDs are attached to the core to illuminate dots on gel

Trip to Boston

Visited Adelson Lab in **December 2019** to meet with GelSight researchers:

- Created our first GelSight prototype
- Learned how to manufacture dot grid
- Changed dot color to yellow from black to allow dots to be "removed" by turning off camera color channel
- Experimented with software and received new software package

Challenge: make GelSight finger-sized so it can fit on the Kinova gripper


Image: Kinova

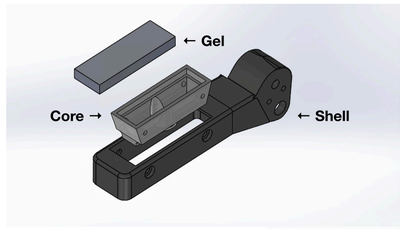
My work since December has been focused on miniaturizing Gelsight

Goals:

- Create force-sensitive alternative to existing Kinova gripper fingers
- Keep finger design simple
- Replace the top segment of the gripper finger

Challenges:

- Work with proprietary Kinova hardware
- Create a reliable, effective design

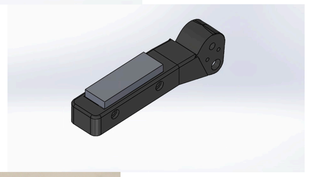


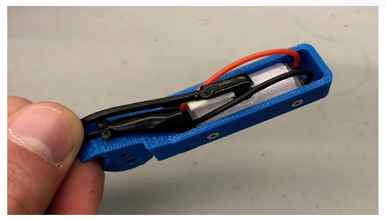
Below and left:

CAD model of fingertip GelSight with exploded view showing 3D printed parts and gel

Below:

Backside of assembled fingertip GelSight protoype, showing camera and LED wires





- Shell is one piece for simplicity
- One LED on each end of the core provides illumination

Design highlight: camera choice


Image: CitiScan


Image: MISUMI

Logitech C310 Webcam	Misumi TD-BL31105
> Large: webcam sized	> Small: fingernail sized
> 720p	> 1080p
> 60° field of view	> 158° field of view

Small, wide angle camera allows a smaller finger with a longer silicone gel pad

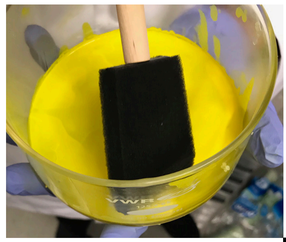
MANUFACTURING PROCESS

Manufacturing process

1) 3D print parts
2) Pour silicone
3) Create tracking dots
4) Add protection layer
5) Assemble with camera and LEDs
6) Install on Kinova hand

Above:

3D printed parts before assembly



At left:

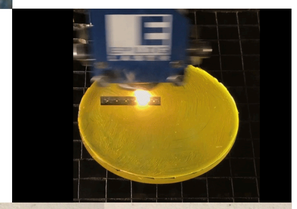
- 3-6mm layer of transparent silicone poured into container and cured
- Very thin yellow silicone layer added on top after curing

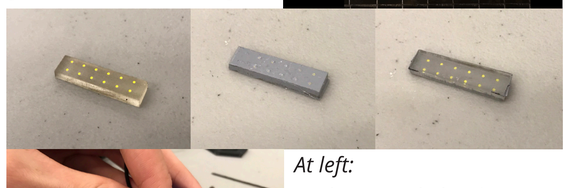
At right:

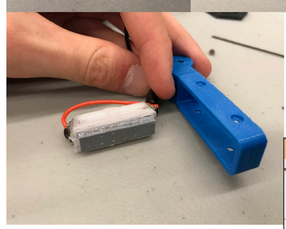
Laser removes yellow layer to create dot pattern

Below:

Thin gray layer added to gel to block external light







At left:

- Silicone gel glued to core
- LEDs glued to core sides for internal illumination

At right:

Complete fingertip GelSight attached to Kinova gripper, replacing original fingertips

FUTURE WORK

Design > Build > Test

- Increase grip strength
- Rectification for wide angle lens and more dots
- Improve sensitivity and accuracy of force feedback: approach sensitivity of F/T sensor
- Decrease camera latency and increase frame rate
- Improve hardware robustness and appearance

References:

Bhattacharjee, Tapomayukh, et al. "Towards Robotic Feeding: Role of Haptics in Fork-Based Food Manipulation." IEEE Robotics and Automation Letters, 2019

Song, Hanjun, et al. "Sensing Shear Forces During Food Manipulation: Resolving the Trade-Off Between Range and Sensitivity." IEEE Robotics and Automation Letters, 2019.