Music at Your Fingertips: An Electrotactile Fader

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~~Human-Computer~~ Interfaces

Human-Console Interfaces

Channel	Input	Output
Visual	Gestures? Eye-tracking?	See positions of faders etc.; 2D/3D visualization?
Aural	Voice control?	Audio playback; button clicks; sonification?
Haptic/Tactile	Set faders etc.	Feel the positions of faders etc.

The Idea

- Augment a fader by tactile output
- Facilitate blind operation
- Examples for uses:
  - Virtual detents/markers
  - Track identification

Outline

- Basics
  - Mechanical Solution
  - Electrotactile Interfaces
- System Prototype
  - Hardware
  - Components
  - Position and level discrimination
- Applications
  - Virtual markers/detents
  - Track identification
- Conclusion

Basics

Mechanical Solution?

- **Vibration:**
  prone to generate acoustic noise
- **Through the fader's motor?**
  Reduces resolution
- **Through special actuators?**
  Non-standard, expensive

Electrotactile Interfaces (1)

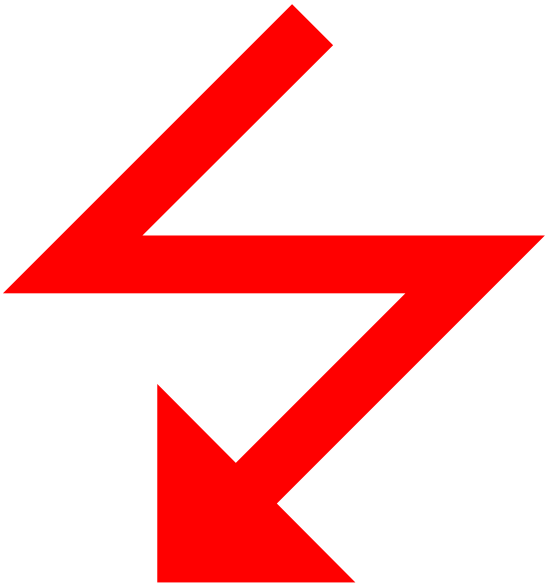
- Series of short-time (< 1 ms, > 30 Hz) low-power pulses applied to the skin
- Varying quality of contact:
  Fixed voltage (e.g., 200 volts)
  imperceptible or painful;
  better use controlled current (< 1 mA)
  [Kaczmarek et al. 1994]
- Positive voltage at active electrode for better response [Kaczmarek et al. 1994]
- Sensation: “pins and needles”

Electrotactile Interfaces (2)

- Currently researched into for:
  - Interfaces for the blind
  - Virtual reality with haptics
- Related areas:
  - Cochlear implants
  - Muscle stimulation

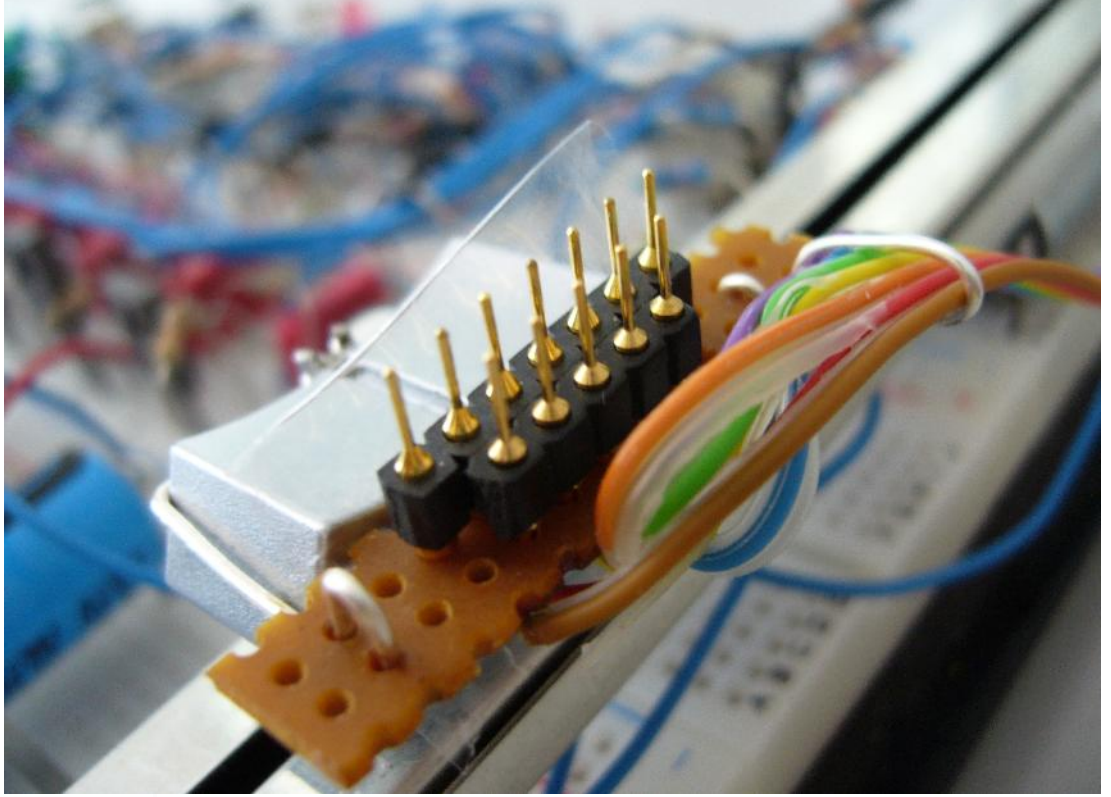
Safety Notes

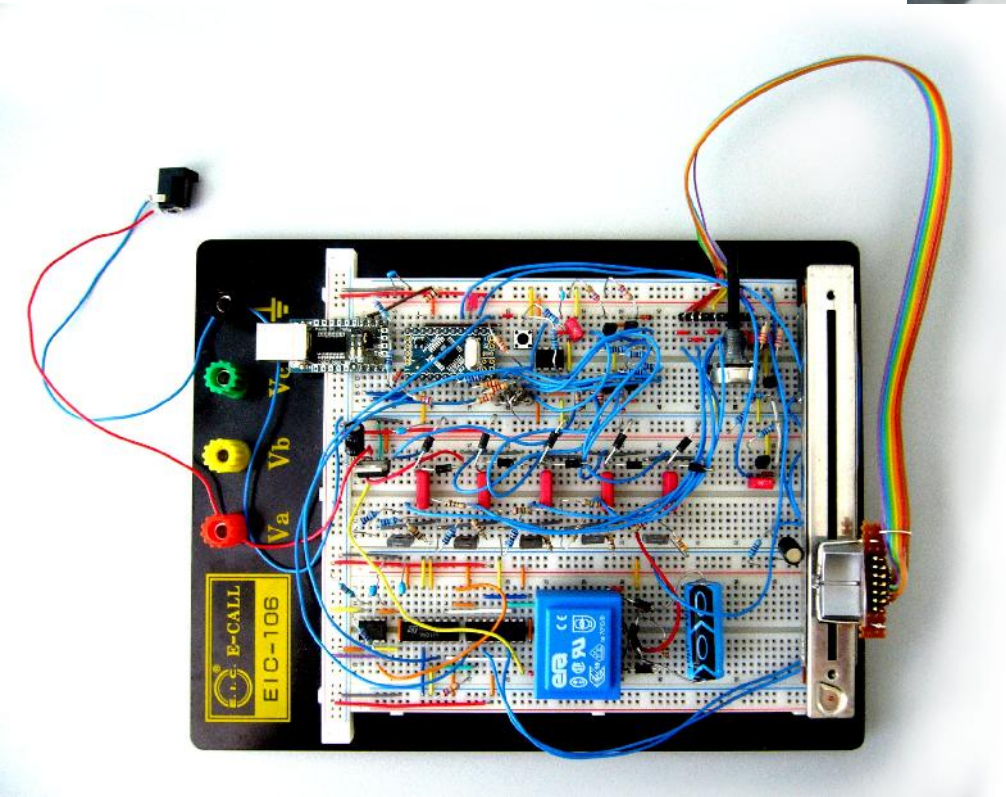
- High voltages potentially dangerous
  - Malfunction may lead to high currents
  - Interference with pacemakers etc.
- Long-term effects to skin/nerves?
- Fatigue?

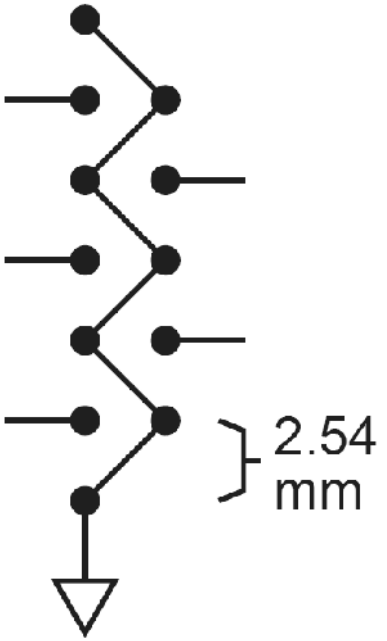


System Prototype

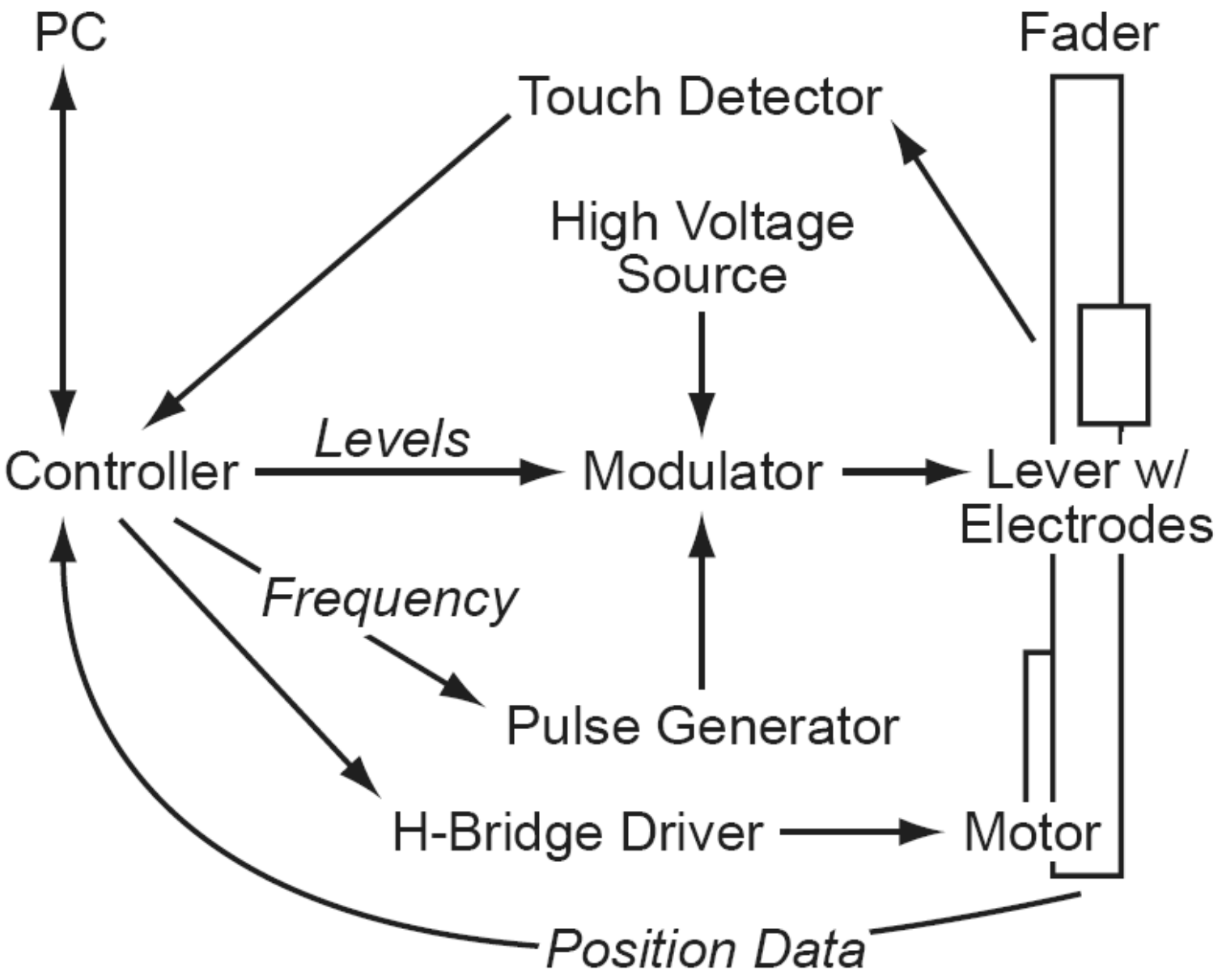
Hardware







Components


PC
Fader
Touch Detector
High Voltage Source
Levels
Controller
Modulator
Lever w/ Electrodes
Frequency
Pulse Generator
H-Bridge Driver
Motor
Position Data

Voltages, Currents, Frequencies

Finger	Hand	Frequency	Minimum		Maximum	
		Hz	V	mA	V	mA
Index	R	40	94	0.21	102	0.30
Index	R	120	96	0.20	112	0.26
Little	L	40	86	0.19	98	0.33

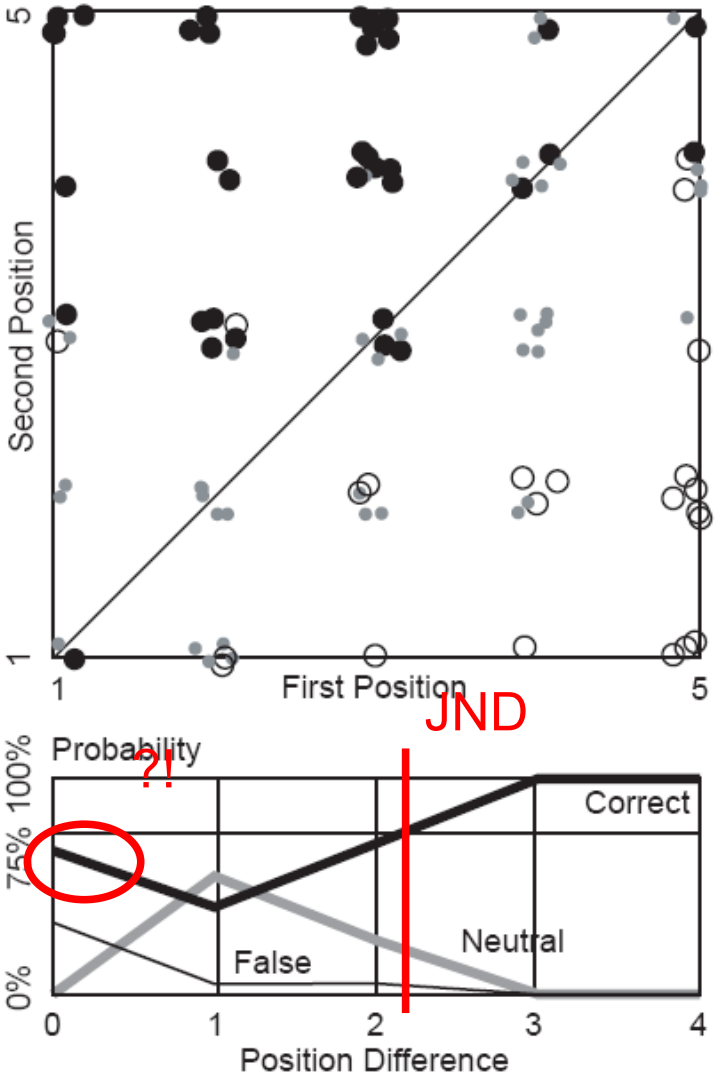
- Firing rate makes little difference in perceived frequency of “pins and needles.”
- Clear variations between fingers

Position Discrimination (1)

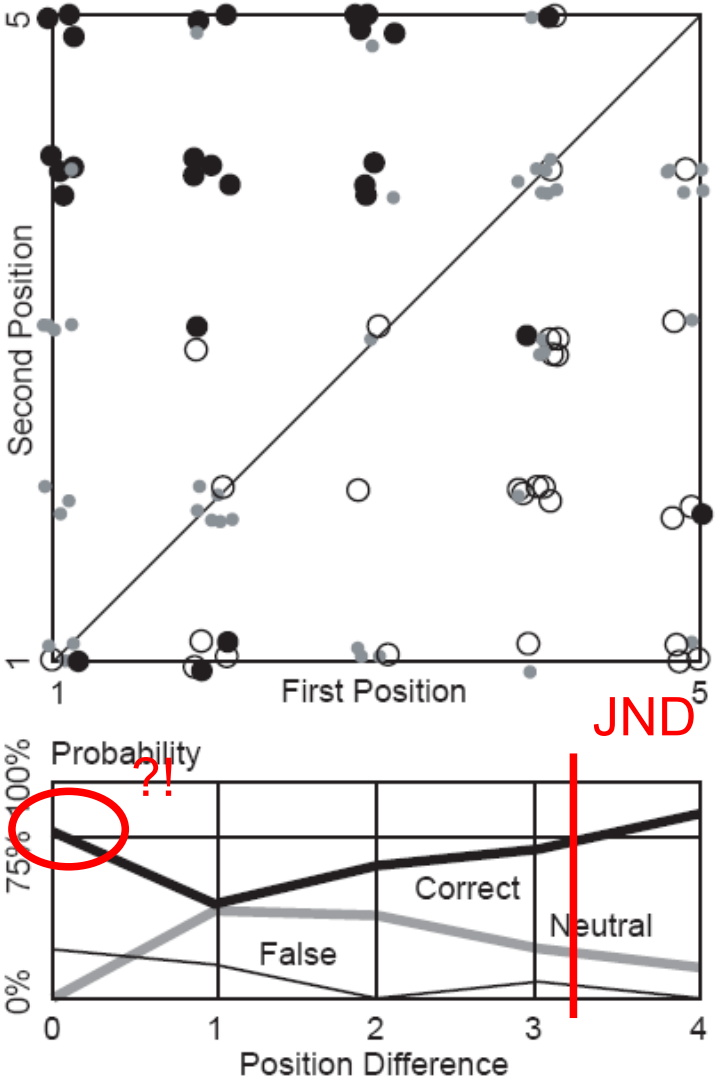
- **Optimum distance:**
  Difference between the electrodes
  is at the threshold of perception.
  (JND: just noticeable difference)
- **Test: Present a sequence of test stimuli;**
  was the current stimulus perceived
  at the position of the previous stimulus
  or above or below?

Position Discrimination (2)

40 Hz, 0.5 s



120 Hz, 0.1 s

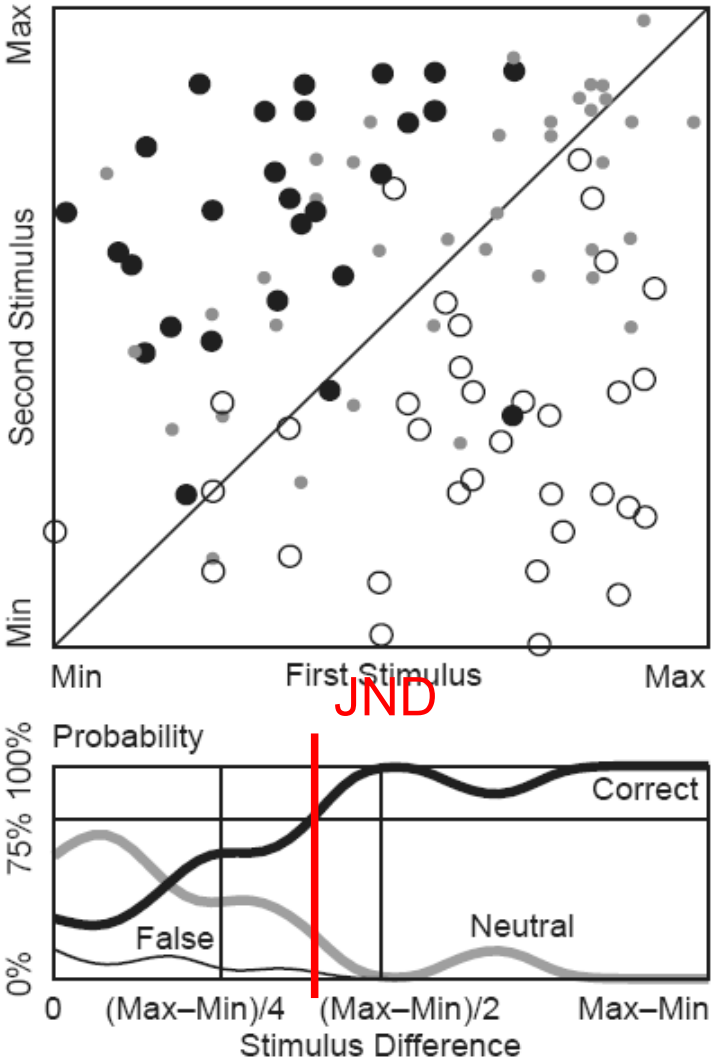


Level Discrimination (1)

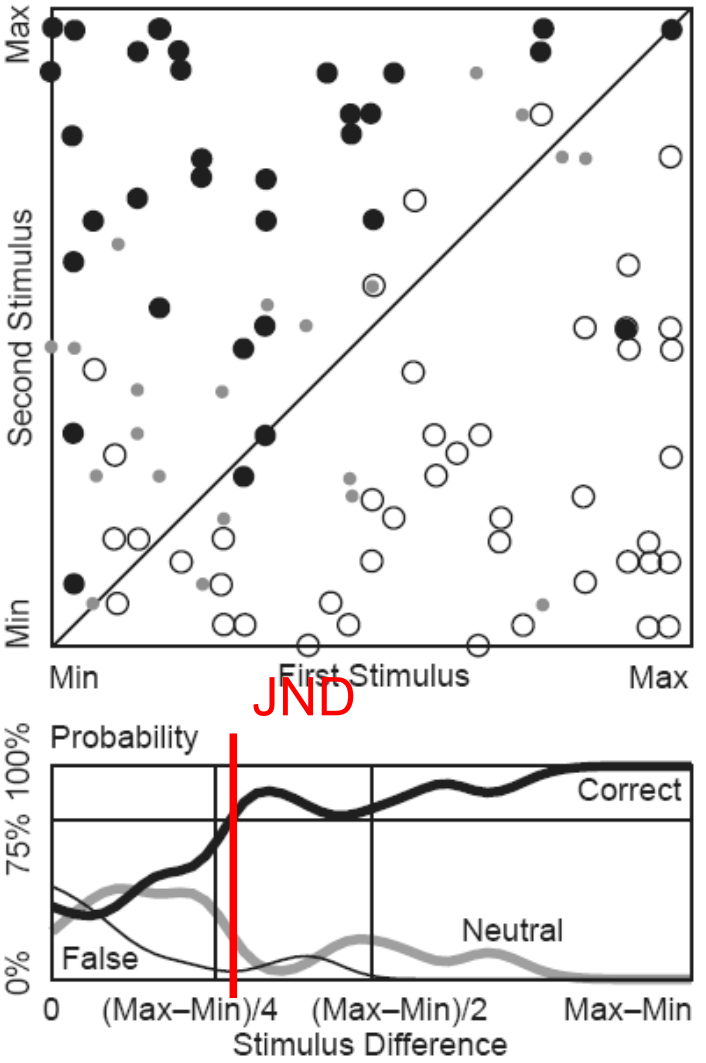
- Can also control the current that is applied: additional information channel
- New question in electrotactile devices: How wide is this information channel? That is: How many JNDs from min (barely perceptible) to max (begins to hurt)?
- Similar test

Level Discrimination (2)

Right index finger

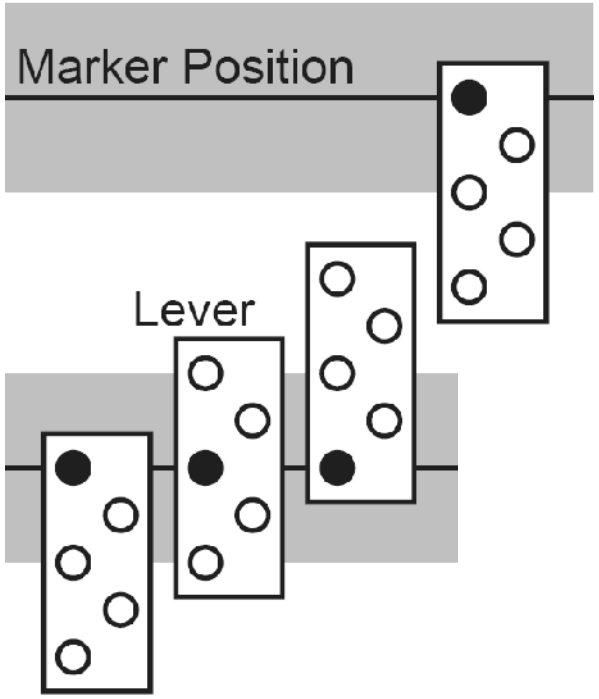


Left little finger



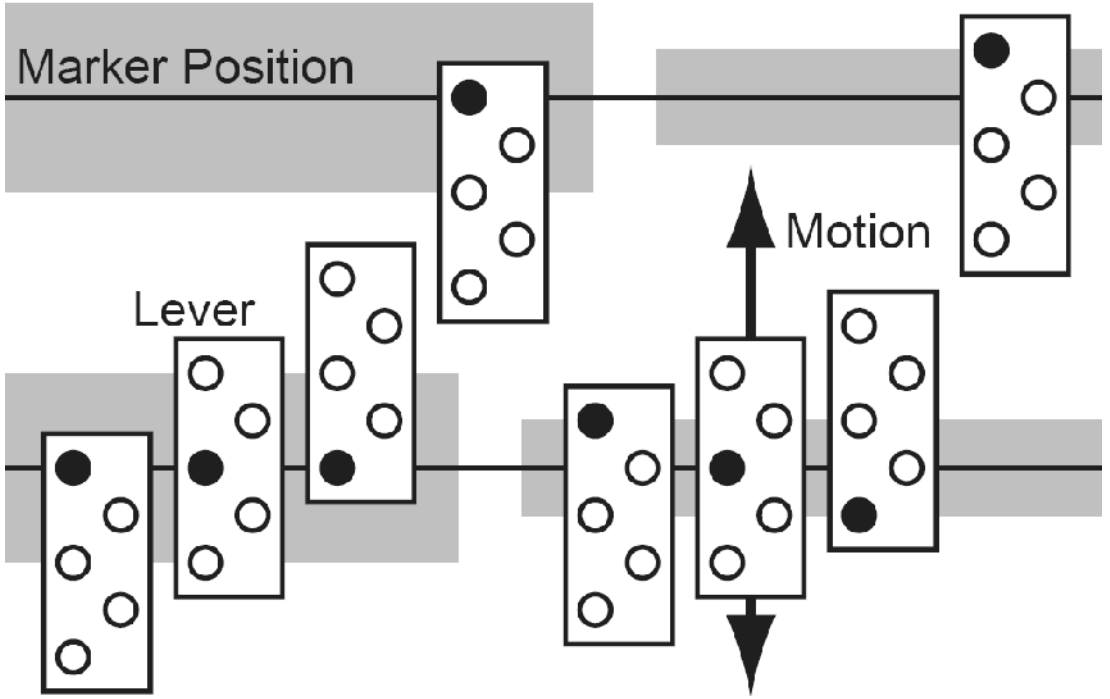
Applications

Virtual Detents/Markers (1)



- **Where am I? How quickly do I move the slider?**
- **Actually no detents: snapping?!**
- **Switch to 120 Hz firing rate for fast motion**

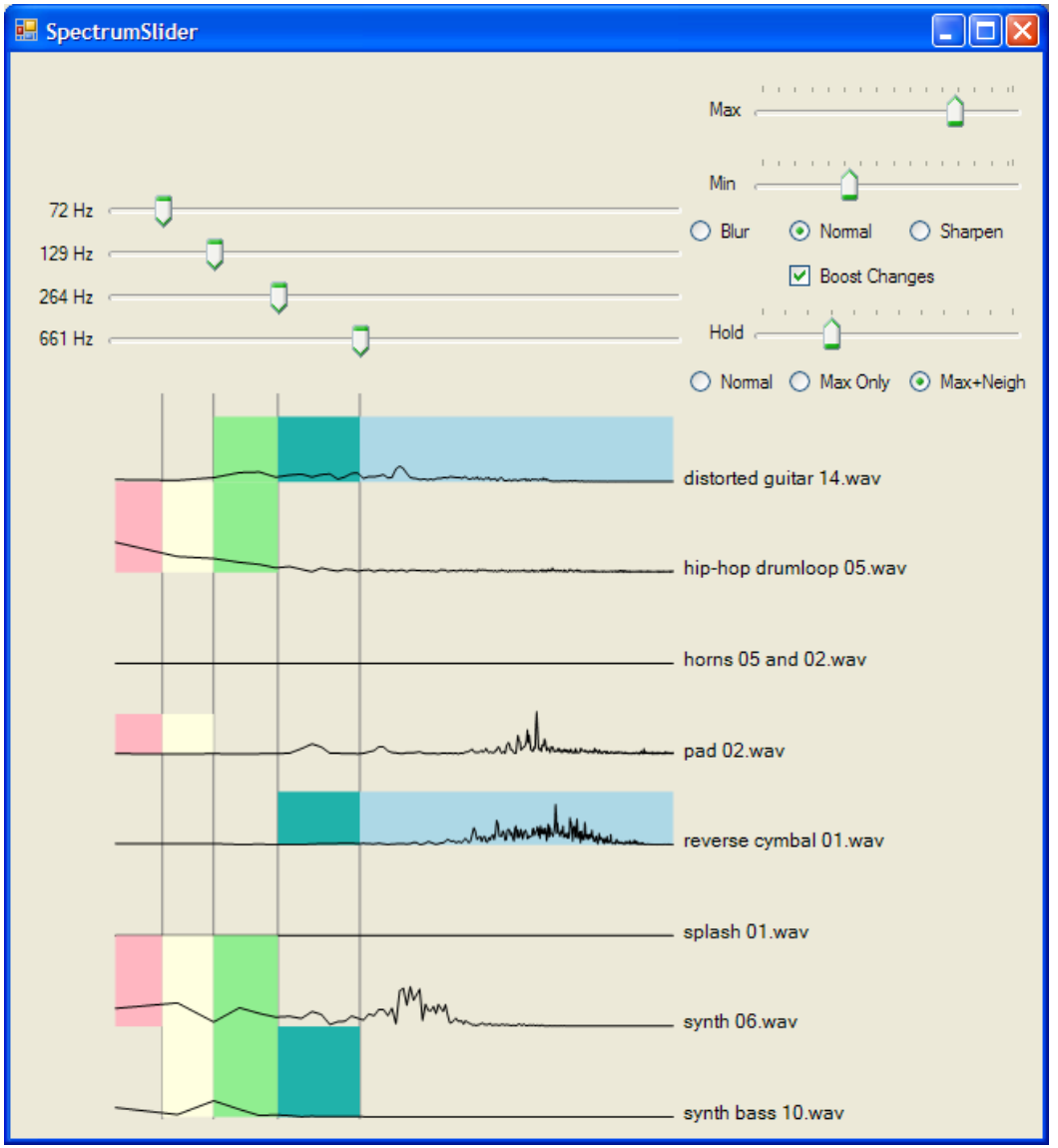
Virtual Detents/Markers (2)



- 1:1 with lever motion
- accelerated for higher precision
- Best with a smaller portion for the middle electrode; positioning error smaller than 1 %

Track Identification (1)

- Are my fingers on the faders of the right tracks?
- Map a coarse real-time spectrum to the five electrodes



Track Identification (2)

- Typically, the rhythm alone suffices for the distinction, like a VU meter
- Critical: different tracks with similar rhythm
- Maximize perceptual contrast between tracks:
  - Strong bands suppress adjacent bands.
  - Strong bands boost adjacent bands.
  - Quick changes are boosted.
  - The duration of peaks is extended.
  - Only the maximum band fires.
  - Only the maximum band and its neighbors fire.
- Demo

Conclusion

Conclusion

- Pros
  - Clear improvement of blind operation
  - No interference with fader motion
  - No acoustic noise
  - Standard, inexpensive components
- Cons
  - Variation between fingers
  - Sensation feels artificial
  - Safety?