Today’s Class

- Questions about Projects
- Lab 1 due Thursday
  - Lab 2 will likely be assigned this Thursday
- Tactile Feedback Devices
- Readings:

Tactile Feedback
(also know as Tactile Display)

- Distinguish between haptic and tactile feedback
  - Tactile = Cutaneous = Skin Sensation
  - Haptic = Kinesthetic + Some Skin Sensation
    = Kinesthetic + Tactile

- Tactile Display (has two meanings)
  - An action
    (e.g., that type of stimulus can be tactilely displayed using a pin array)
  - A physical device
    (e.g., please attach your tactile display to that kinesthetic display)

- Tactile Displays excite a variety of mechanoreceptors
- Most common Display types
  - Vibrotactile
  - Pin arrays
    - Vertical
    - Lateral
  - Electrotactile
Electrotactile- Electrostatic Pin Arrays

- TeslaTouch: Electrovibration for Touch Surfaces (Olivier Bau, Ivan Poupyrev, Ali Israr, Chris Harrison)

- Electrotactile feedback


Vibrotactile Feedback

- Sensory substitution – vibrotactile feedback to replace force feedback

[Murray, Klatzky, Khosla, Psychophysical Characterization and Testbed Validation of a Wearable Vibrotactile Glove for Telemanipulation Presence, 12(2) 2003]

[Kontarinis & Howe 1995]
Pin Arrays
- RC servo driven

Tactile Feedback in Telemanipulation

Pin Arrays
- Electromagnetic Rocker Arm Mechanism

Pin Arrays
- Linear DC Motors

Pin Arrays
- Stimulate primarily SA, type II receptors

[Wagner, et al. 2002]
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[Kammermeier, et al. 2000]
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[Goodfellow, et al. 2008]
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[Pawluk, et al. 1998]
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Pin Arrays (Stimulate primarily SA, type II receptors)

- Shape Memory Alloy (SMA) coil springs
  - 8x8 pin array
  - 0.5 N force
  - 3.5 mm pin stroke
  - 0.1 mm stroke accuracy

Advantages
- Moderately compact
- High pin density

Disadvantages
- High power consumption
- Low pin force

-Fisher 1996-

Telemanipulation with Capacitive Pressure Array and SMA Pin Array

- Shape Memory Alloy (SMA)
  - Cantilever beam and SMA pullwire design

-[Hasser, et al. 1993]-

[Top View]

-[TiNi Inc.]-

Disadvantages
- 0.1 mm stroke accuracy

- Compact Braille Display

- 0.5 N force

- 3.5 mm pin stroke

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[Bottom View]

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[Kontarinis, et al. 1995]
Applications for telesurgery

- Capacitive Pressure Sensor
- SMA Pin Array

Harvard Biorobotics Lab

(Pawluk ‘97)


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Pin Arrays

- Pneumatic

Advantages
- Simple mechanical design
- Conforms to fingertip

Disadvantages
- Requires air pressure source
- Bulky (routing air lines)
- Relatively Low B/W


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Disadvantages
- Requires air pressure source
- Poor control over pin height
- Bulky (routing air lines)
- Relatively Low B/W

[Moy, et al. 2000]

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- Simple mechanical design
- Conforms to fingertip

Disadvantages
- Requires air pressure source
- Bulky (routing air lines)
- Relatively Low B/W


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- Simple mechanical design
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Pin Arrays

- Piezoelectric

Advantages
- High B/W
- High pin density
- Relatively compact design

Disadvantages
- Frangible
- High voltage source for actuators
- Small pin stroke length?

[Summers & Chantner 2002]
**Pin Arrays on Consumer Products**

- Piezoelectric

  ![Image of a piezoelectric pin array](image)

- MEMS electrostatic pin array

  ![Diagram of a MEMS electrostatic pin array](image)

  **Advantages**
  - High pin density
  - Potential for mass production via MEMS/VLSI processing

  **Disadvantages**
  - Low stroke length of pins
  - Low force level

- Air Chamber

  ![Diagram of an air chamber](image)

  **Advantages**
  - High pin density
  - Potential for mass production via MEMS/VLSI processing

  **Disadvantages**
  - Requires a pump for vacuum
  - Currently has low "pin" density
  - Bulky (routing air lines)

- Vacuum/Suction Pin Array

  ![Diagram of a vacuum/suction pin array](image)

  **Advantages**
  - Simple mechanical design
  - Can not display profile shapes

  **Disadvantages**
  - Requires a pump for vacuum
  - Currently has low "pin" density
  - Bulky (routing air lines)

[Homma, et al. 2004]

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Electrorheological Tactile Display

For sensing finger forces

Tactile feedback via magnet array

• Magnets glued to skin

More vibrotactile than pressure sensation

Pin Arrays

• Other types
  ▪ Solenoids [Fischer 1995]
  ▪ Ultrasonic
  ▪ MR
  ▪ …

Lateral Skin Shear

• Skin shear via piezoelectric actuation

[Hayward & Cruz-Hernandez 2000]
Pin Arrays with laterally moving pins, cont.

Lateral Skin Shear, Virtual Braille Dots

Display of Virtual Braille Dots by Lateral Skin Deformation: A Pilot Study

J. Pasquero  M. Legault
V. Lévesque  V. Hayward

Tangent Plane Display


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Simulating curvature via tangent plane

[Dostmohamed & Hayward 2004]

Slip Displays

Through-hole for index finger

Hole in outer handle to contact inner rotating mandrel

Combined tactile and kinesthetic display

[Salada, et al. (2002-5)]

Variable Friction Shear Display


TPaD: Tactile Pattern Display.

ShiverPaD

- Concept
- Alternate motion & change of friction
- ~.25mm motion currently from voice-coil at 40-220Hz
- TPaD ~2 μm at 40 KHz
- ShiverPaD 2 ±20 μm 854 Hz

Skin Stretch Feedback

- Fingertip Skin Stretch Feedback for Haptic (Directional) Guidance & Sensory Substitution

Current Hot Areas of Interest of Haptics and Tactile Display

- Displaying skin shear / skin stretch with variable friction
- Multi-finger manipulation
- Simple tactile display for consumer electronics (PDAs, Cell Phones…)
  - Primarily vibrotactile and now electrostatic/electrotactile

Current Challenges of Haptics and Tactile Display

- Fusion of multiple display types (e.g., tactile pin array and shear)
- Miniaturization