Today’s Class

- Tactile Feedback Devices

Readings: No readings
- Work on HW
- Work on getting together with your project partner and writing a couple of paragraphs for 1 or 2 proposed projects

Tactile Feedback (also known 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 Feedback (also known as Tactile Display)

- Tactile Displays excite a variety of mechanoreceptors
- Most common Display types
  - Vibrotactile
  - Pin arrays
    - Vertical
    - Lateral
**Vibrotactile + Force Feedback**

- Sensory substitution – vibrotactile feedback to replace force feedback

![Diagram of vibrotactile feedback system](image)

**Vibrotactile Feedback**

- RC servo driven

**Pin Arrays**

- FM Condition (increased range of sensation)

![Diagram of pin arrays](image)

---

**[Kontarinis & Howe 1995]© W. Provancher 2009**

---

**[Kontarinis & Howe 1995]© W. Provancher 2009**

---

**Pin Arrays**
- RC servo driven

**Tactile Feedback in Telemanipulation**

[Wagner, et al. 2002]

---

**Pin Arrays**

- Electromagnetic Rocker Arm Mechanism

![Diagram of Electromagnetic Rocker Arm Mechanism](image)

[Kammermeier, et al. 2000]

---

**Pin Arrays**

(Stimulate primarily SA, type II receptors)

- Linear DC Motors
  - Remote actuator box
  - Pull wires

![Remote actuator box with pull wires](image)

Johns Hopkins Somaticsensory Lab: Dianne Pawluk

[Pawluk, et al. 1998]

---

**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

[Shape Memory Alloy (SMA) coil springs example](image)

[Fisher 1996]
Pin Arrays
(Stimulate primarily SA, type II receptors)

- Shape Memory Alloy (SMA) coil springs
  - Compact Braille Display

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

Telemanipulation with Capacitive Pressure Array and SMA Pin Array

Applications for telesurgery
- Capacitive Pressure Sensor
- SMA Pin Array

Harvard Biorobotics Lab

(Pawluk ‘97)


Pin Arrays

- **Pneumatic**

  **Advantages**
  - Simple mechanical design
  - Relatively Low B/W Low B/W

  **Disadvantages**
  - Requires air pressure source
  - Bulky (routing air lines)
  - Poor control over pin height

  [Cohn, et al. 1992]

- **Piezoelectric**

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

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

  [Summers & Chanter 2002]

Pin Arrays on Consumer Products

- **Piezoelectric**

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

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

  [Summers & Chanter 2002]
Pin Arrays
- MEMS electrostatic pin array

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

Disadvantages
- Low stroke length of pins
- Low force level

[Fedder & Lopez referenced in Siegel 2002]

Vacuum/Suction Pin Array
- Palm and finger scale suction arrays
  - Feels similar to little electrical shocks

Advantages
- Simple mechanical design
- Can not display profile shapes

Disadvantages
- Requires a pump for vacuum
- Currently has low “pin” density
- Bulky (routing air lines) [Shinoda 2004]

Electrorheological Tactile Display
- For sensing finger forces

Figure 1: Cross-section of ER sensor and tacter [Voyles, et al. 1996]
Tactile feedback via magnet array

- Magnets glued to skin

More vibrotactile than pressure sensation

[Asamura, et al., 1998]

( http://www.alab.t.u-tokyo.ac.jp/%7Eshinolab/research/asamura/TF_Display2.html )

© W. Provancher 2009

Lateral Skin Shear

- Skin shear via piezoelectric actuation

[Breslav, et al. (2002)]

© W. Provancher 2009

Pin Arrays with laterally moving pins, cont.

-Hayward, et al. (2003-7)

Fritschi, et al. (2006)

"STReSS2" [Wang, et al. (2006)]

© K. Kuchenbecker 2008 + W. Provancher 2009

Lateral Skin Shear, Virtual Braille Dots

- Mechanical design of the tactile Shear Force Display

Fritschi, et al. (2006)


© W. Provancher 2009
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


© W. Provancher 2009

Pin Arrays

- Other types
  - Solenoids [Fischer 1995]
  - Ultrasonic
  - MR
  - ...

Tangent Plane Display

Simulating curvature via tangent plane

κ = 1/γ

[Dostmohamed & Hayward 2004]
Slip Displays

Variable Friction Shear Display

Shear Motion Display

Contact Display Prototype
Current Hot Areas of Interest of Haptics and Tactile Display

- Displaying skin shear / skin stretch
- Multi-finger manipulation
- Simple tactile display for consumer electronics (PDAs, Cell Phones…)
  - Primarily vibrotactile

Current Challenges of Haptics and Tactile Display

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