Vibrotactile Stimulator

Optimization of Skin Response to Vibration

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Overview

Problem Statement

+ A device must be developed **to improve the workers' response** time by stimulating their sense of touch through **vibrations** in their hands.
+ The device must be **MR-compatible** in order to analyze brain activity during the stimulus to the hand.

Problem Statement

+ The overall goal

  To prove that a continuous stimulus on the hand can improve the range of sensory frequency perception.

Background

+ Falls from ladder or scaffold at workplaces
  - #1 cause of disabling injuries
  - #2 cause of fatalities[1][2]
+ Compensation: $6.2 billion annually[1][2]

Background

+ Skin sensation of hand is the first sensory cue for detecting the fall [3]
+ Stochastic resonance [4]
  - Enhance sub-threshold signal by adding adequate noise
  - Effect already shown in vibration stimulation on feet

Motivation

+ Falling can be stopped by detecting the fall initiation
+ Current device is bulky
+ Not MR-compatible for monitoring brain activity

Current device for feet [4]

Design Specifications

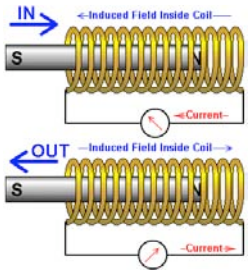
+ MR-compatibility
+ Smaller factor
  - 1 mm thickness, 1 cm diameter
+ Adjustable frequency (30 Hz to 300 Hz)

Design Options

1) Solenoid
2) Piezoelectric Device
3) Pneumatic Device

Design Option 1: Solenoid

+ Inducing a magnetic field in a coil of wire is used to move a magnetic core.
+ Springs or AC can be used to reverse direction



Design Option 1: Solenoid

Advantages

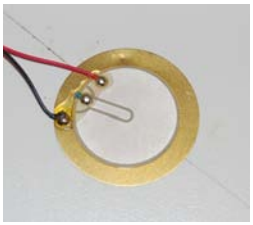
+ Vibration frequency easily adjustable
  - Signal generator
+ Relatively inexpensive

Disadvantages

+ Require MR shielding for MR-compatibility
+ Difficult to build at small size

Design Option 2: Piezoelectric Device

+ Applied charge excites the particles of a piezoelectric material, resulting in a force or vibration



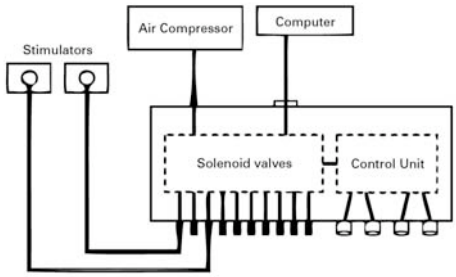
Design Option 2:
Piezoelectric Device

Advantages
+ Vibration frequency easily adjustable
  - Proportional to the charge applied
+ Relatively inexpensive

Disadvantages
+ Wiring of the system may affect (and be affected by) magnetic field of the MRI
+ Low frequency = Larger size (area)

Design Option 3:
Pneumatic Device

+ Using the change in pressure of air to produce motions, or vibration



Design Option 3:
Pneumatic Device

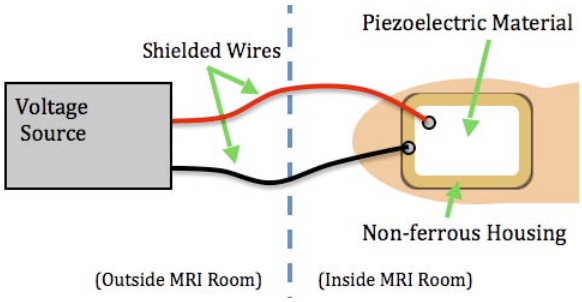
Advantages
+ MR-compatibility
+ Adjustability
  - Solenoid valves, Control Unit

Disadvantages
+ Low vibration frequency (<100Hz)
+ Higher cost

Design Matrix

	Solenoid	Piezoelectric Device	Pneumatic Device
MR Compatibility (25)	0	20	24
Frequency (20)	15	15	10
Tactor Size (15)	8	12	10
Driver Size (10)	7	8	5
Adjustability (15)	10	11	9
Longevity (10)	6	8	7
Cost (5)	3	3	2
Total (100)	**49**	**77**	**67**

Final Design



Future Work

Main limitation to overcome:
Large area vs. low frequency (300Hz)

+ Possible solutions
  - Frequency translation
  - Similar mechanism as "Tesla coil"
  - (Consult piezoelectrics experts)
    (Prof. Xu-Dong Wang)

Future Work

Fabrication	Testing
Circuits construction Tactor networking Tactor attachment System enclosure	MR compatibility 30~300Hz verification Subthreshold optimization

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Reference

Journals

[1] Bureau of Labor Statistics. (2009). Census of fatal occupational injuries.

[2] Bureau of Labor Statistics. (1993). Survey of occupational injuries and illness.

[3] Motawar BR, Hur P, Seo NJ. (2011). Roles of cutaneous sensation and gloves with different coefficients of friction on fall recovery during simulated ladder falls. *The 35th Annual Meeting of the American Society of Biomechanics.*

[4] Wells, C., Ward, L.M., Chua, R., Inglis, J.T. (2005). Touch Noise Increases Vibrotactile Sensitivity in Old and Young. *Psychological Science*. 16(4). 313-320.

[5] Briggs, R.W., Dy-Liacco, I., Malcolm, M.P., Lee, H., Peck, K.K., Gopinath, K.S., Himes, N.C., Soltysik, D.A., Browne, P., Tran-Son-Tay, R. (2004). A pneumatic vibrotactile stimulation device for fMRI. Magnetic Resonance in Medicines. 51. 640-643.

Images

[6] "Scaffold" - http://www.post-gazette.com/xtras/pghimages/default.asp?page=2

[7] "Fall Hazard" - http://www.mysafetysign.com/Safety-Signs/Fall-Hazard-Guardrail-Safety-Net-Sign/SAF-SKU-S-4187.aspx

[8] "Solenoids" – http://www.societyofrobots.com/actuators_solenoids.shtml

[9] "Piezosensor" - http://josephmalloch.wordpress.com/projects/mumt619/

Questions