On developing an instrument to quantify the perception of touch

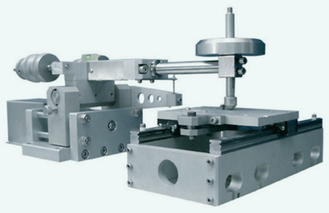
Jeremy A. Fishel PhD[1]
SynTouch, Los Angeles, CA USA

Problem Statement:

How do people perceive touch?



Human Perception
Relevant
Not Precise



Tribology Instruments
Not Relevant
Precise

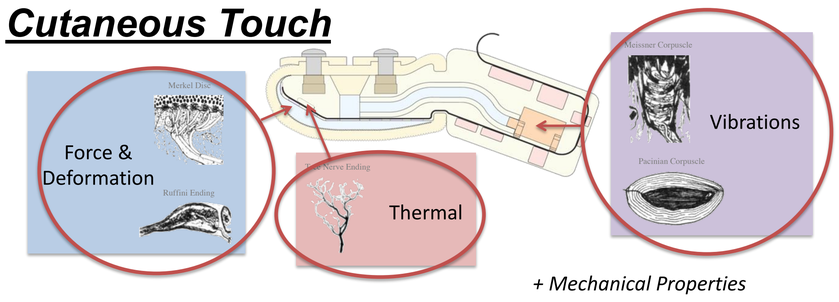
Can we design an instrument to mimic human tactile exploration?



Human-Like Tactile Sensing

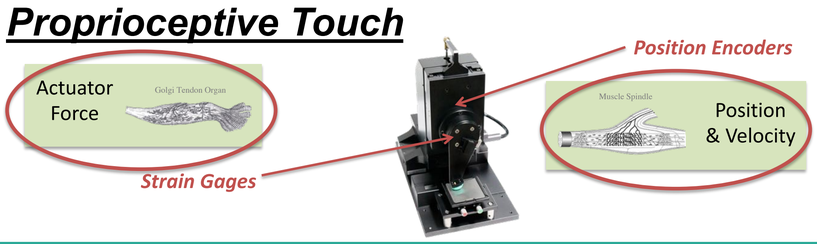
Key Point: We have developed a tactile sensor that has the same **sensory capabilities** and **mechanical properties** as the human fingertip

Cutaneous Touch



+ Mechanical Properties

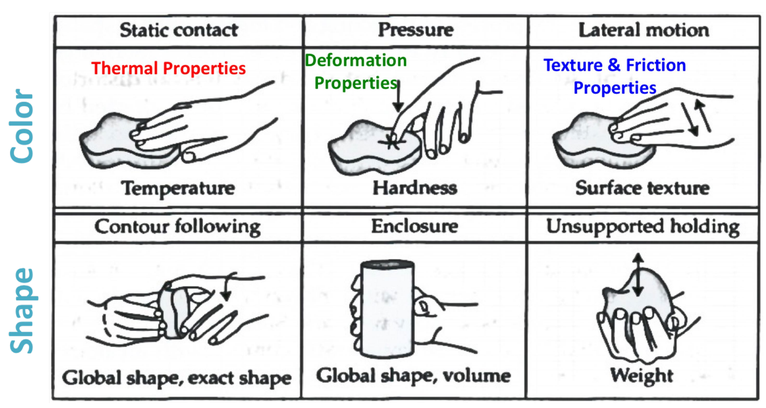
Proprioceptive Touch

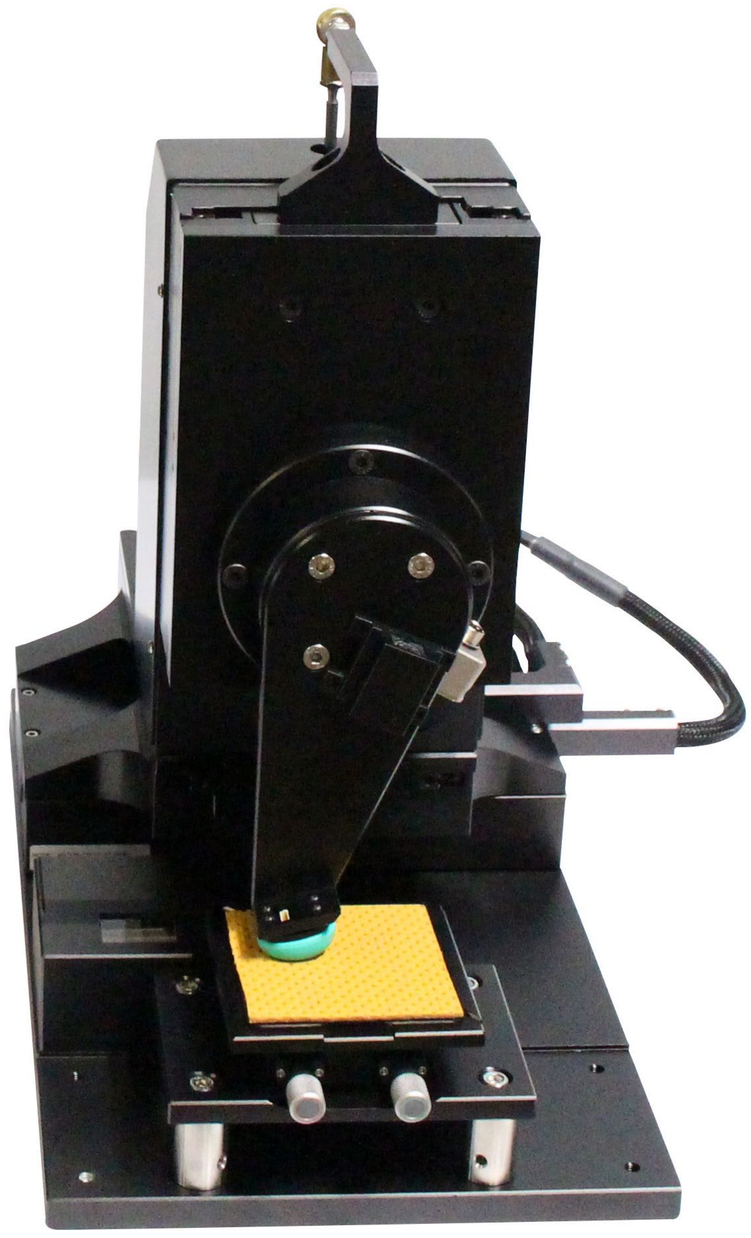


Human-Like Exploratory Movements

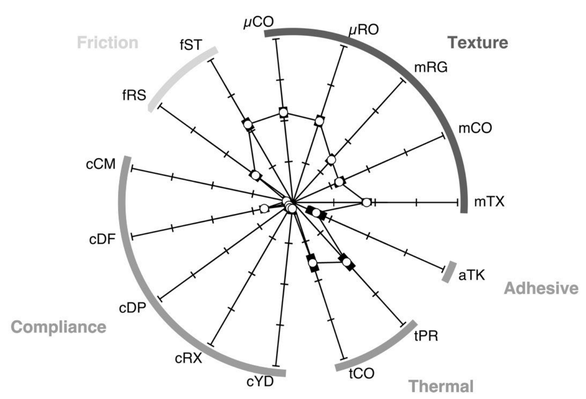
Key Point: We studied the types of movements humans make when exploring surfaces, and have developed an instrument to mimic them.

Tactile Exploratory Movements





The Toccare



15 Dimensions Of Touch

Evaluation of Precision:

- Instrument could reliably discriminate all 500 test surfaces with 100% accuracy.
- Outperformed novice human subjects in A/B discrimination tasks for challenging pairs of surfaces.

Evaluation of Relevance (Pilot):

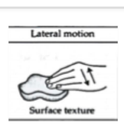
- Working with Sensory Spectrum, we constructed a pilot study to evaluate if the 15 dimensions developed and measured by this instrument were relevant to human perception.
- The initial study compared the 15 SynTouch dimensions with 14 standard descriptors used by Sensory Spectrum.
- Future work will focus on developing a universal standard for tactile properties with the sensory community.



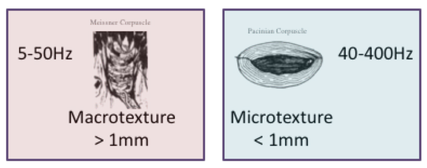
Signal Processing Inspired by Human Neurophysiology

Key Point: We studied the neurophysiology of touch and human language to develop thousands of possible movement/signal processing combinations useful to identify objects by touch. These were then tested across more than 500 surfaces for validation of their utility.

Texture Dimensions



Primary: Are any **vibrations** produced when sliding over a surface?

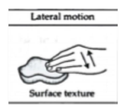


- **Texture**
  - •Texture
  - •Macrotexture
  - •Macrotexture Coarseness
  - •Macrotexture Regularity
  - •Microtexture Roughness
  - •Microtexture Coarseness

Intensity, Regularity, Frequency

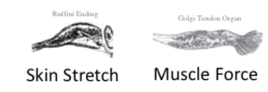
	Neurophysiology	Signal Processing
Intensity	Recruitment Spread	Vibration Power (on a log scale)
Frequency	Rate Code (Phase-Lock)	Spectral Centroid (essentially average frequency)
Regularity	Spike train regular or irregular	Vibration Purity

Grip Dimensions



Primary: Is any **resistance** felt when sliding over a surface initially?

- **Grip**
  - •Tactile Stiction
  - •Sliding Resistance
  - •Adhesive Tack

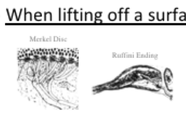


Signals: Tangential Force while sliding

Does the **resistance** sustain when sliding over a surface?

When lifting off a surface is there any adhesion?





Signals: Normal Force while lifting

Skin Stretch and Deformation

Deformability Dimensions



Primary: Does the surface **deform** when pressed?



Position / Velocity

Signals: Distance displaced while pushing

- **Deformability**
  - •Tactile Compliance
  - •Local Deformation
  - •Damping
  - •Relaxation
  - •Yielding

Does the object wrap around the finger?



Signals: Skin Deformation

Does it resist returning to its original shape?



Signals: Energy Recovery

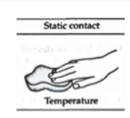
Does it stop pushing back after being deformed?

Force — *Signals: Force after hold*

Does it remain deformed?

Position / Velocity — *Signals: Position after release of force*

Cooling Dimensions



Primary: Is there any change in **thermal flow** when pressed?



Signals: Change in temperature flow (initially)

- **Cooling**
  - •Transient Cooling
  - •Thermal Persistence

Does that change persist?

Signals: Change in temperature flow (persistent)

Expert Validation: 1-to-1 Results

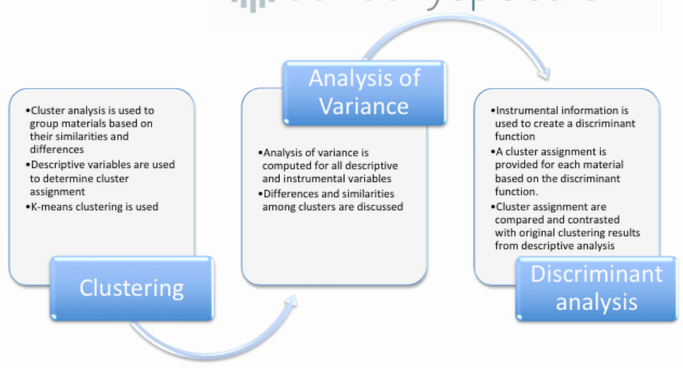
Study with: sensoryspectrum

- Through multiple linear regression, the following models were uncovered. All models are significant but vary in the amount of variability in the descriptive variable that they explain.

Descriptive Variable	Equivalent Instrumental Measure(s)	% Variability Explained (R-sq*100)
Perceived Surf. Temp	Thermal Cooling	66% - 80%
Moist Feel	Adhesive Tack	50%
Gritty	Microtexture Roughness	33%
Grainy*	Macrotexture Coarseness, Microtexture Coarseness, and Yielding	48%
Lumpy *	Macrotexture Coarseness and Macrotexture Regularity	32%
Fuzzy*	Tactile Stiction and Damping	53%
Surface Roughness	Macrotexture Regularity	52%
Surface Roughness*	Macrotexture Regularity, Microtexture Coarseness	67%
Surface Roughness*	Macrotexture Regularity, Microtexture Coarseness, Sliding Resistance	72%
Hand Friction	Sliding resistance, Microtexture Coarseness, and Damping	43%
Stickiness	Adhesive Tack	79%
Stickiness*	Adhesive Tack and Tactile Stiction	82%
Depression Amount	Tactile Compliance (Rigid --> Compliant)	91%
Conformance to Finger	Damping (Springy --> Damped)	84%
Conformance to Finger*	Damping and Adhesive Tack	89%
Return Time	Local Deformation	91%
Return Amount	Damping	84%

Expert Validation: Mutual Information

Study with: sensoryspectrum



	Thermal	Deformation	Grip & Texture
# of Clusters	4	5	5
Agreement	90.1%	88.6%	86.4%

Results Summary: While the 15 SynTouch dimensions did not match up perfectly with sensory panel, initial results indicated that there was a reasonable amount of mutual information across categories.