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The Human Body as an Interactive Computing Platform

Chris Harrison

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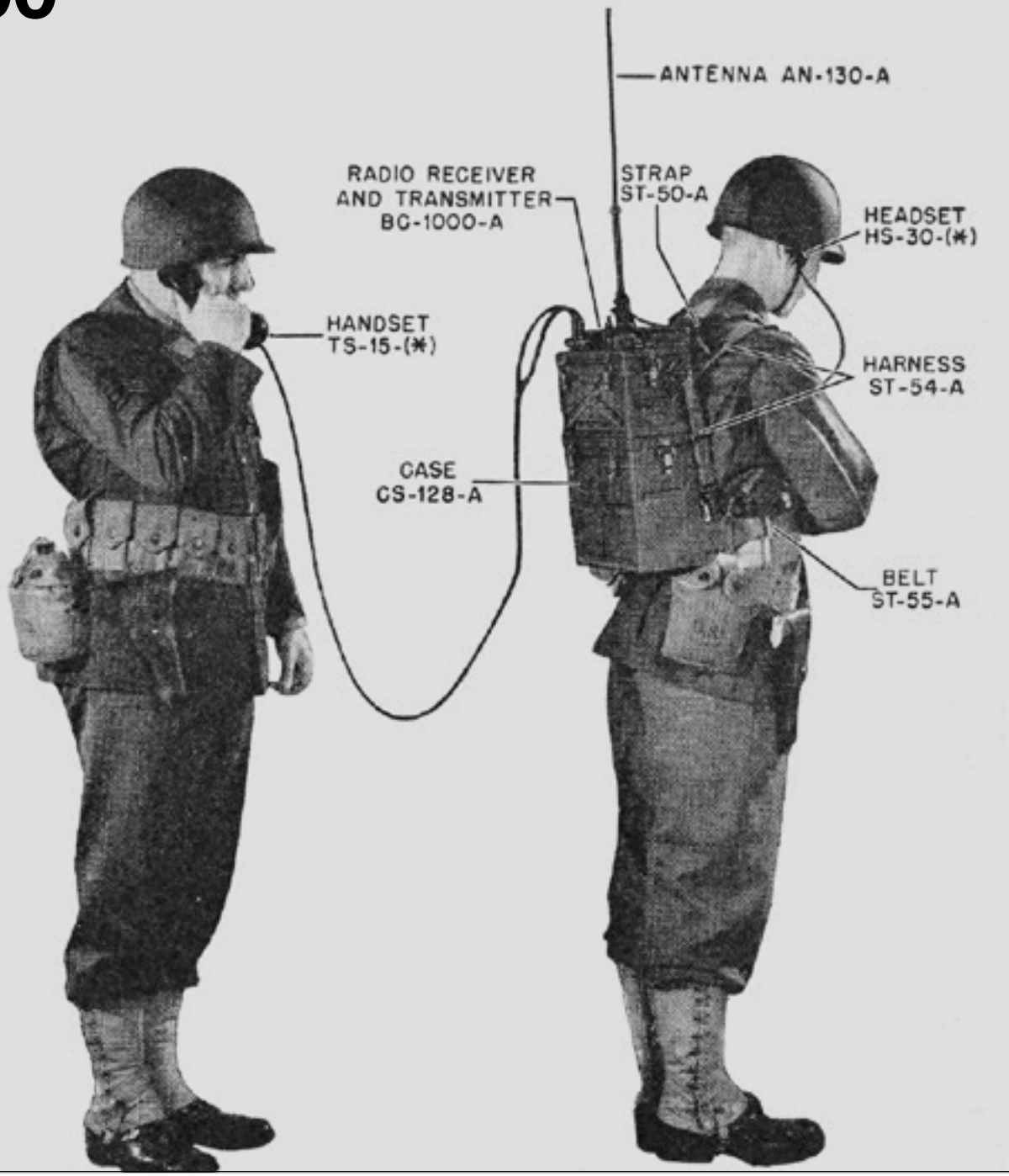
Carnegie Mellon
Fit in your pocket / bag
Communicate
Create
Access information
Play Angry Birds
NOKIA
3

SCR-300

1943


ANTENNA AN-130-A
RADIO RECEIVER AND TRANSMITTER BC-1000-A
STRAP ST-50-A
HEADSET HS-30-(*)
HANDSET TS-15-(*)
HARNESS ST-54-A
CASE CS-128-A
BELT ST-55-A

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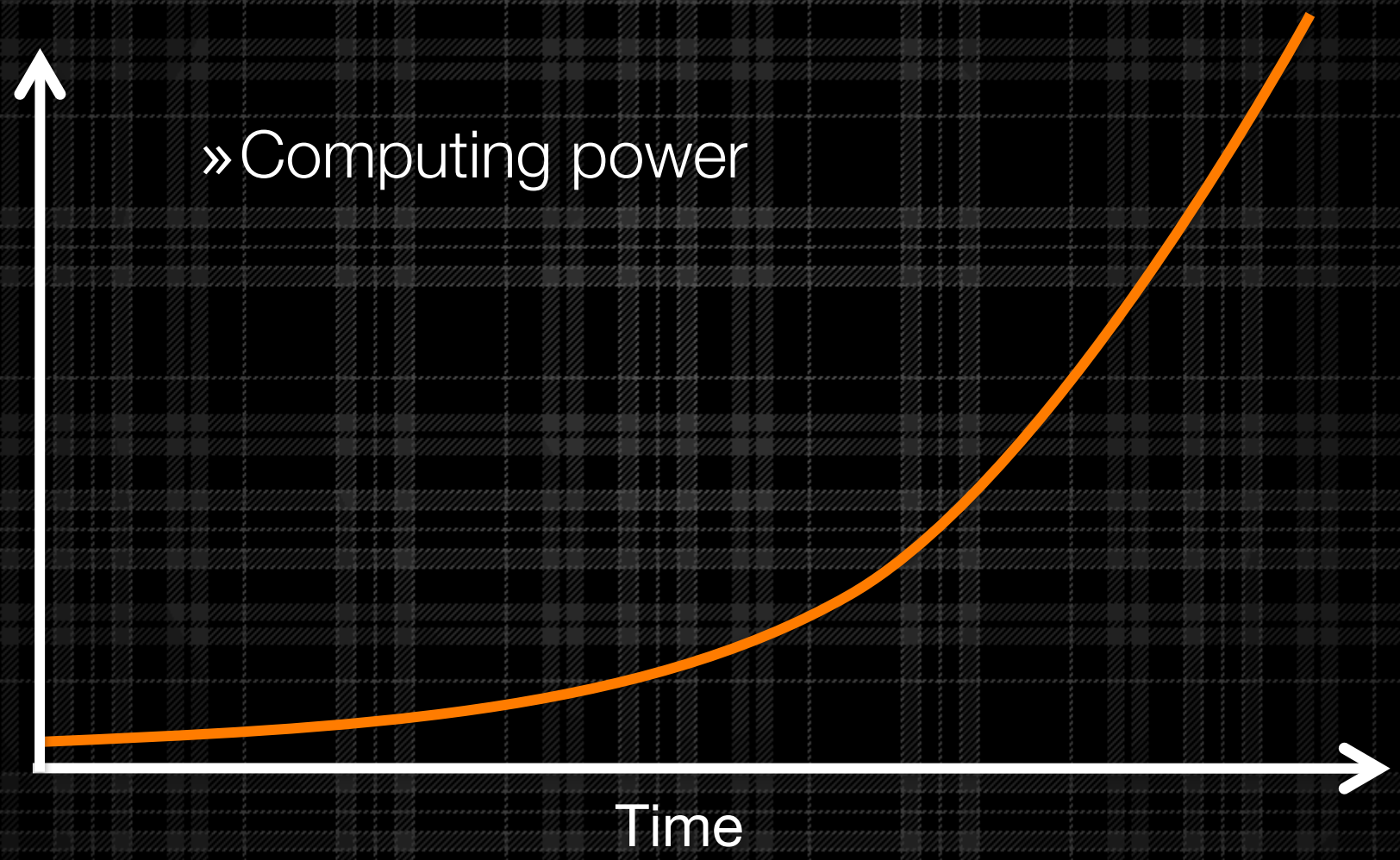
Motorola DynaTAC 8000x

1983

Apple iPod Touch

2007

Computing Factors



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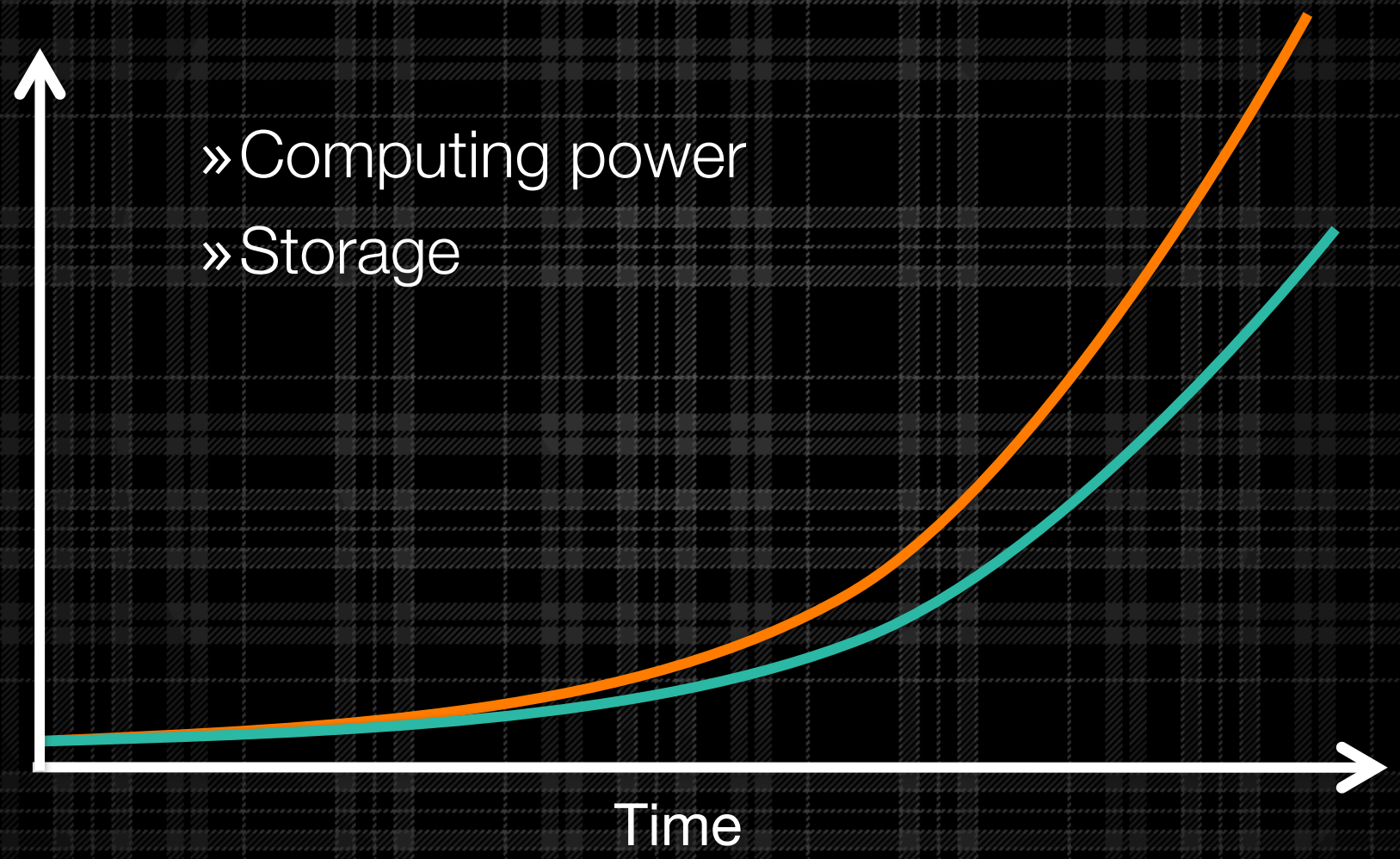

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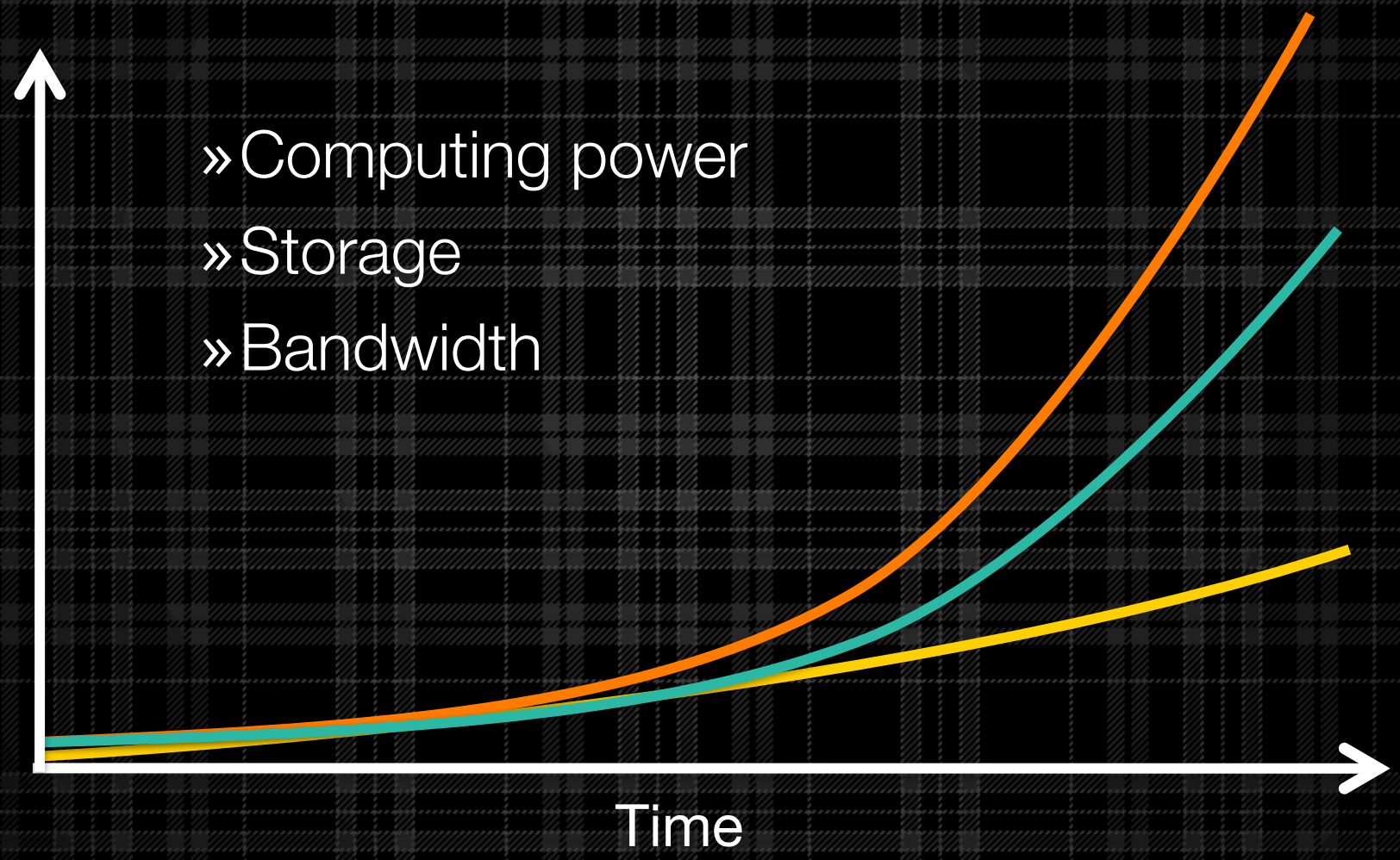

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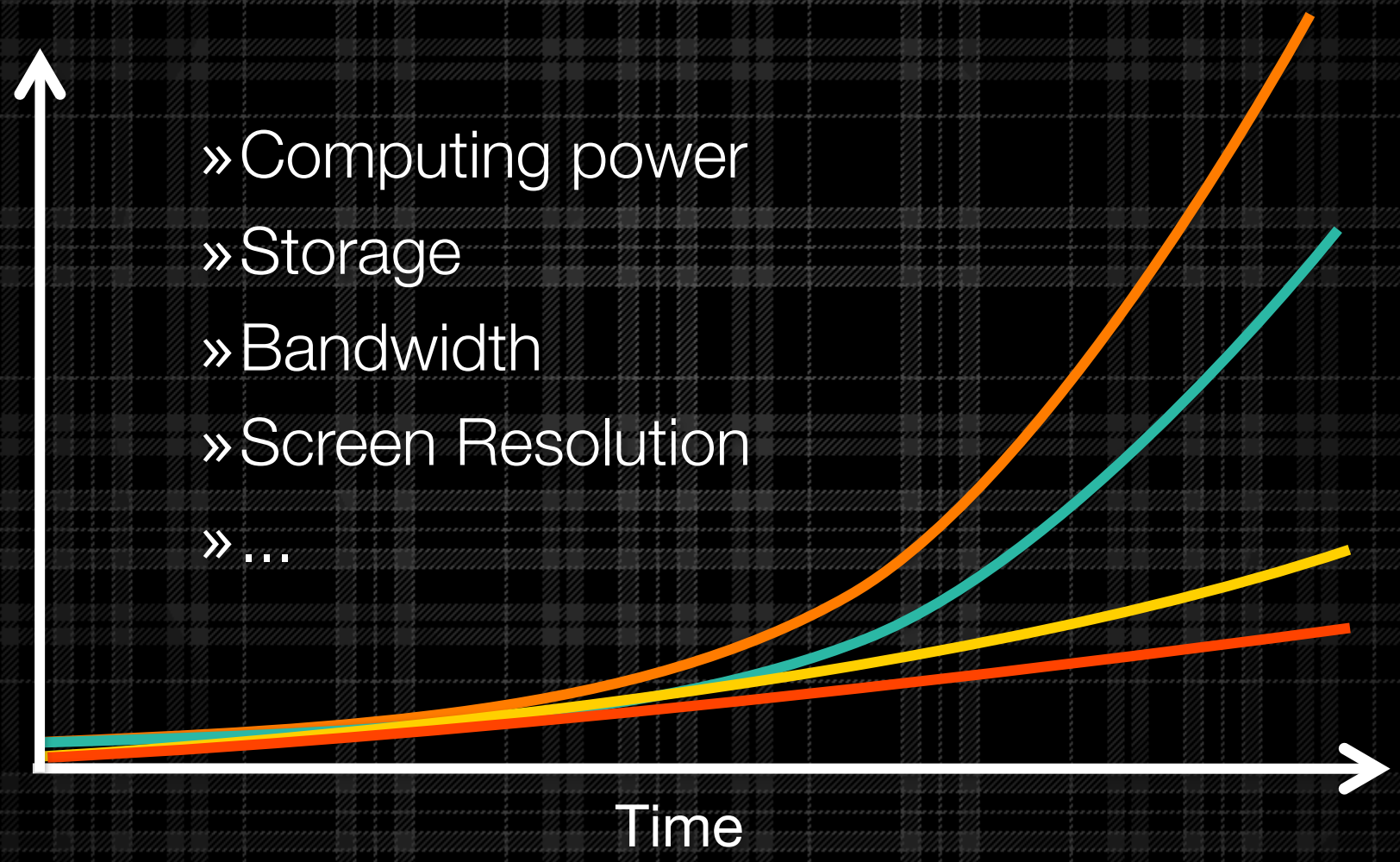

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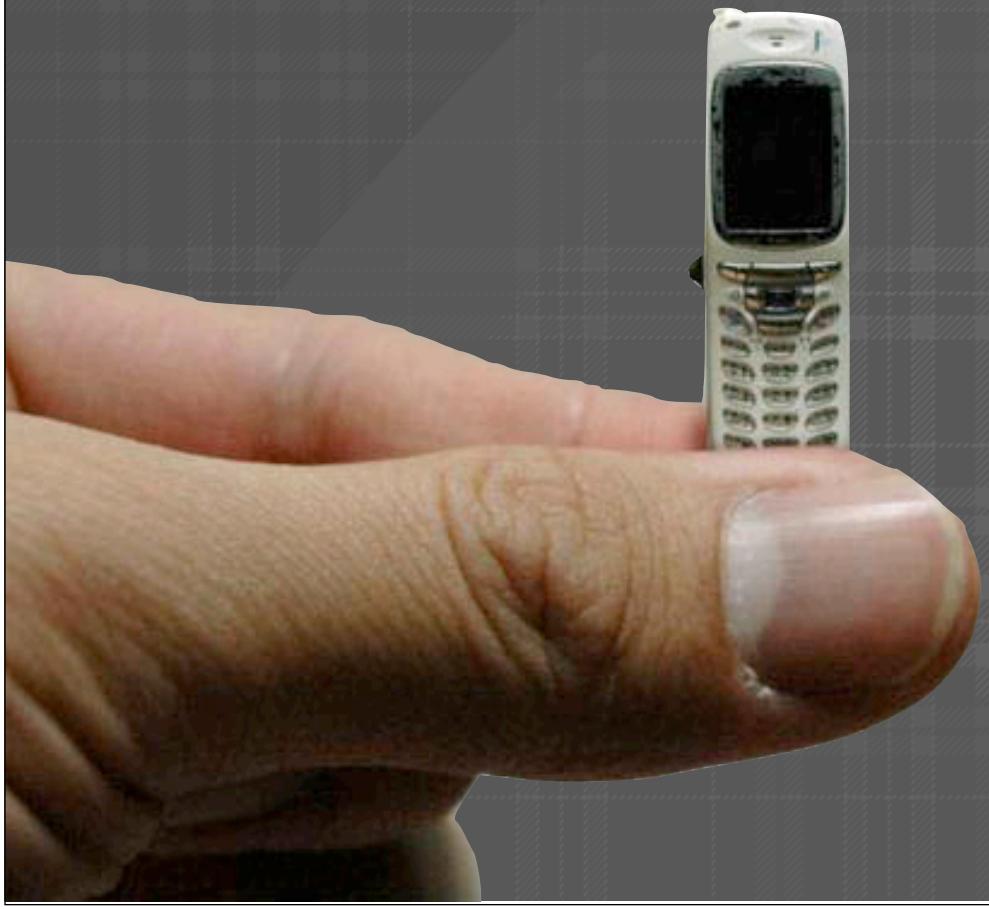
Small + Powerful
Call <Name or Nu
Listen Voicemail
Missed Calls
Messages
Time & Date

Why not this?



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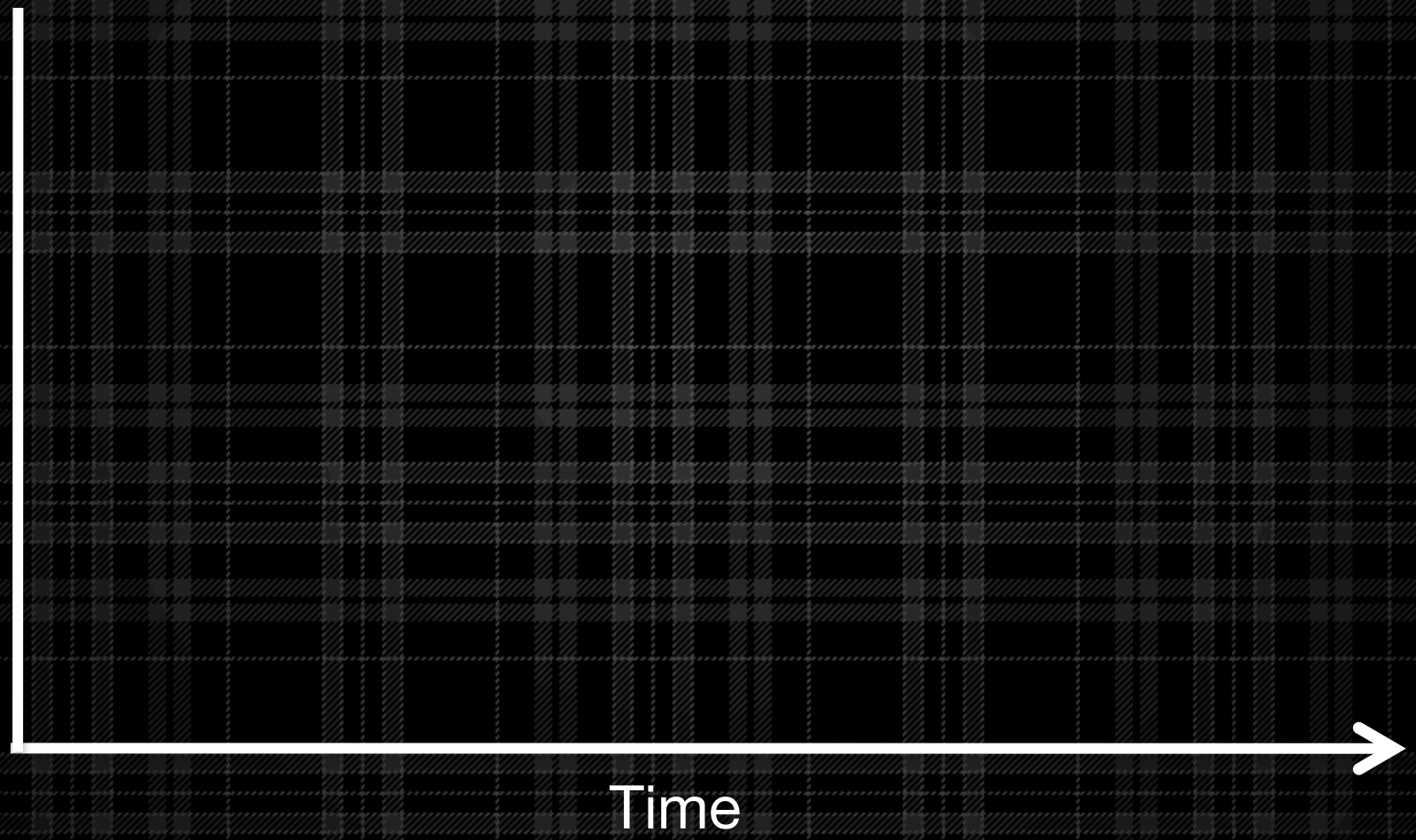
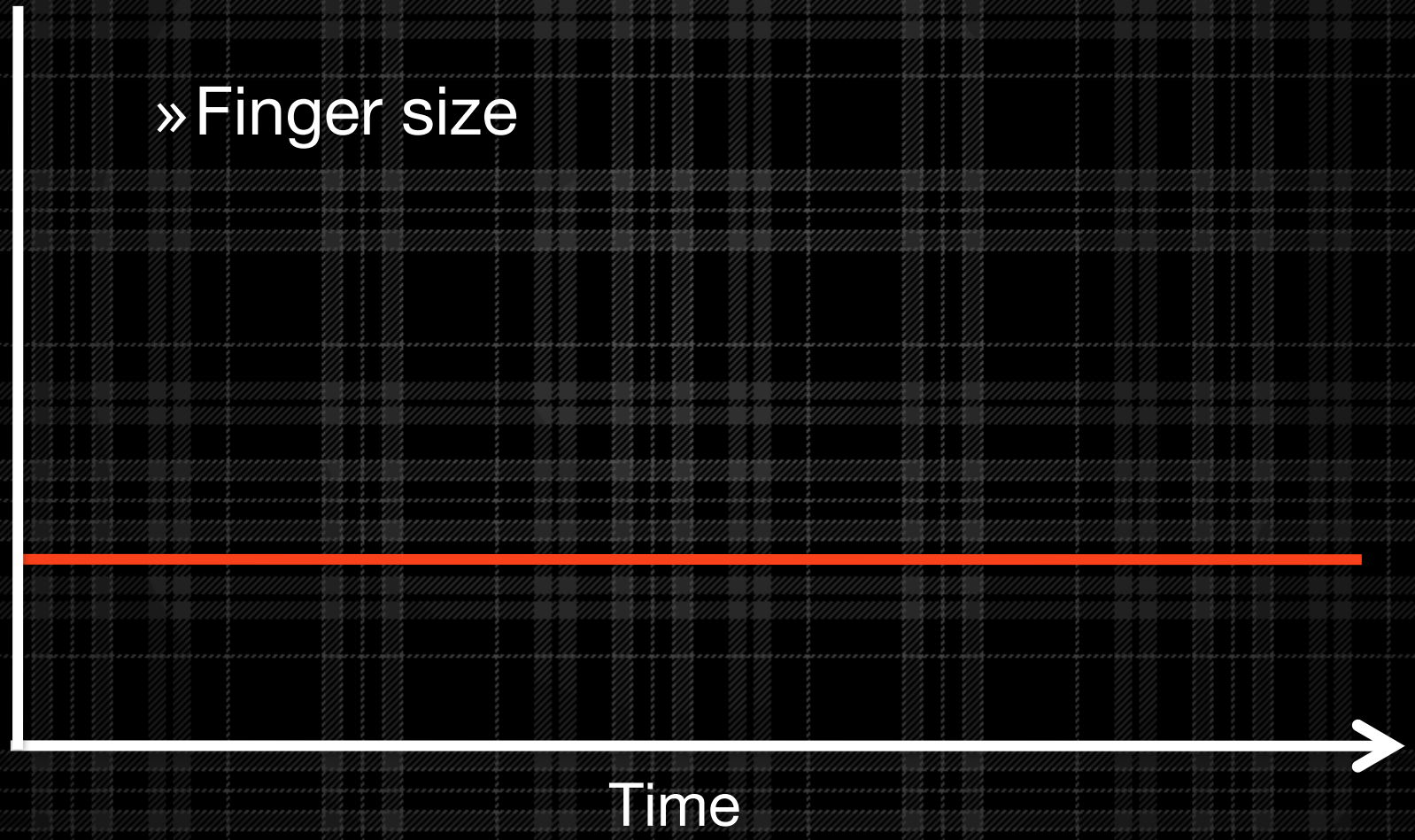
Human Factors



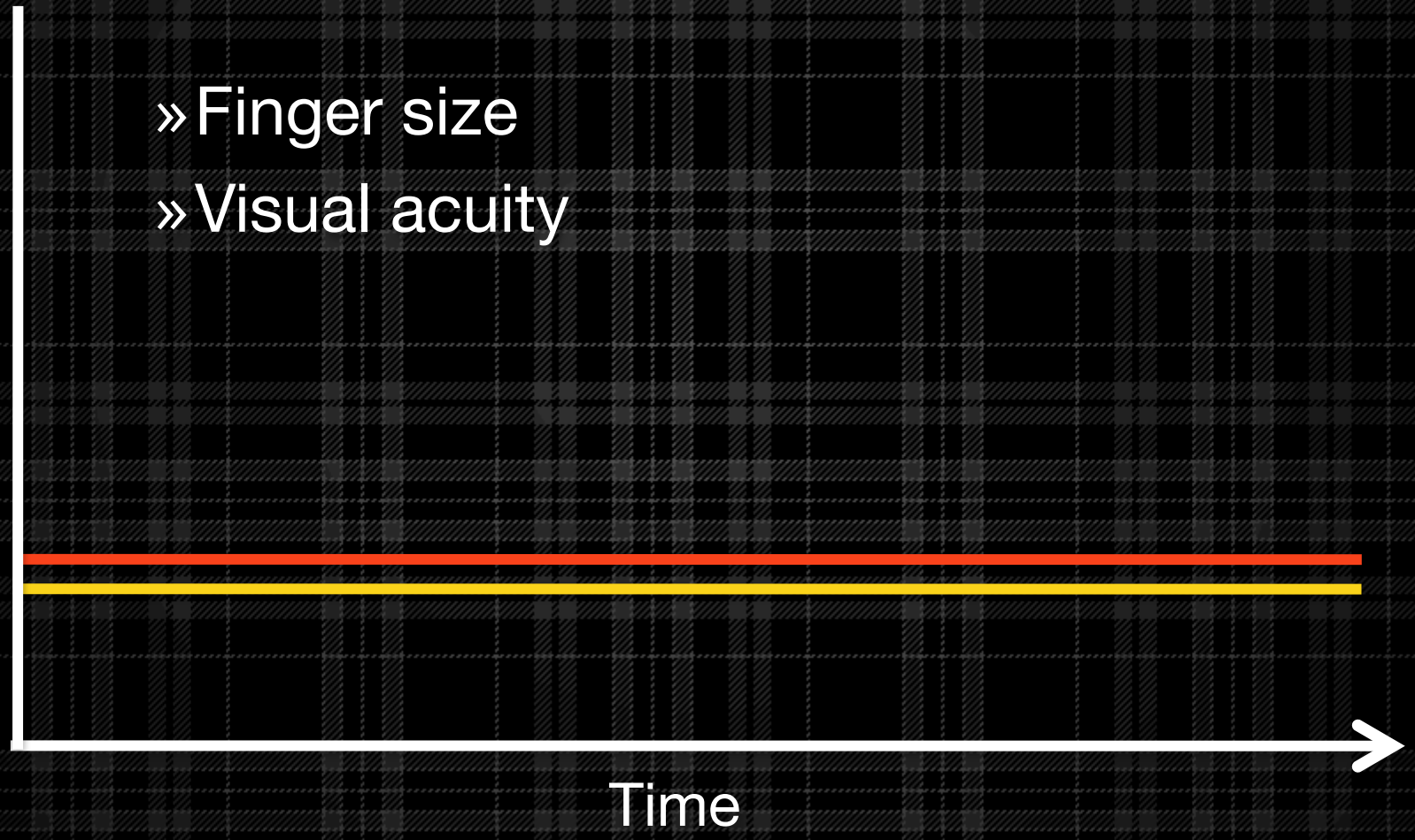
Human Factors

- Finger size



Human Factors

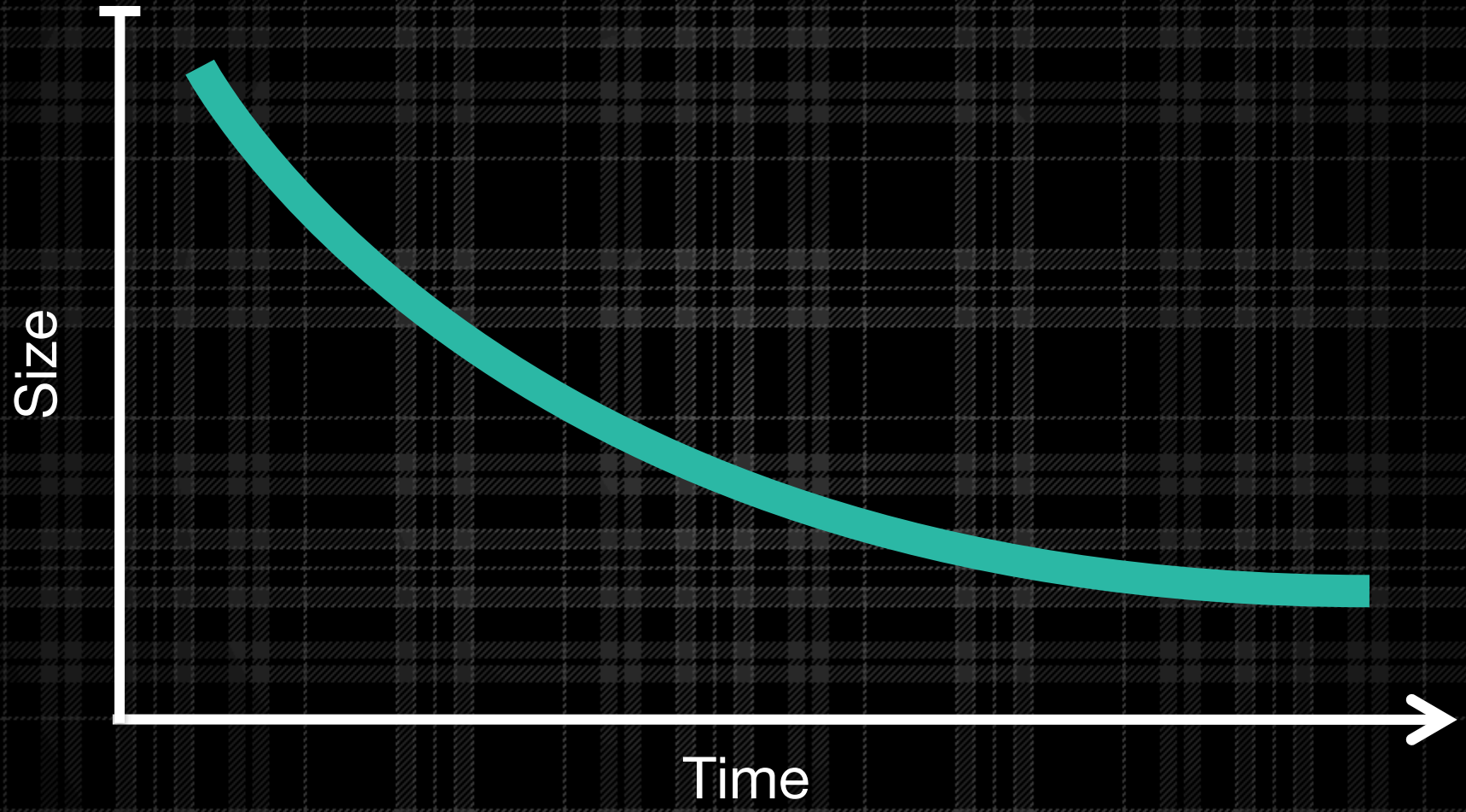
- Finger size
- Visual acuity



Human Factors

- Finger size
- Visual acuity
- Manual dexterity
- …

Mobile Device Size



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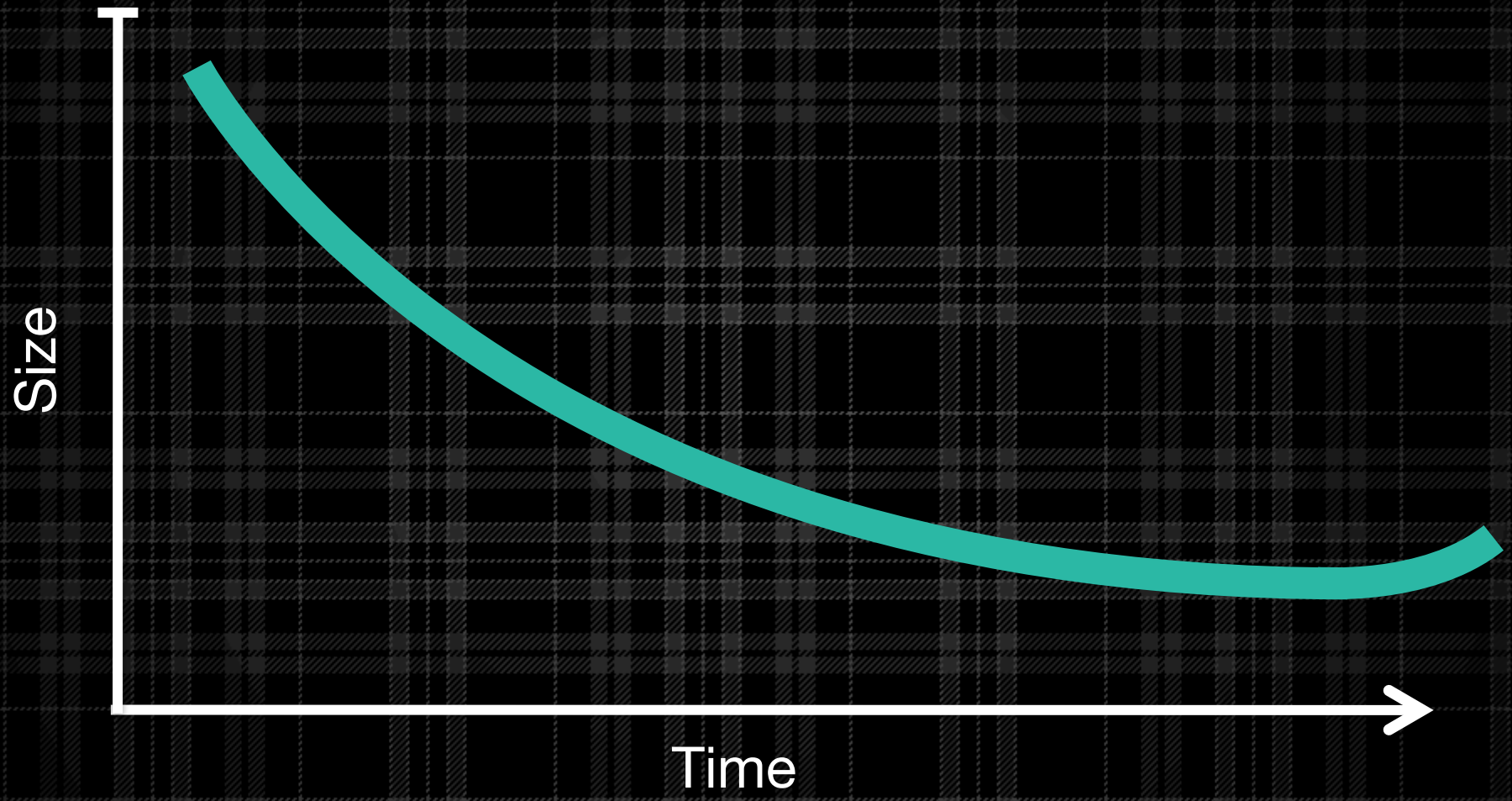
Mobile Device Size



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mobile device
=
limited surface area
20

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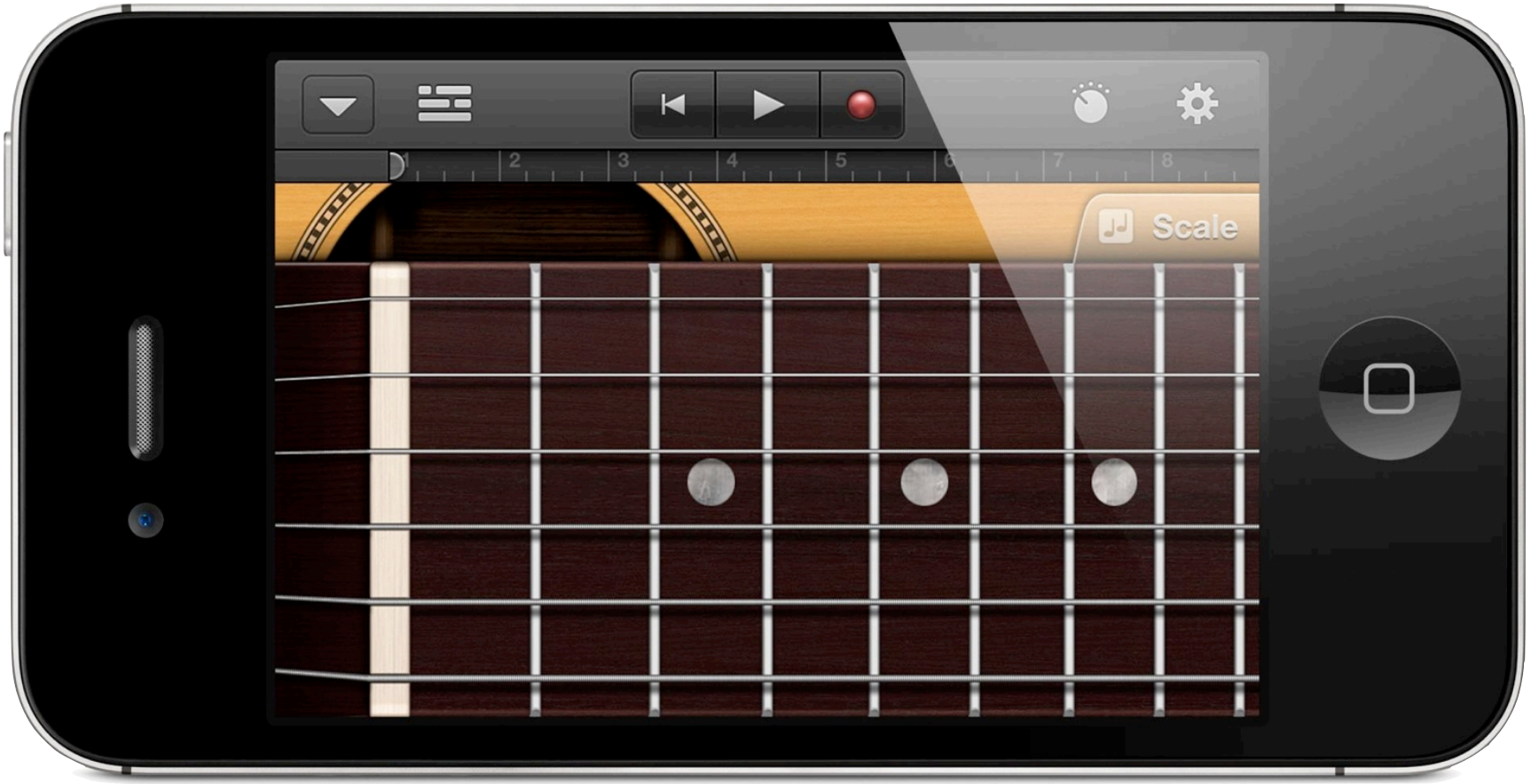
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2
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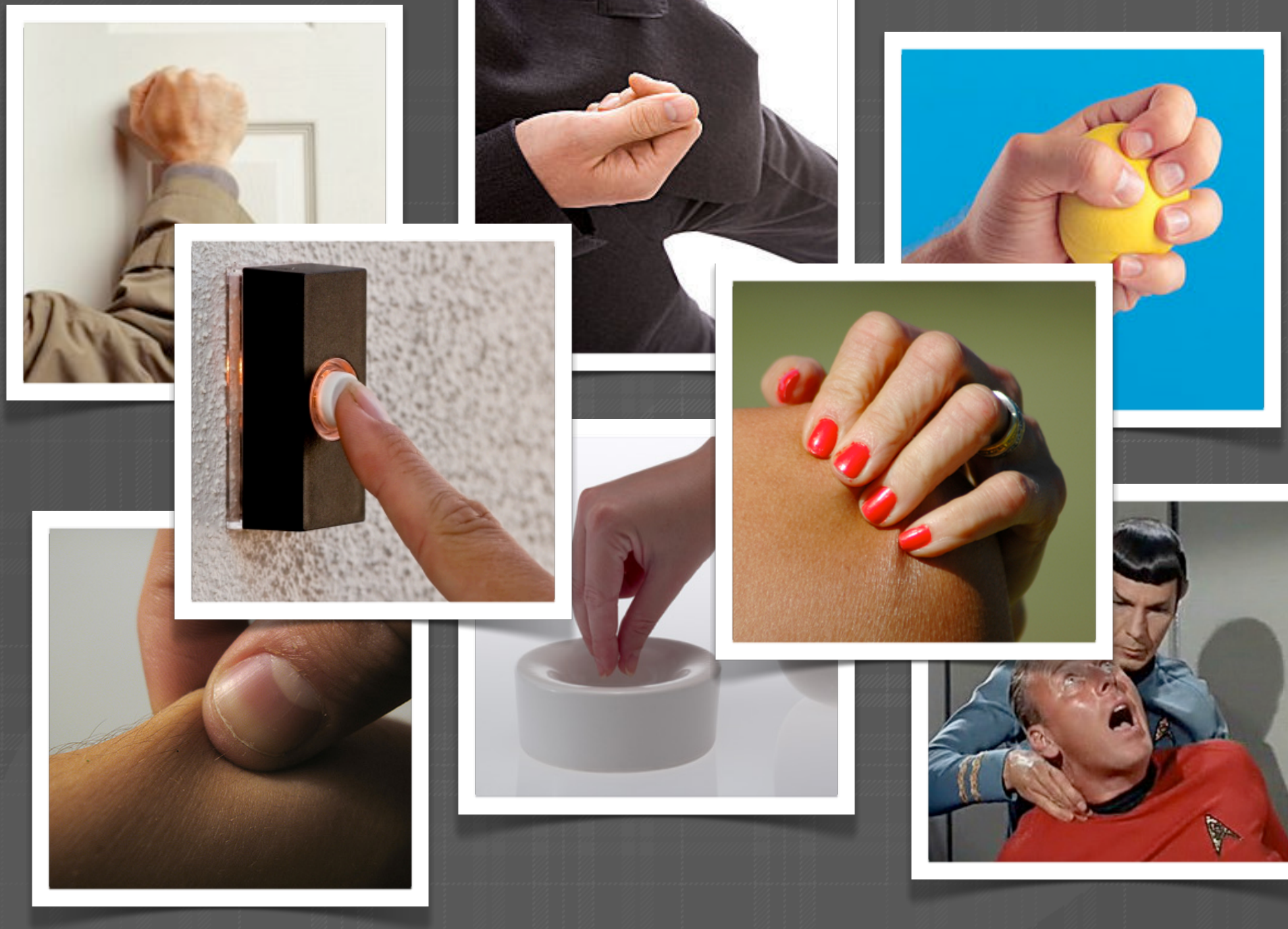
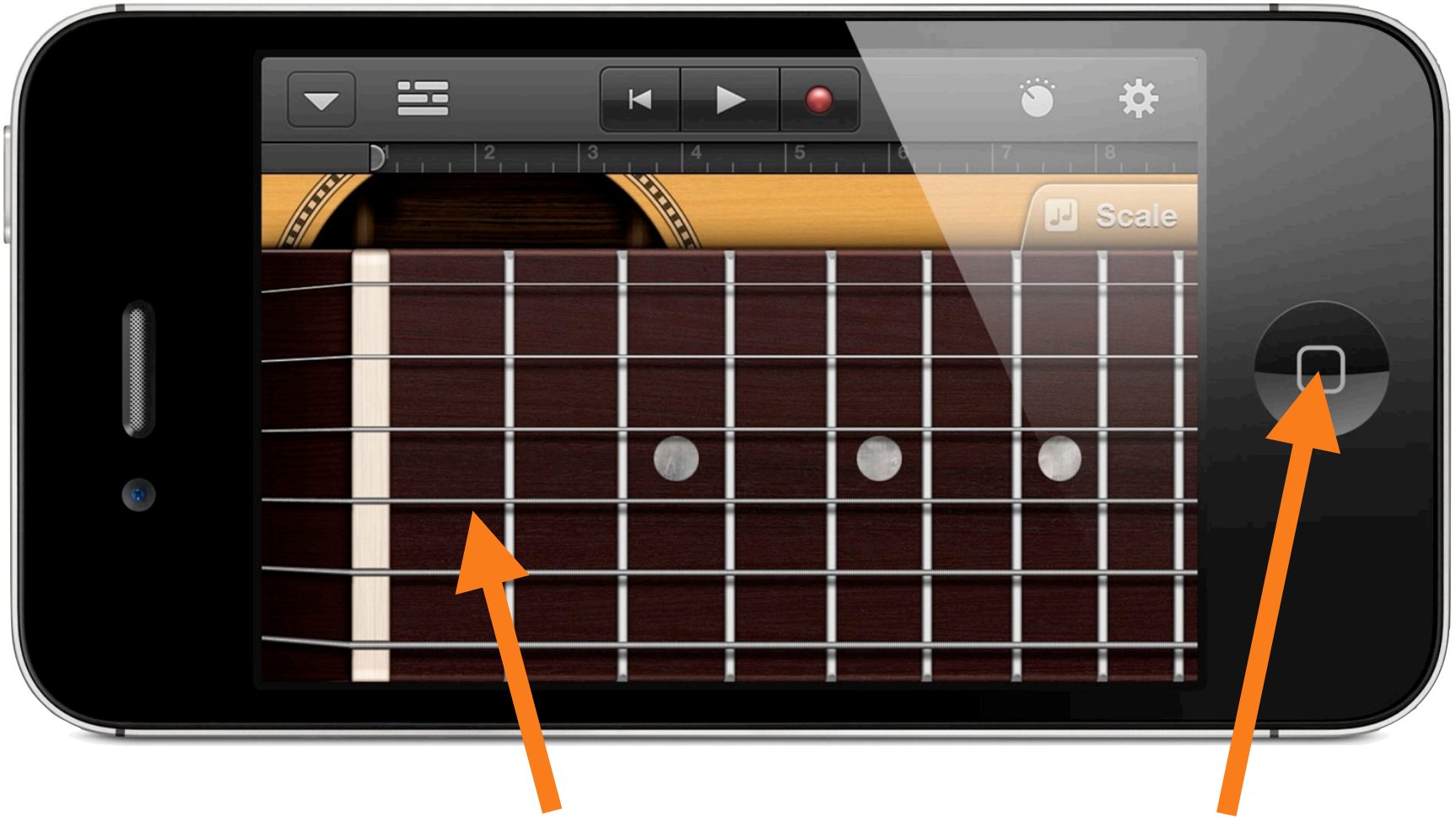
6
7
8
Scale

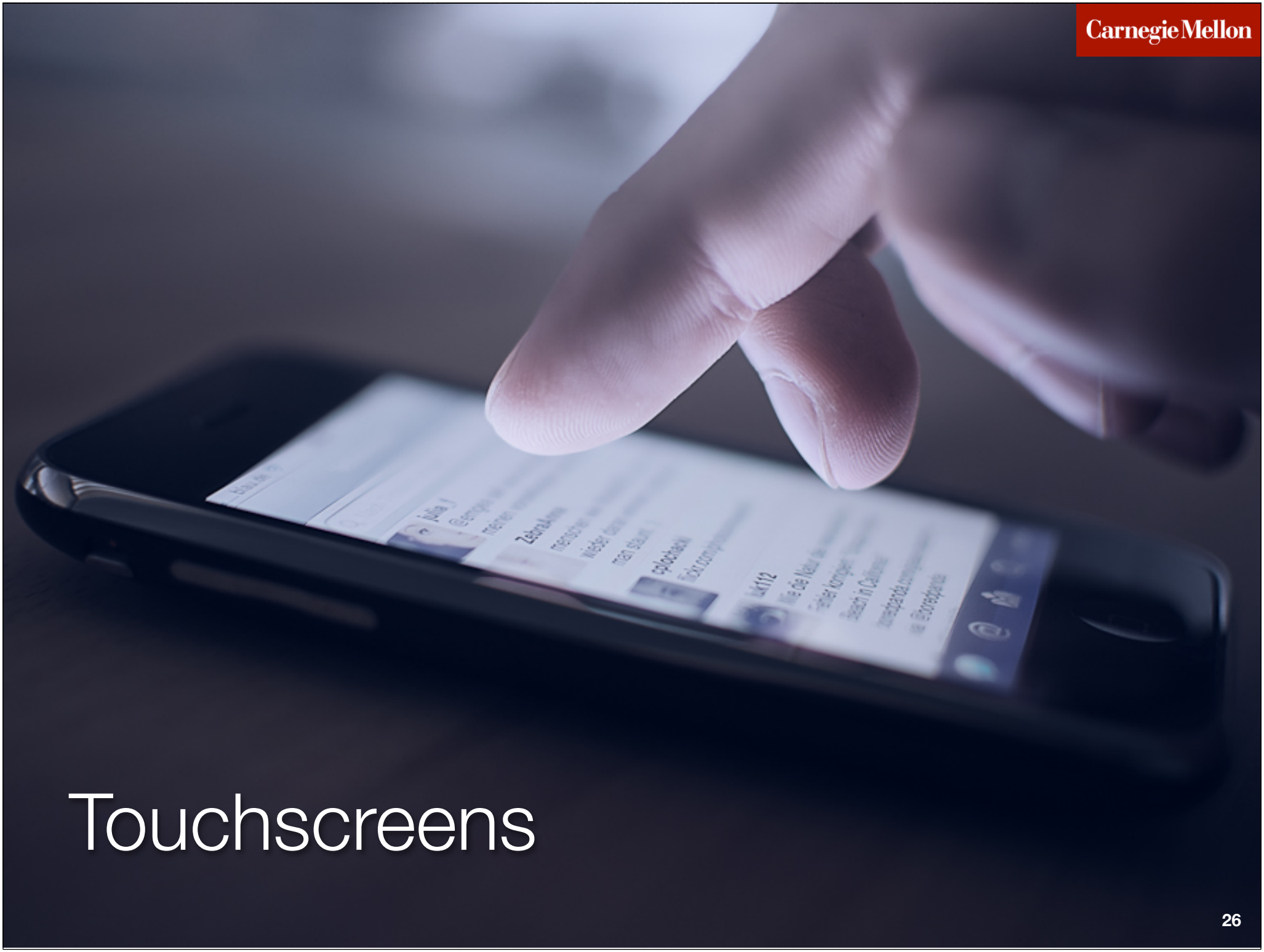




Touchscreen

Button

Physical controls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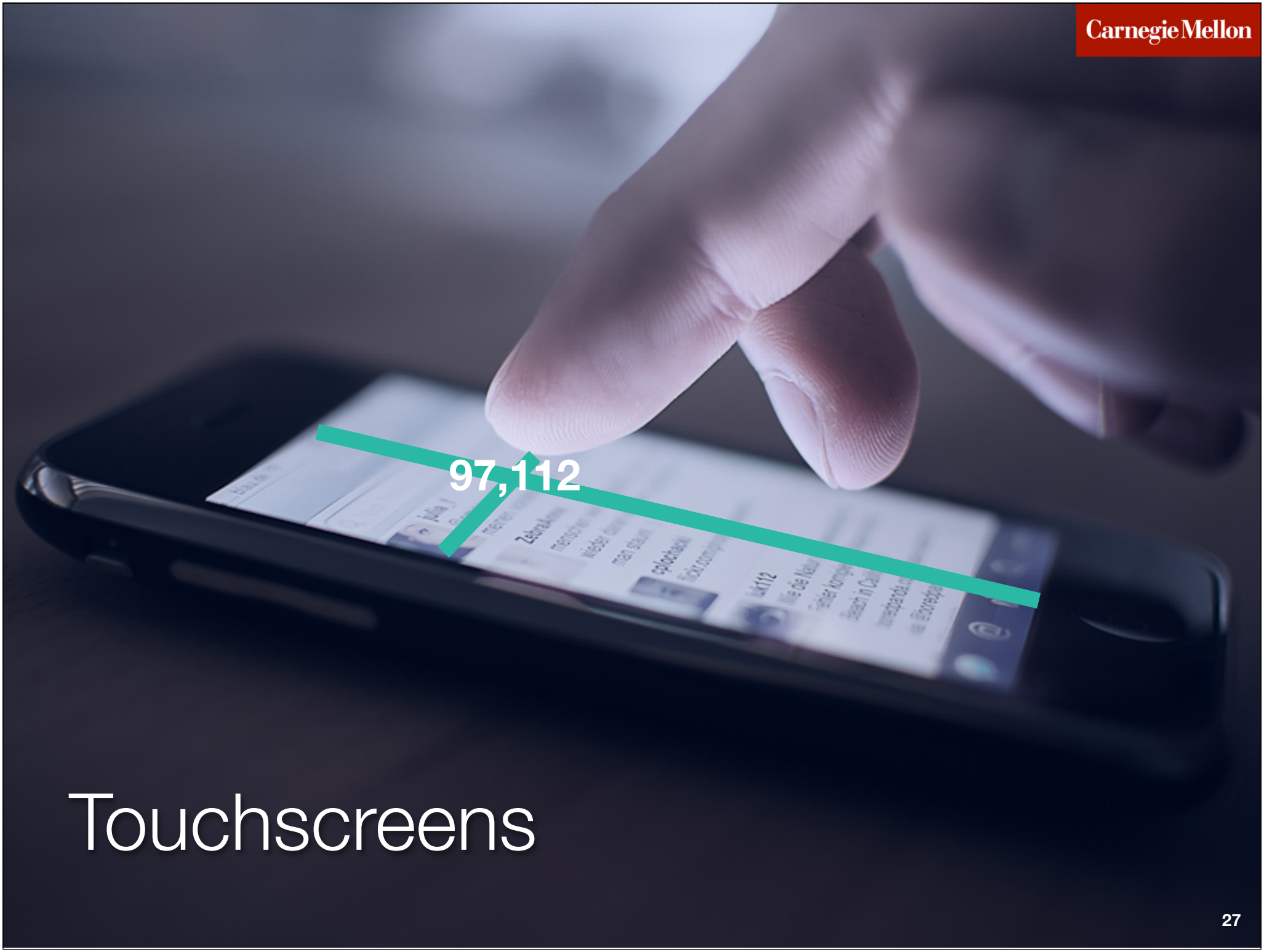
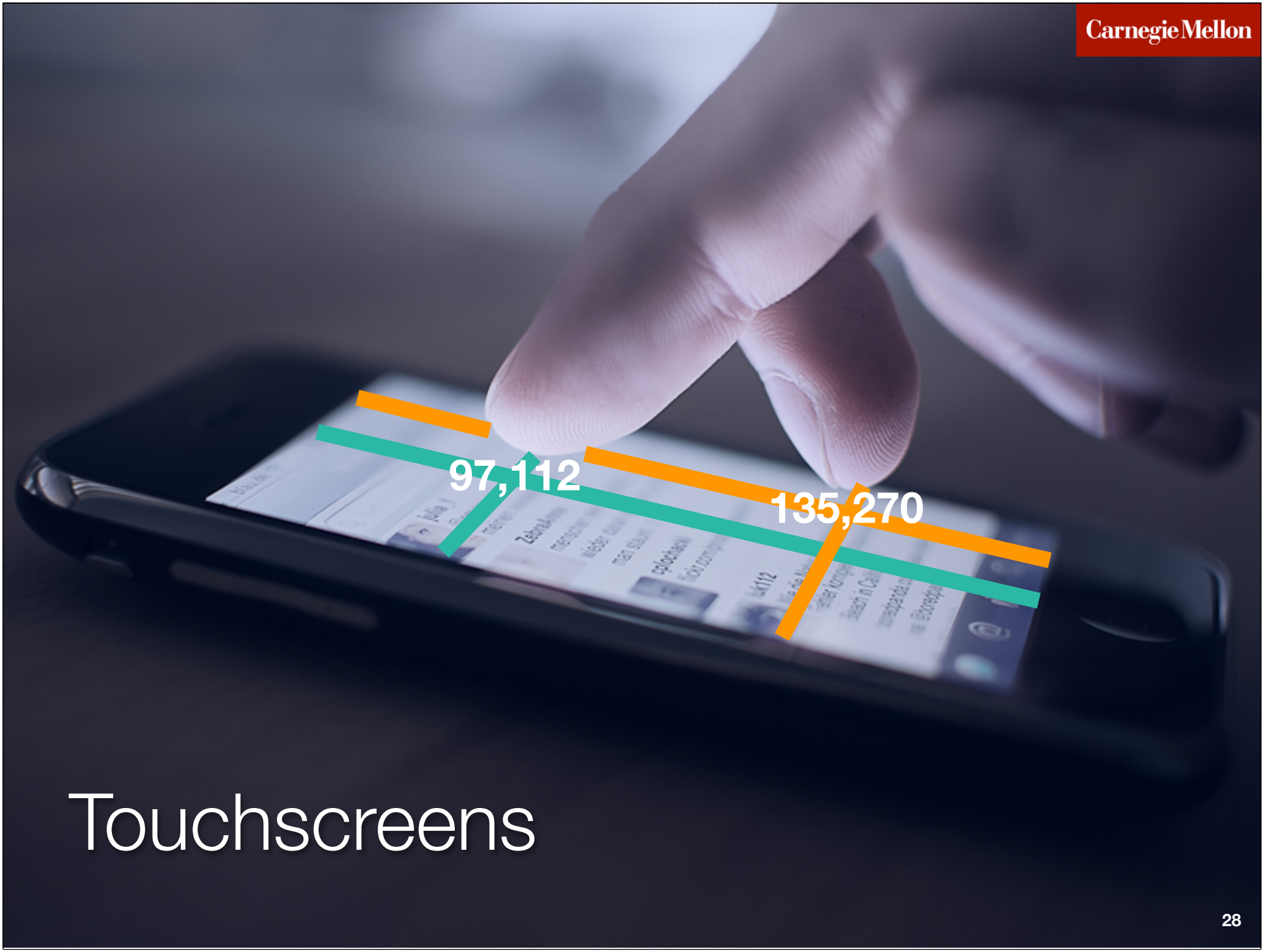
Touchscreens



Touchscreens



Touchscreens

mobile device
=
=
limited input richness

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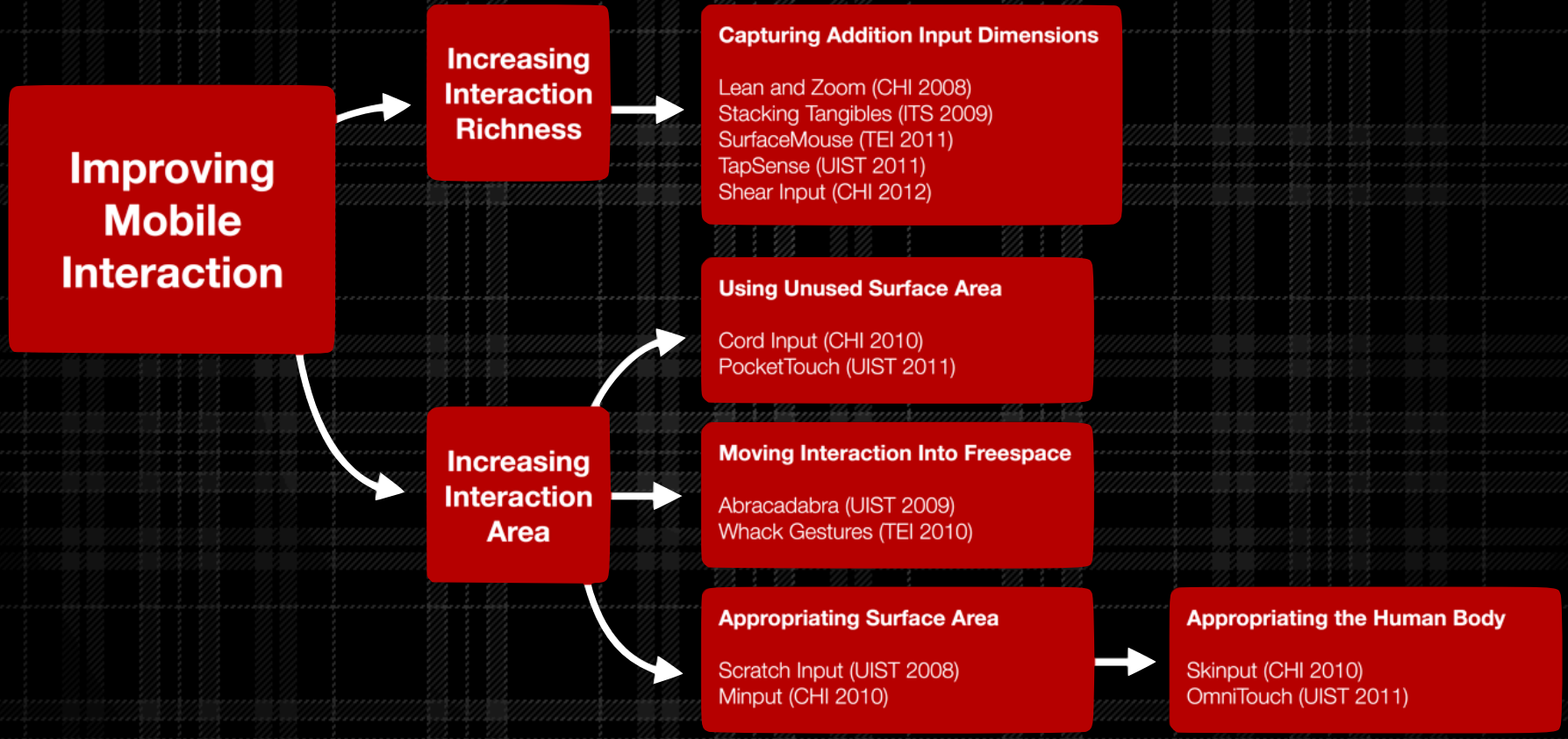
Input Richness

x Input Area

= Input Power


Improving Mobile Interaction
Increasing Interaction Richness
Capturing Addition Input Dimensions
Lean and Zoom (CHI 2008)
Stacking Tangibles (ITS 2009)
SurfaceMouse (TEI 2011)
TapSense (UIST 2011)
Shear Input (CHI 2012)
Increasing Interaction Area
Using Unused Surface Area
Cord Input (CHI 2010)
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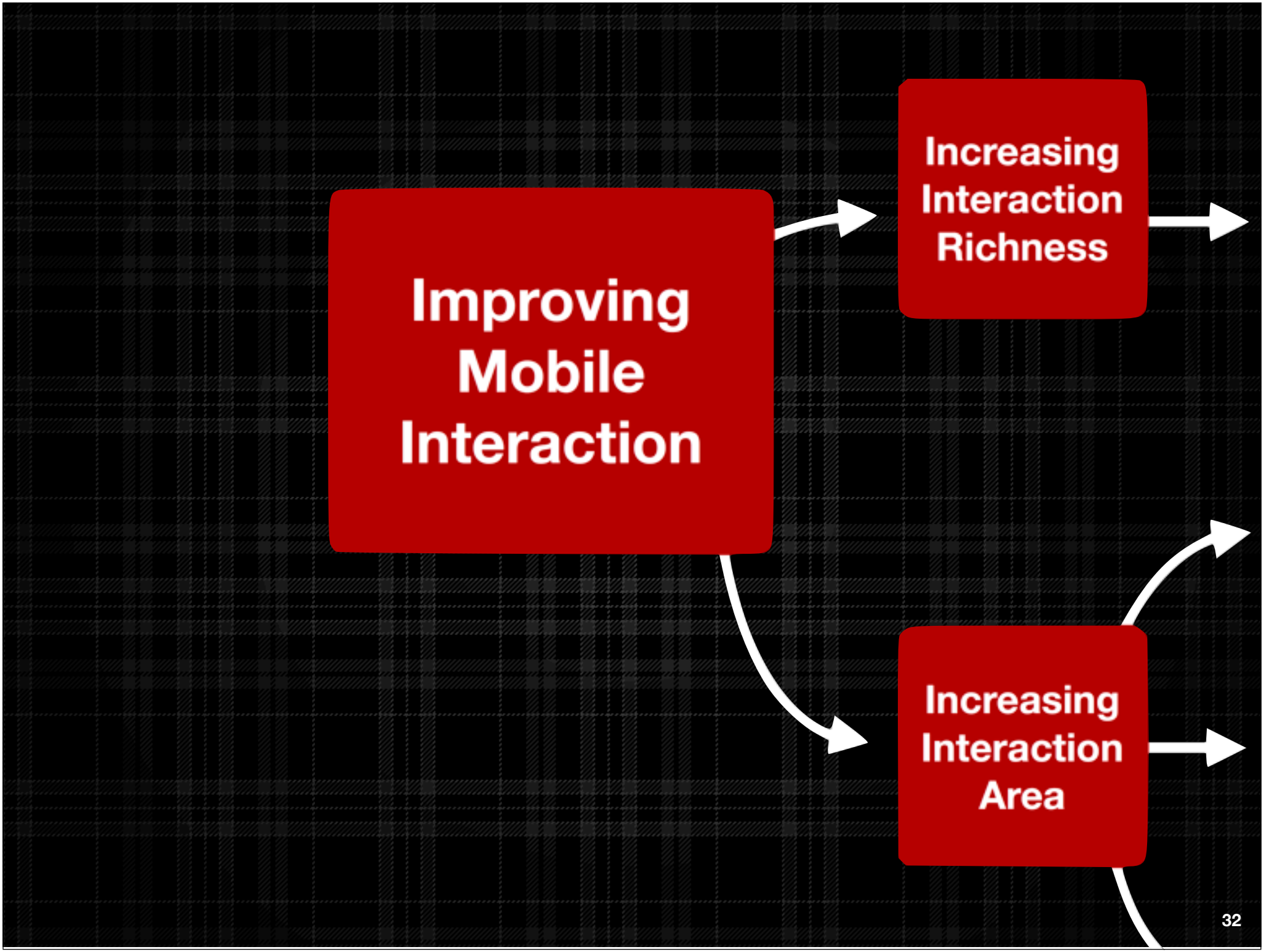
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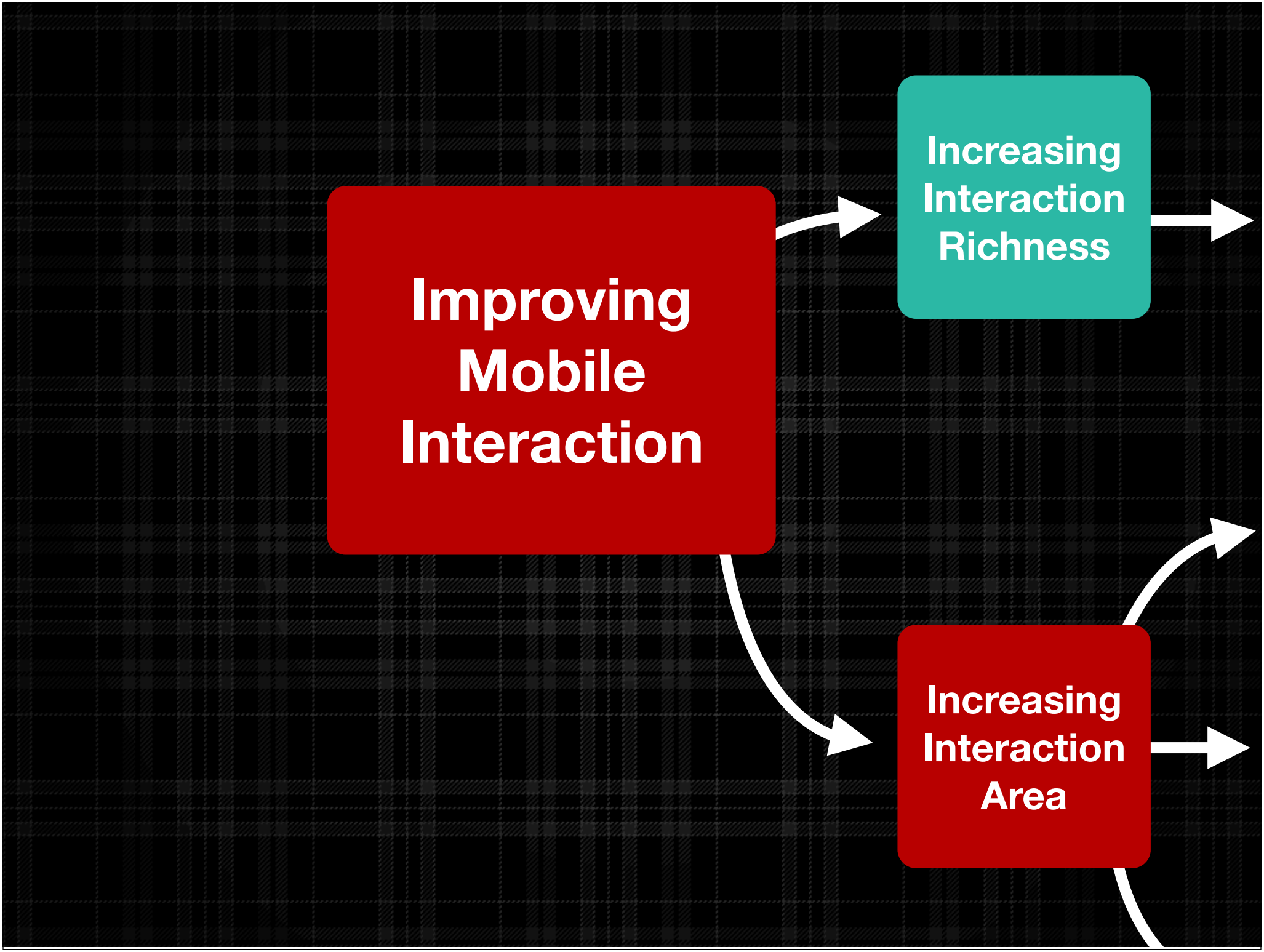
Increasing Interaction Area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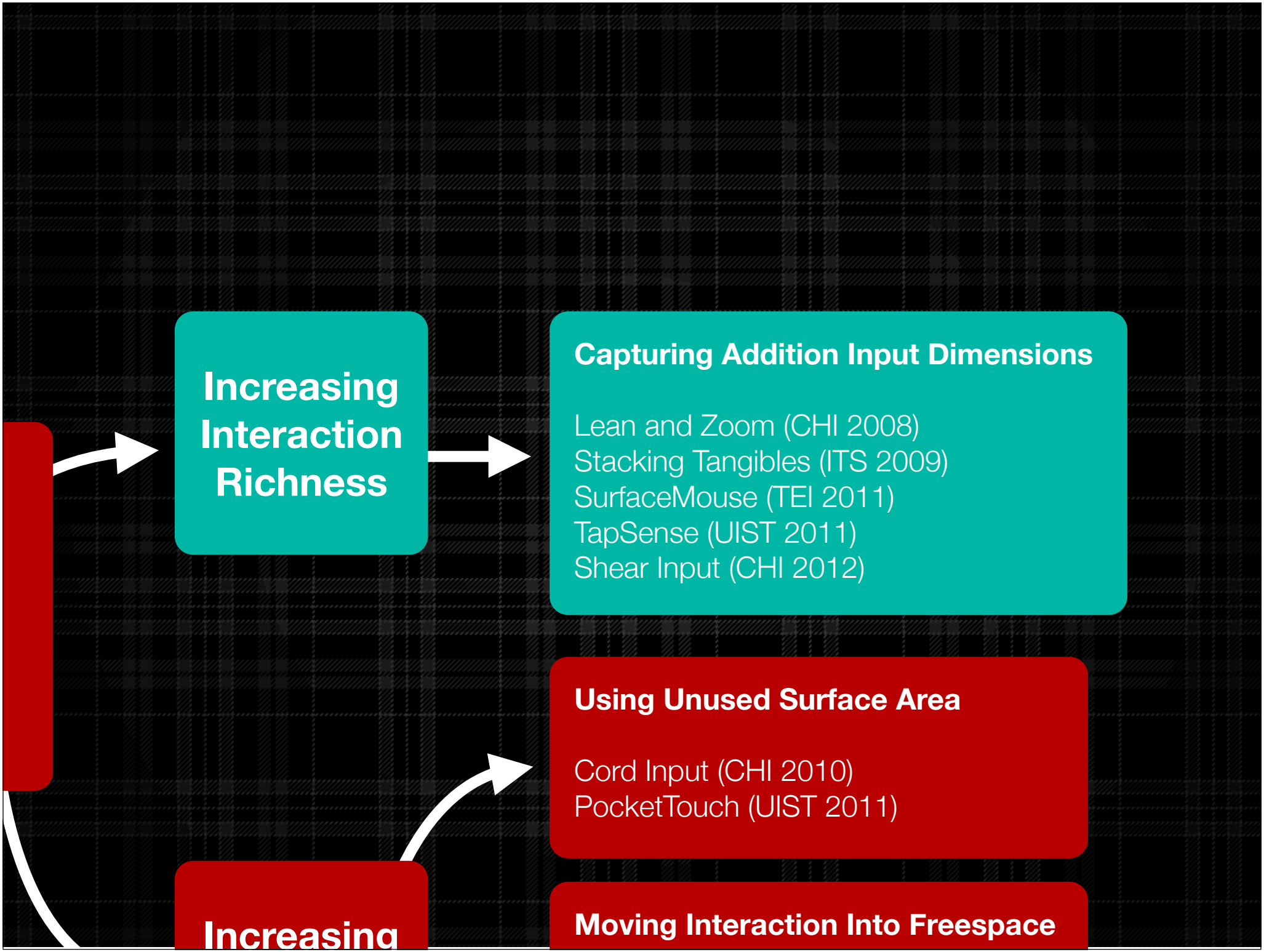
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Increasing
Moving Interaction Into Freespace

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TapSense

UIST 2011

Chris Harrison Julia Schwarz Scott Hudson

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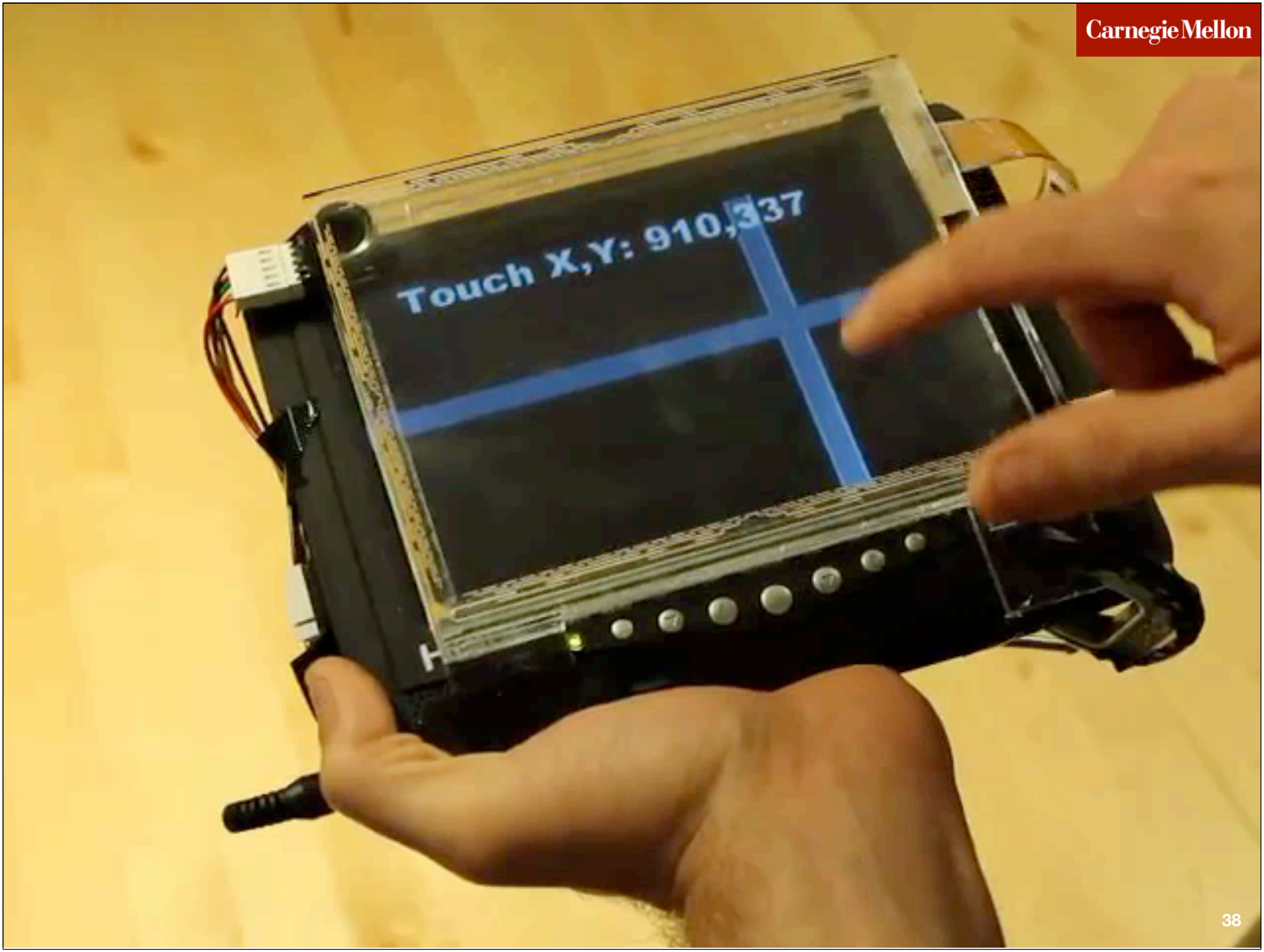
Shear Input

CHI 2012

Chris Harrison Scott Hudson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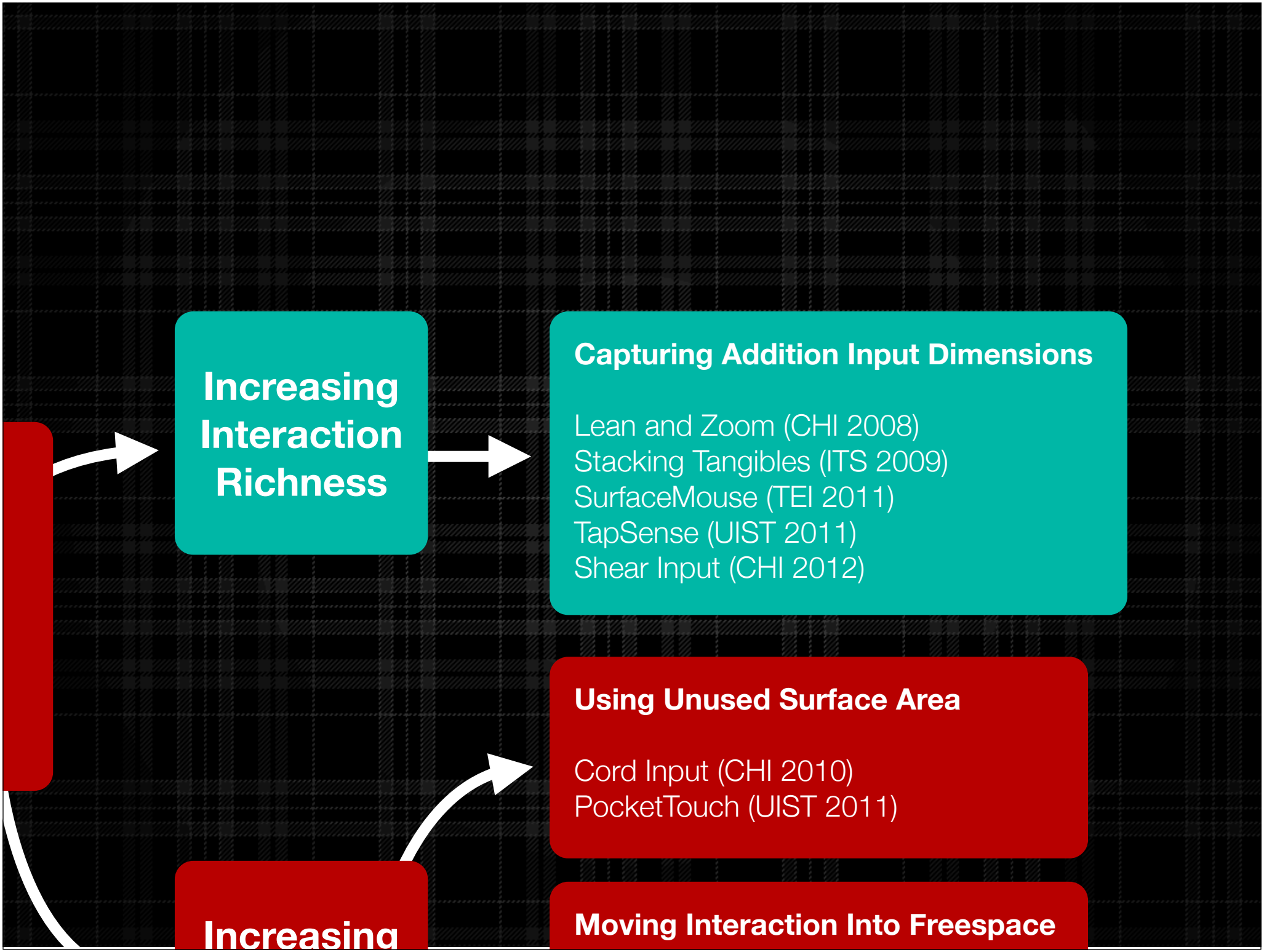
Touch X,Y: 910,337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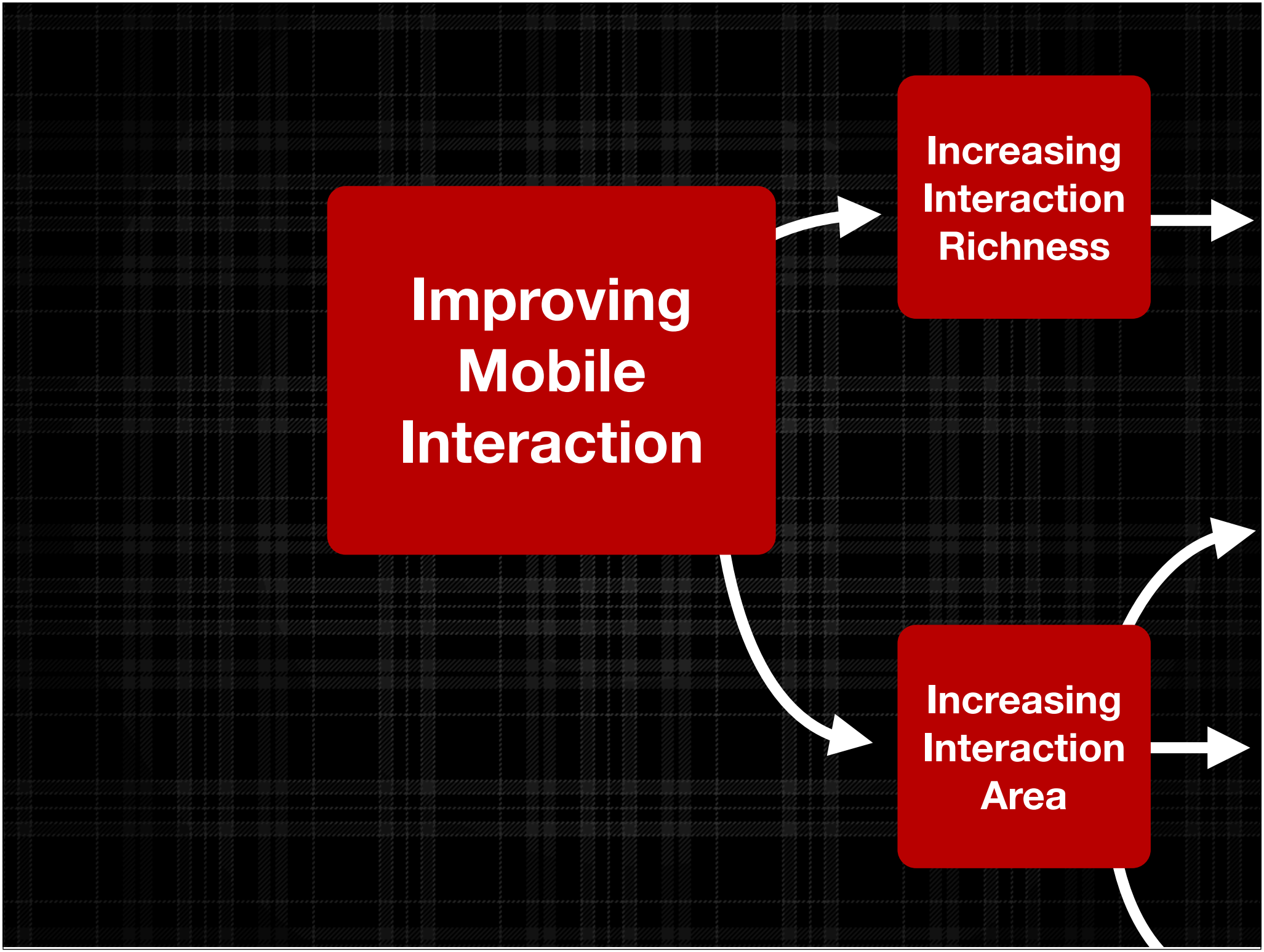
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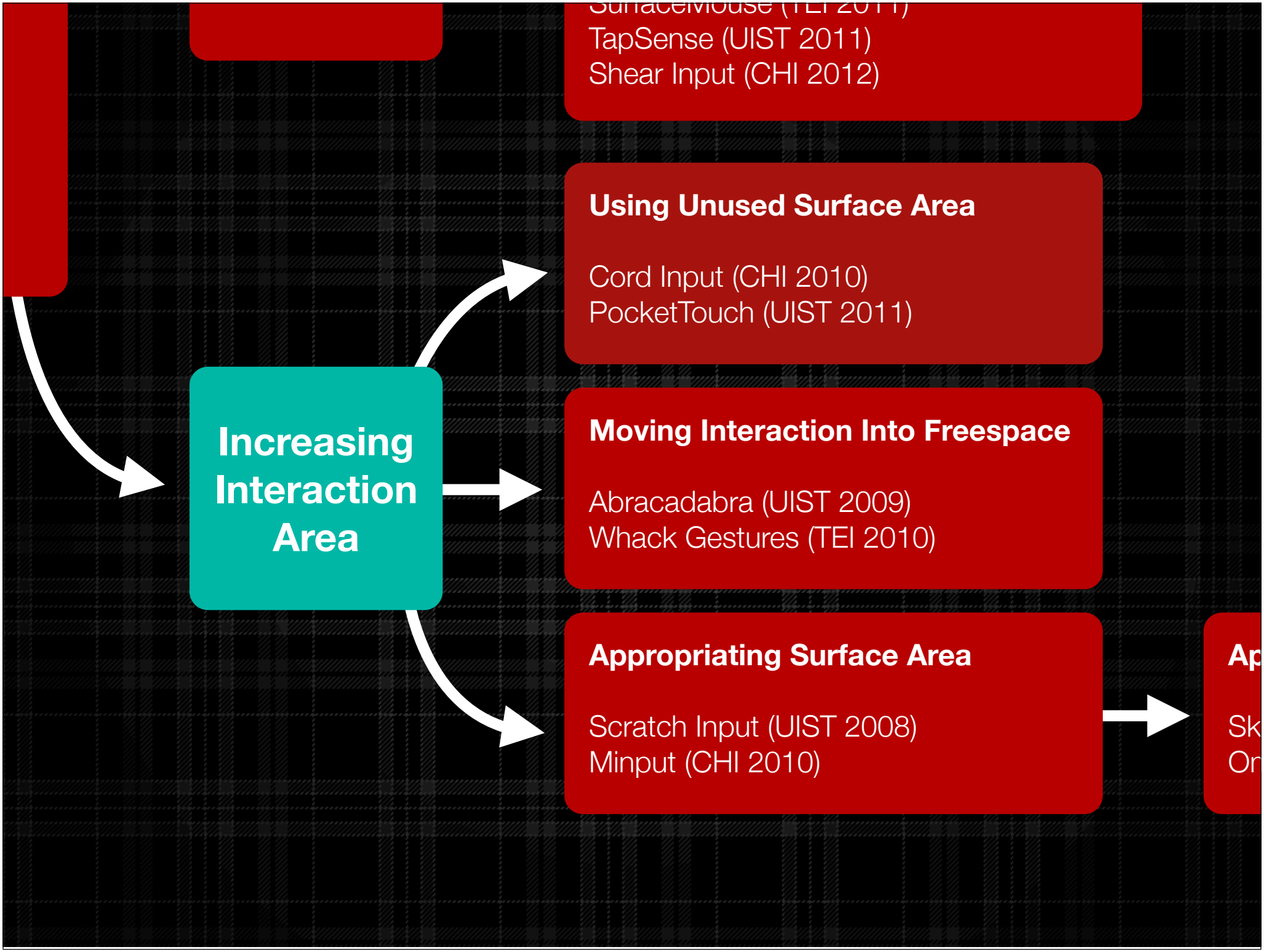
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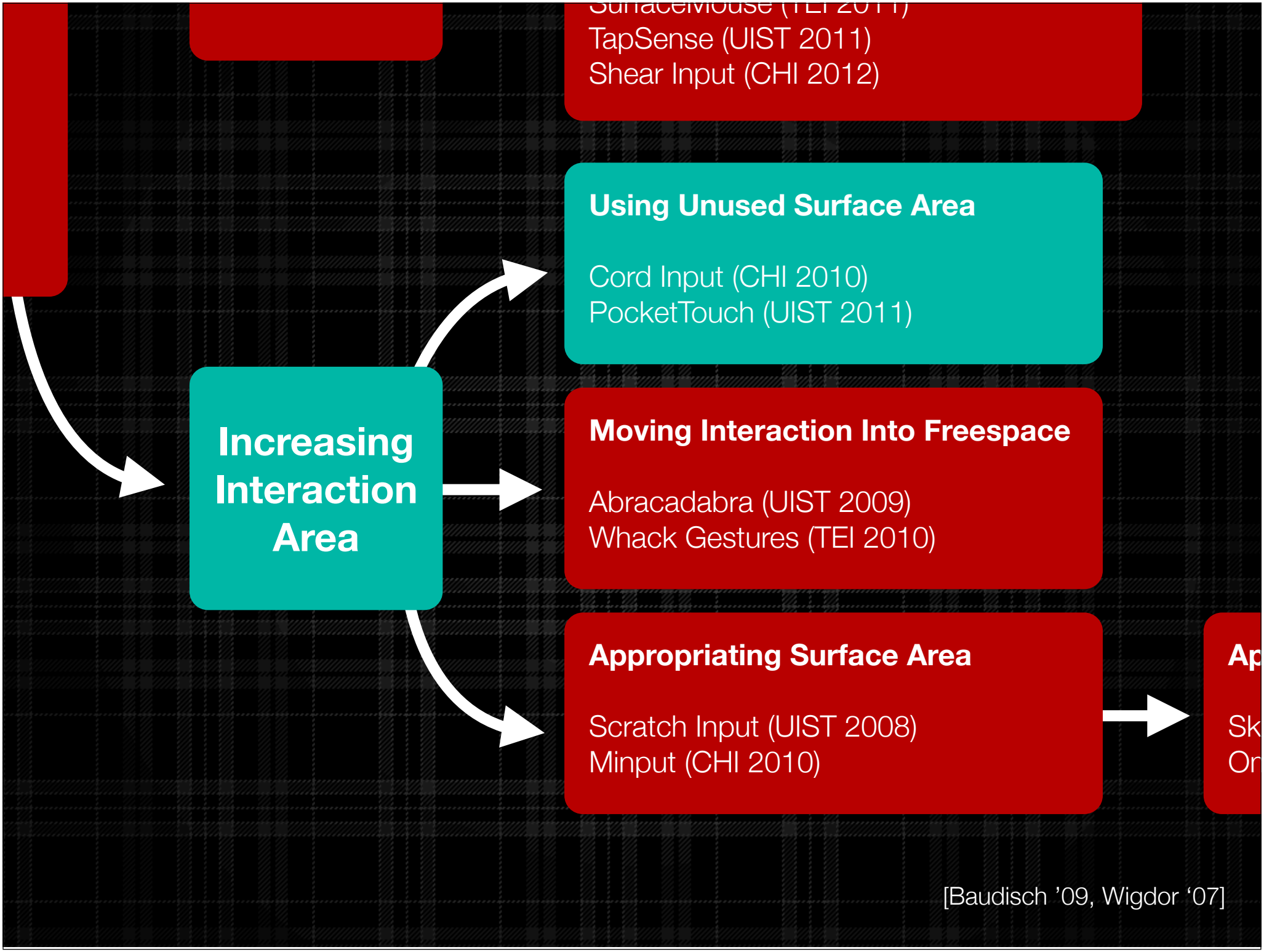
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[Baudisch '09, Wigdor '07]

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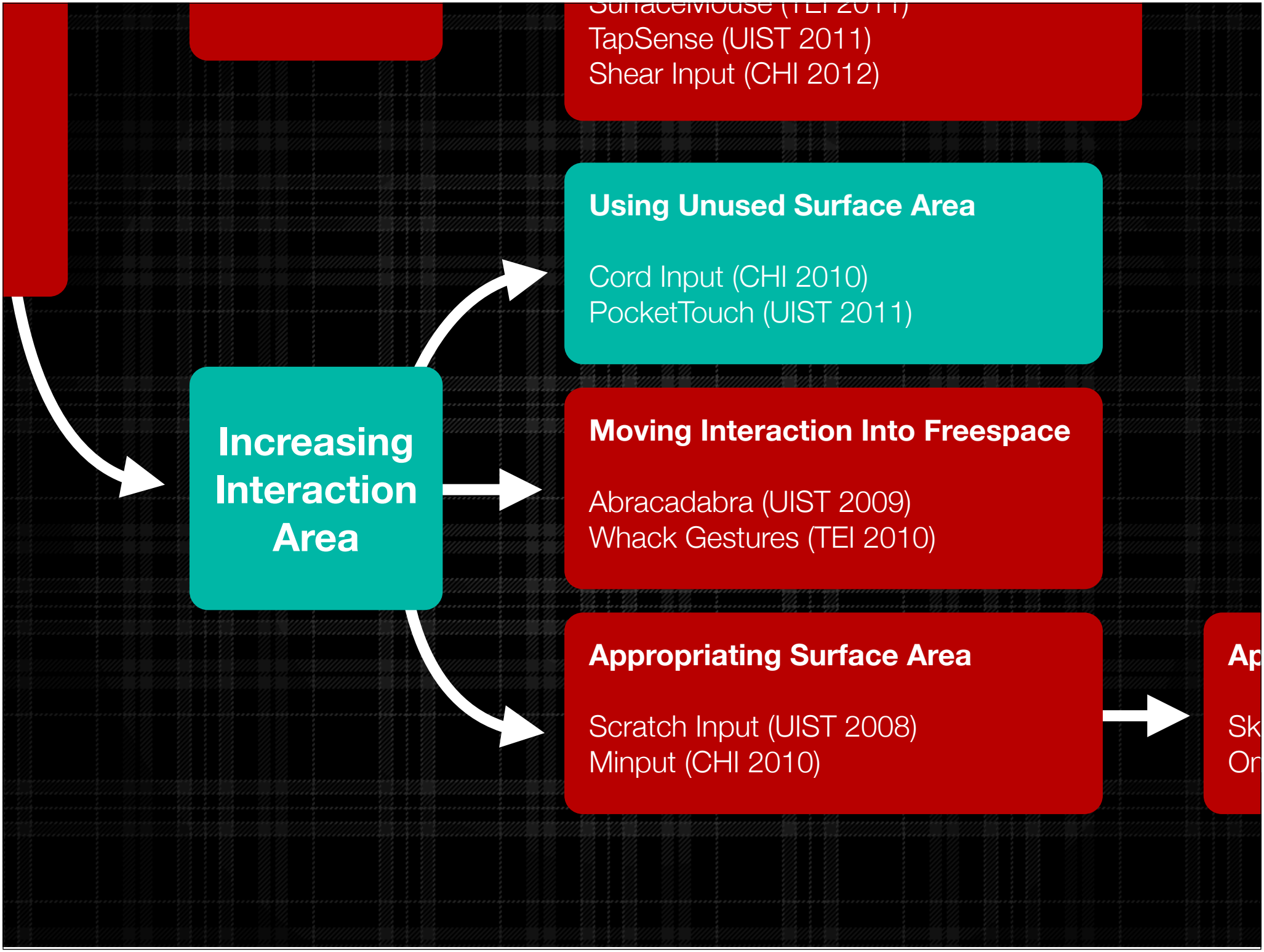
Cord Input

CHI 2010

Julia Schwarz Chris Harrison Jennifer Mankoff Scott Hudson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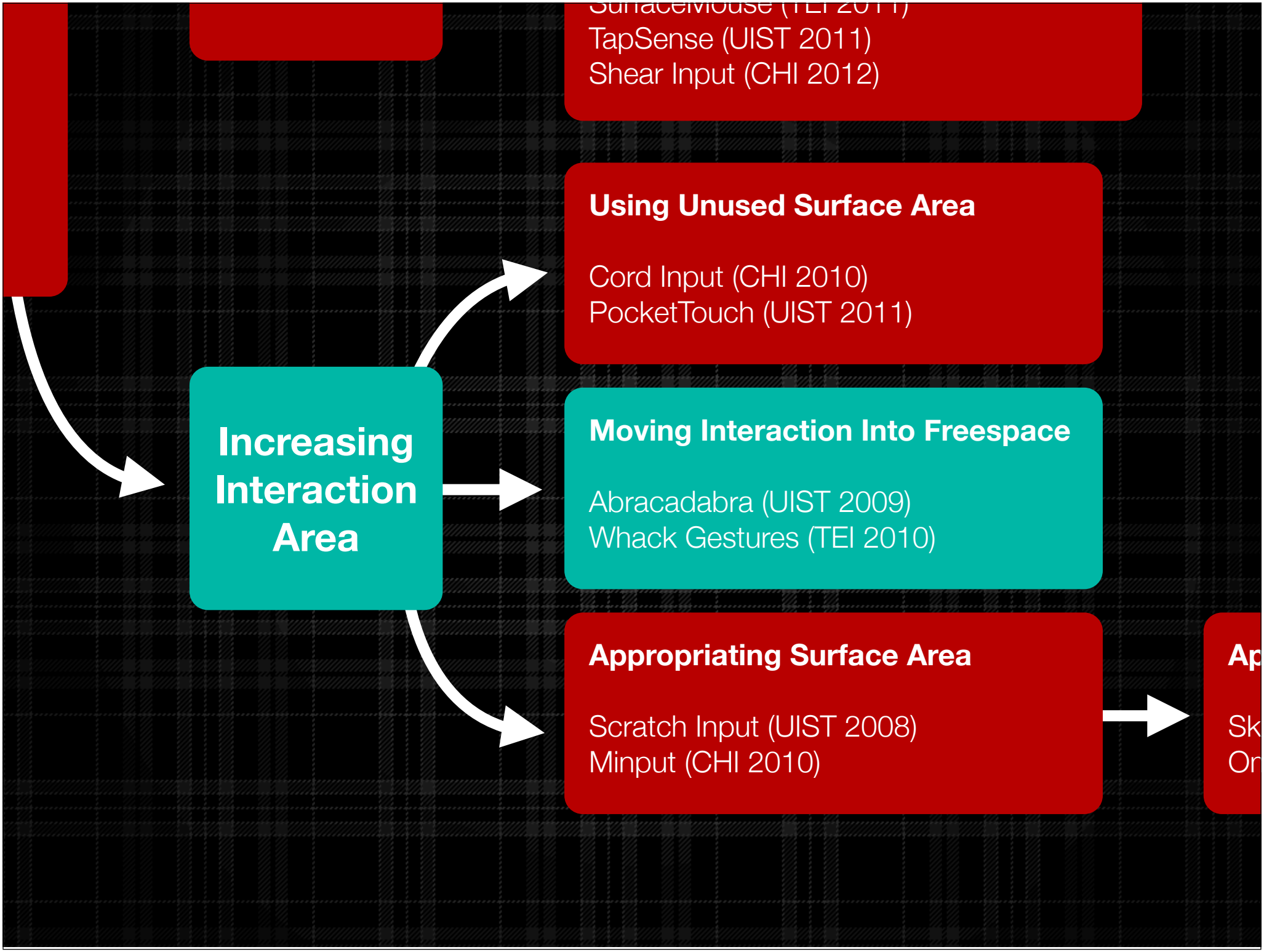
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Minput (CHI 2010)

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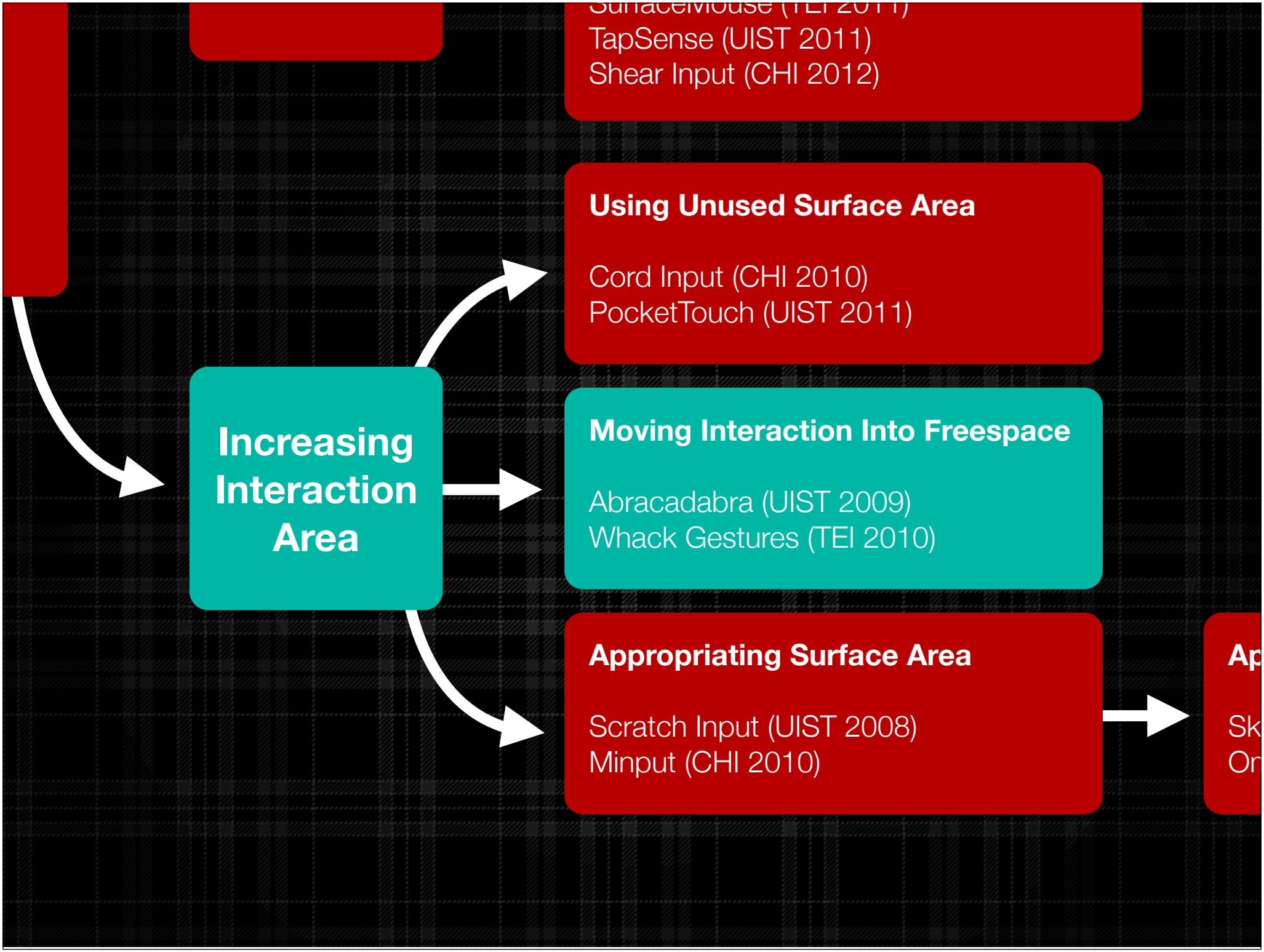
Abracadabra

UIST 2009

Chris Harrison Scott Hudson

SONGS
>>
<<
PAUSE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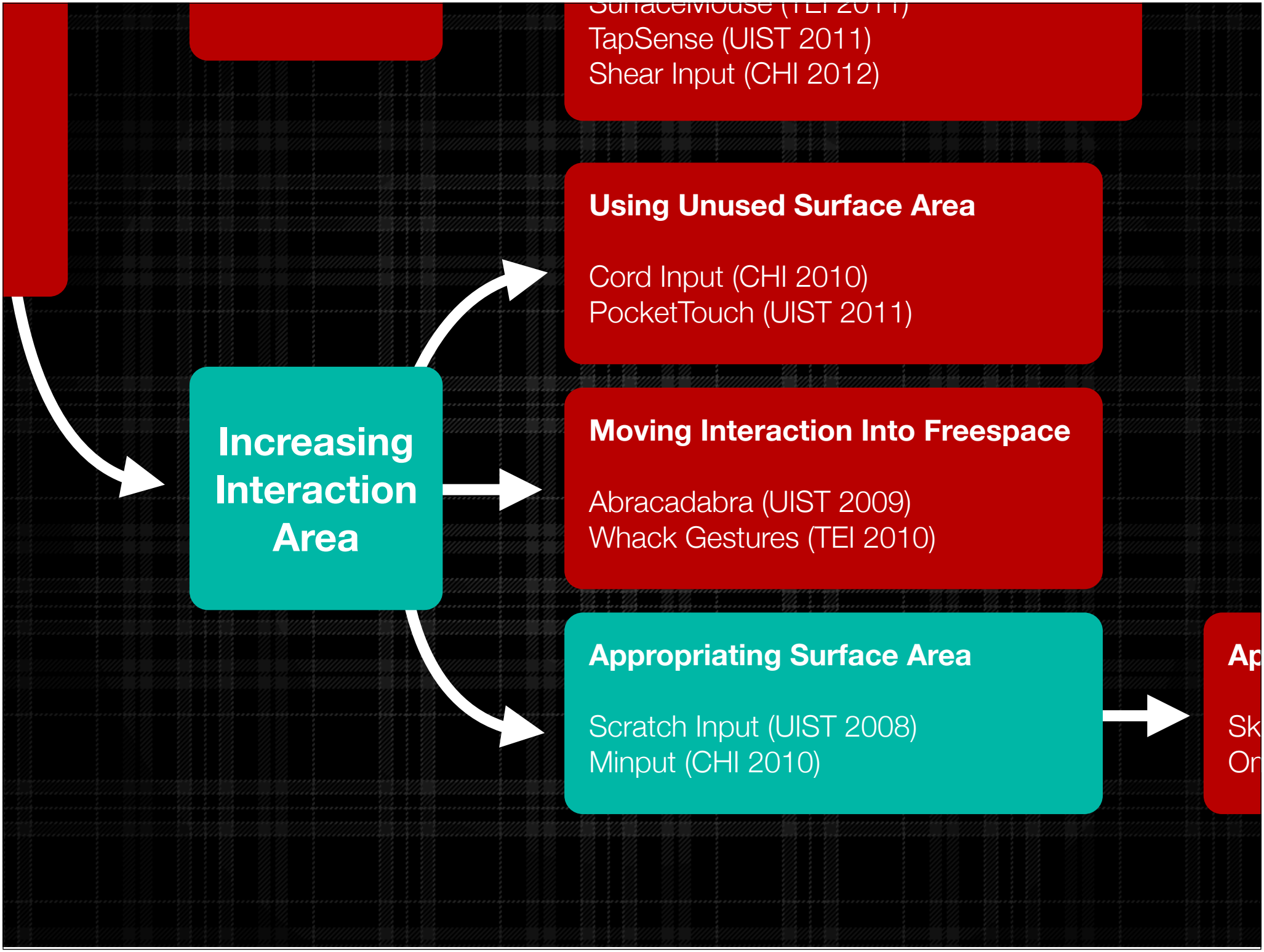
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Scratch Input

UIST 2008

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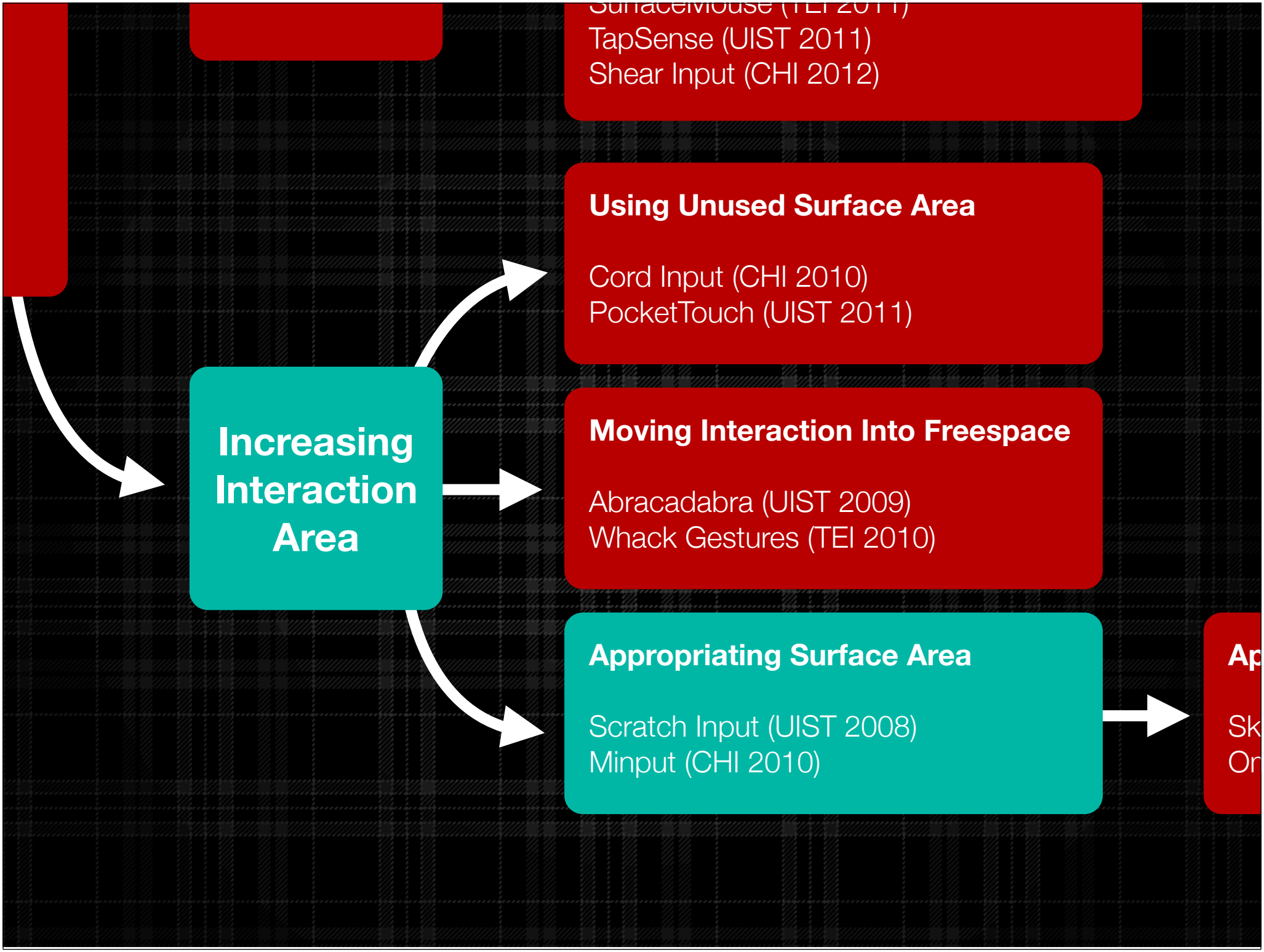
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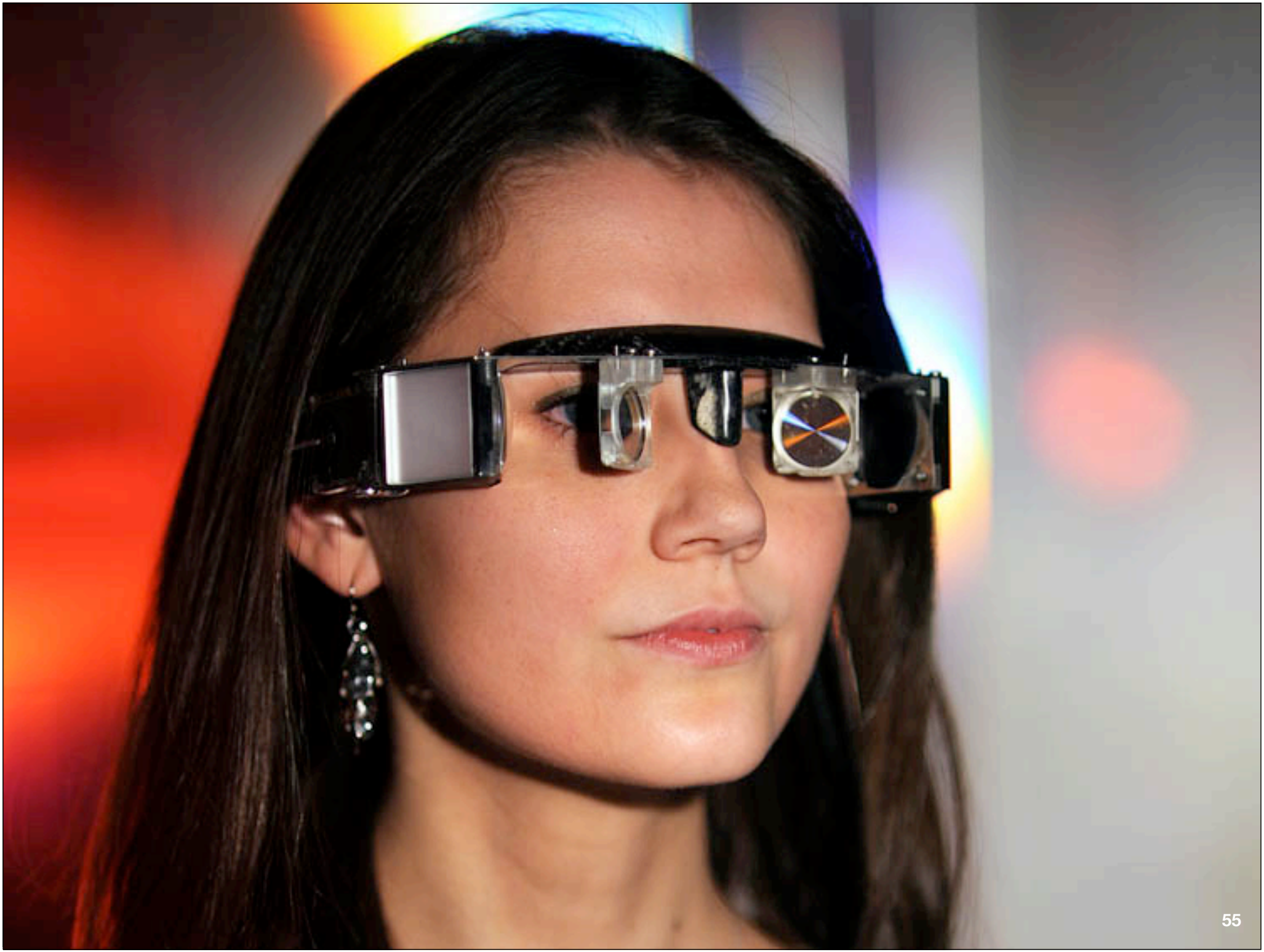

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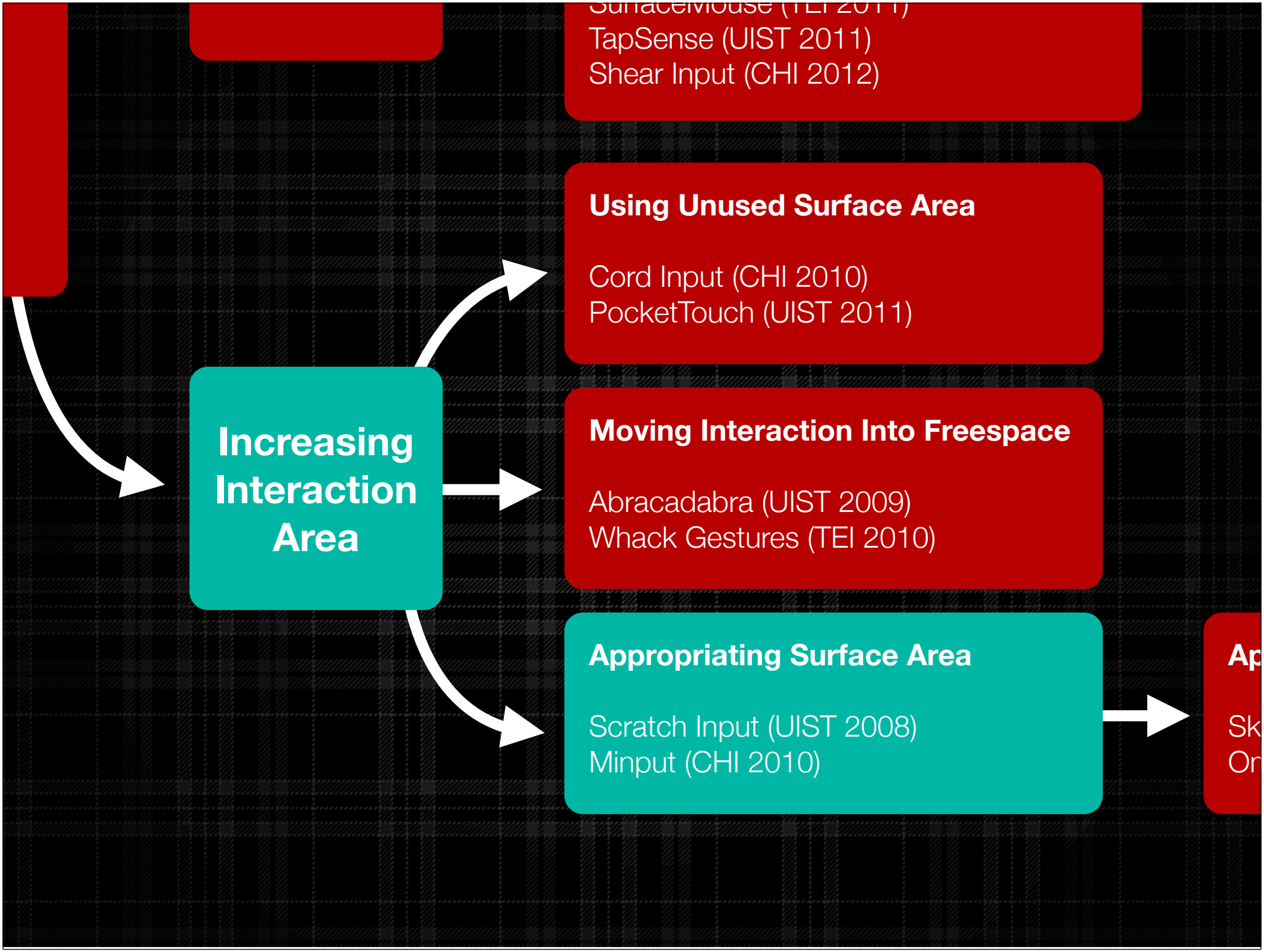
The Human Body as an Interactive Computing Platform

- Goes where we go
- Always-available input
  [Tan 2010, Saponas 2009]
- Skin is the largest organ
  - Two square meters of surface area
  - Hand alone offers more surface area than a smartphone
- Kinesthetic senses
  - Rapidly and accurately position our body
  - Fine tuned muscle memory, hand eye coordination
  - Eyes free interaction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Skinput

CHI 2010

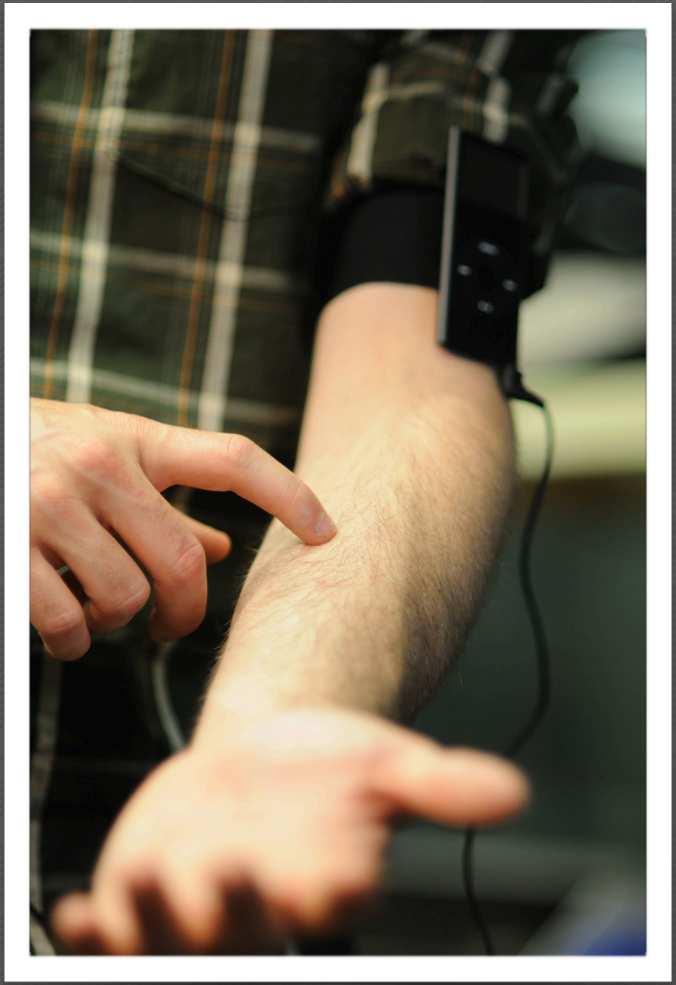
Chris Harrison Desney Tan Dan Morris

Acoustic Sensing

- Enhanced transmission through solids/liquids
  - Longer transmission distances
  - Better preservation of signal (high SNR)
- Intra-object acoustics less prone to outside interference
- Allows surfaces to be appropriated
  - Remote, indirect sensing
  - Without permanent instrumentation

Taps on the Body

- Input is by tapping on body, like touchscreen
- Taps on body create unique acoustic signatures
- Signature affected by:
  - Density of tissues
  - Anatomical features
  - Joints



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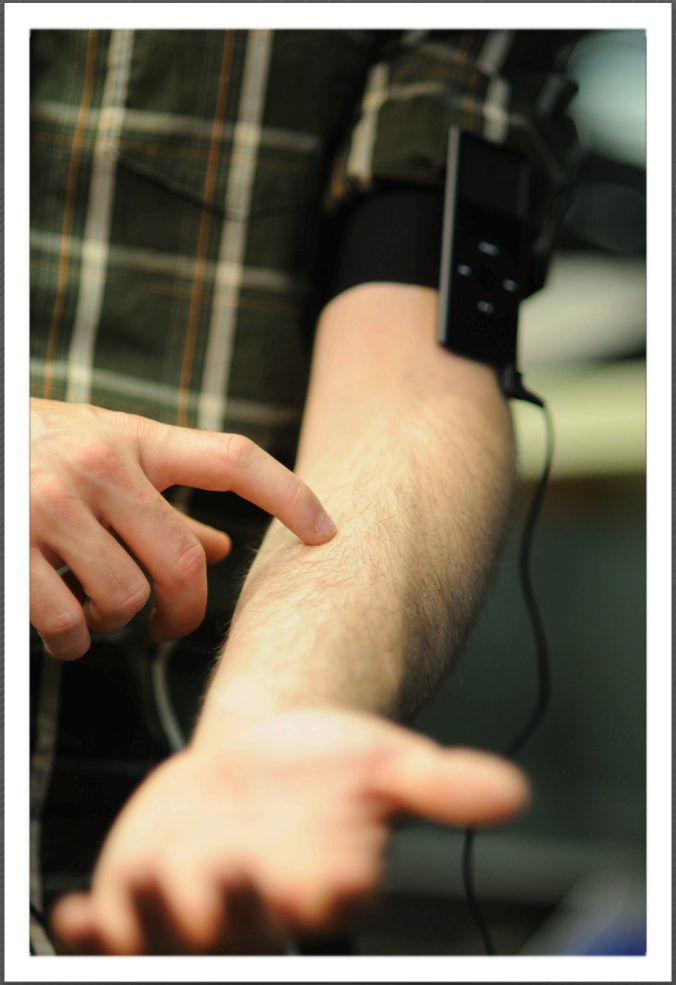
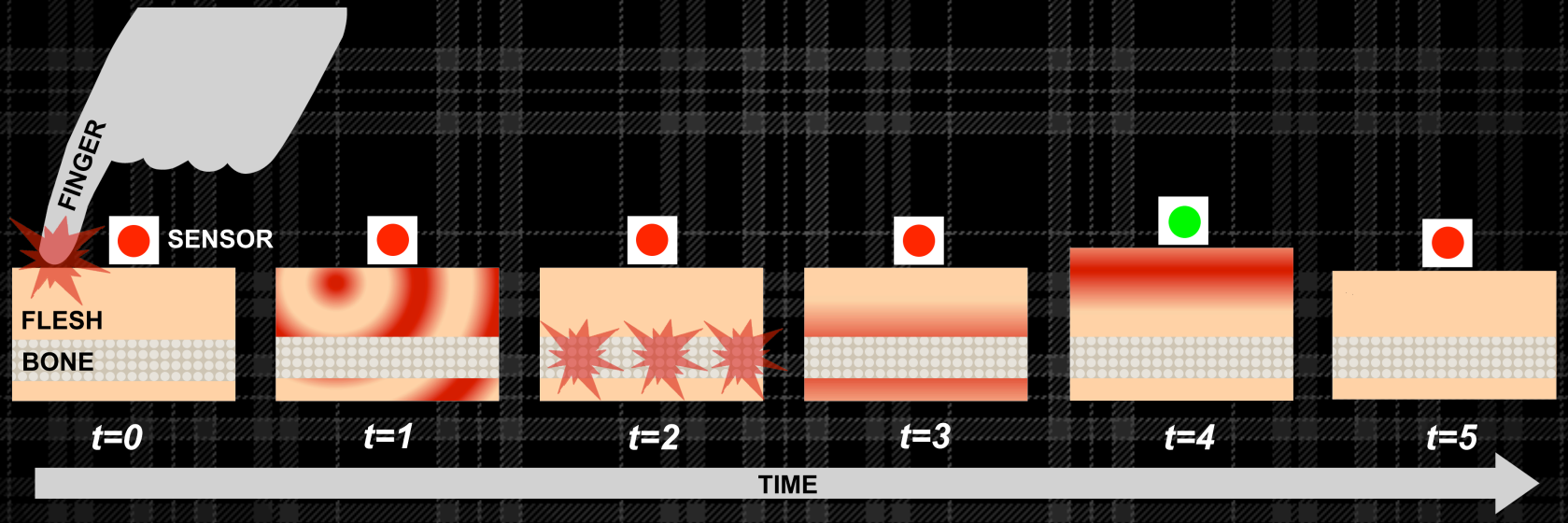
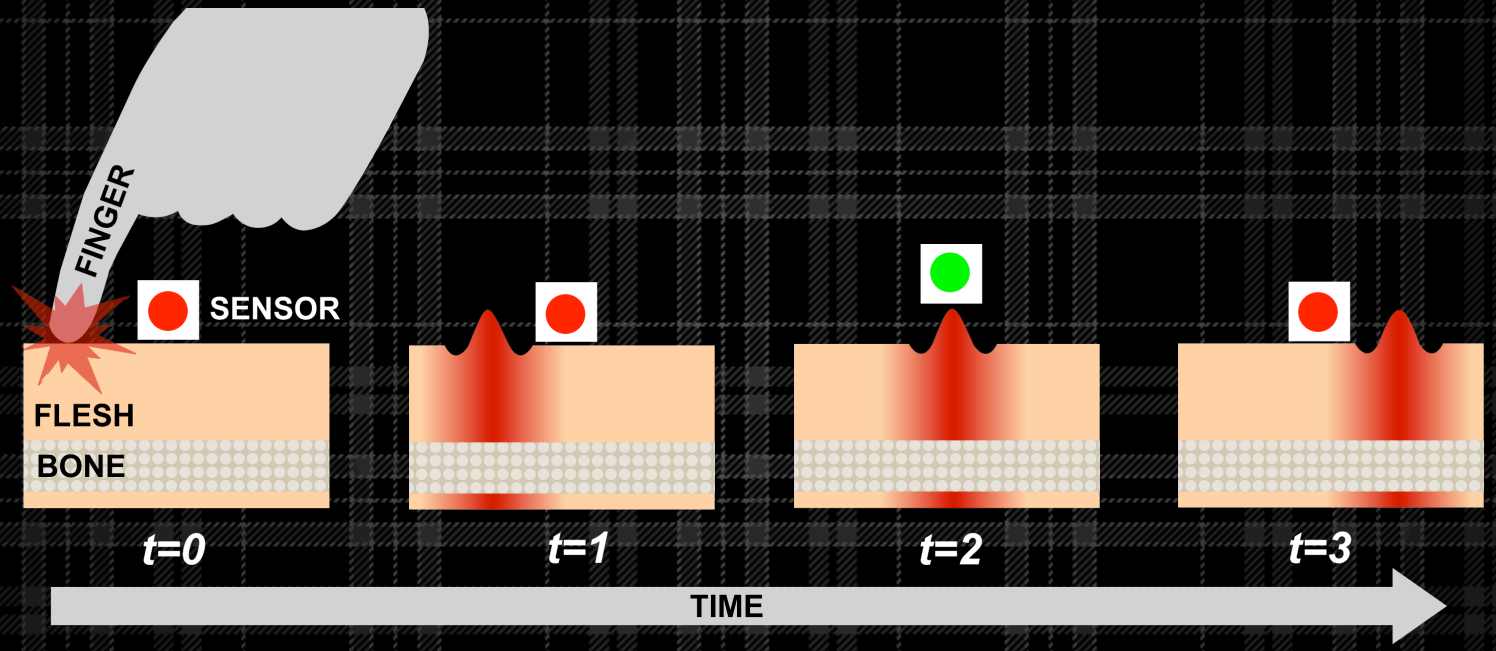


Acoustics on the Body



Longitudinal (compression) waves

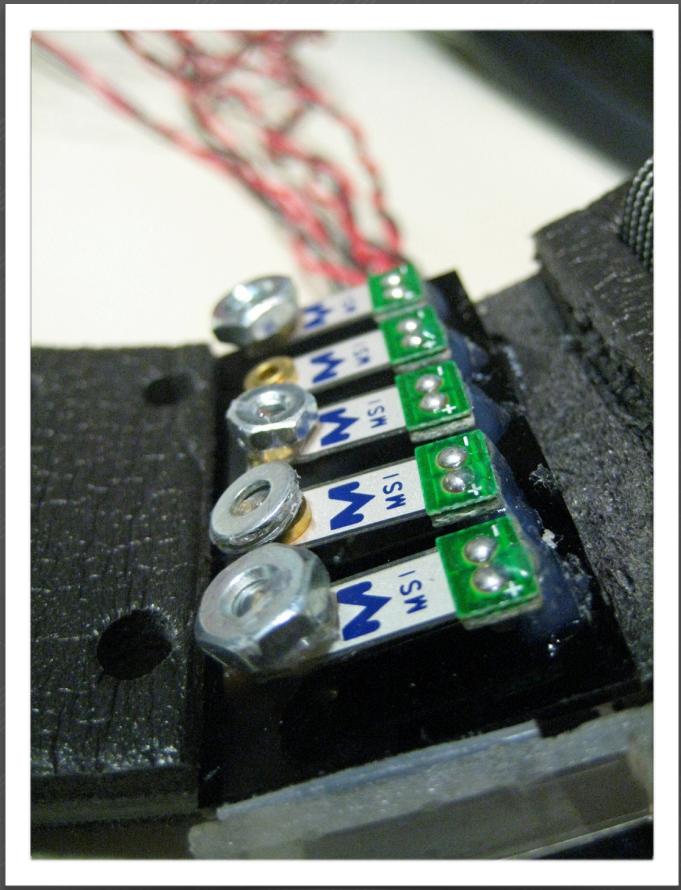
Acoustics on the Body

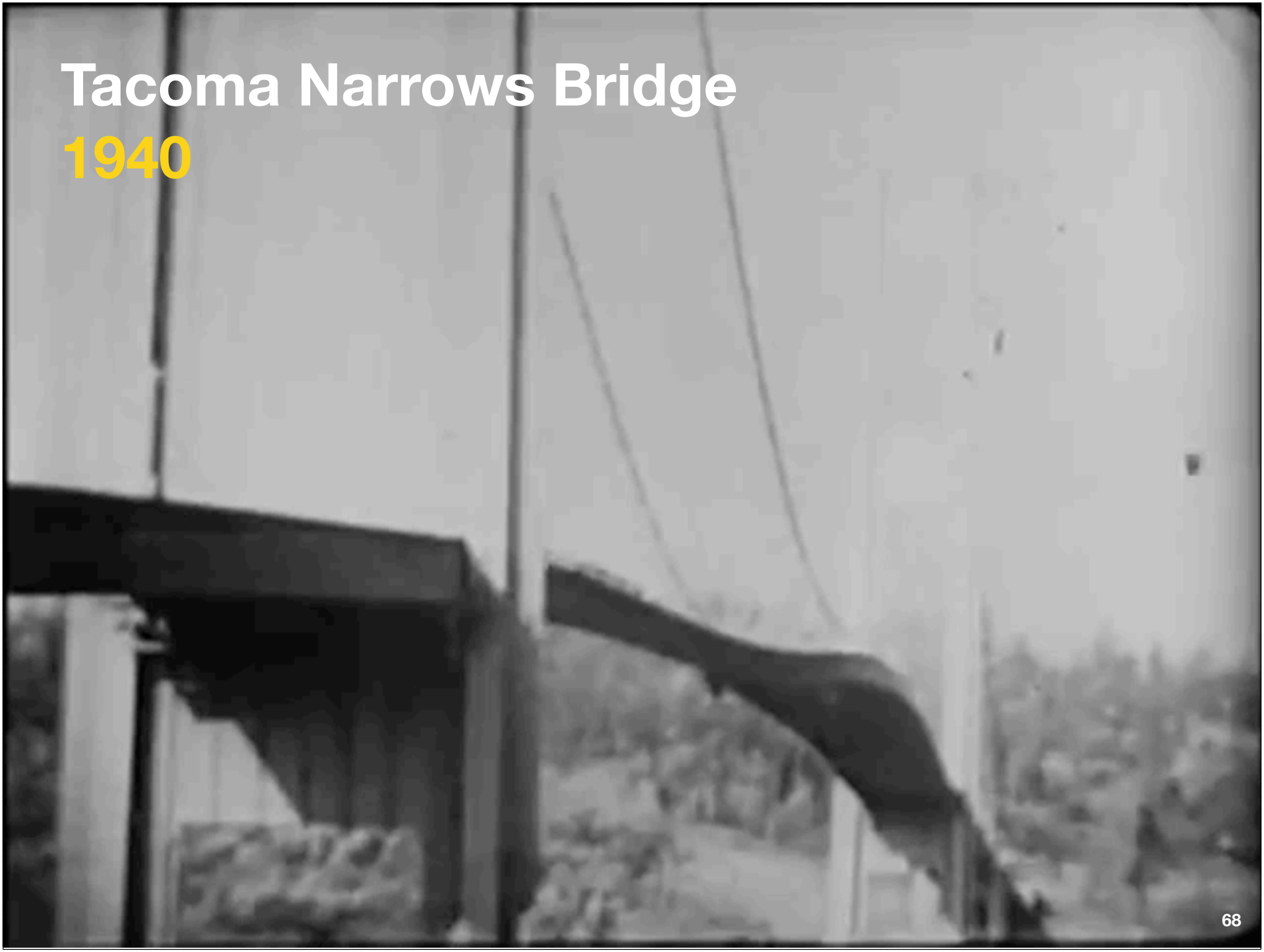


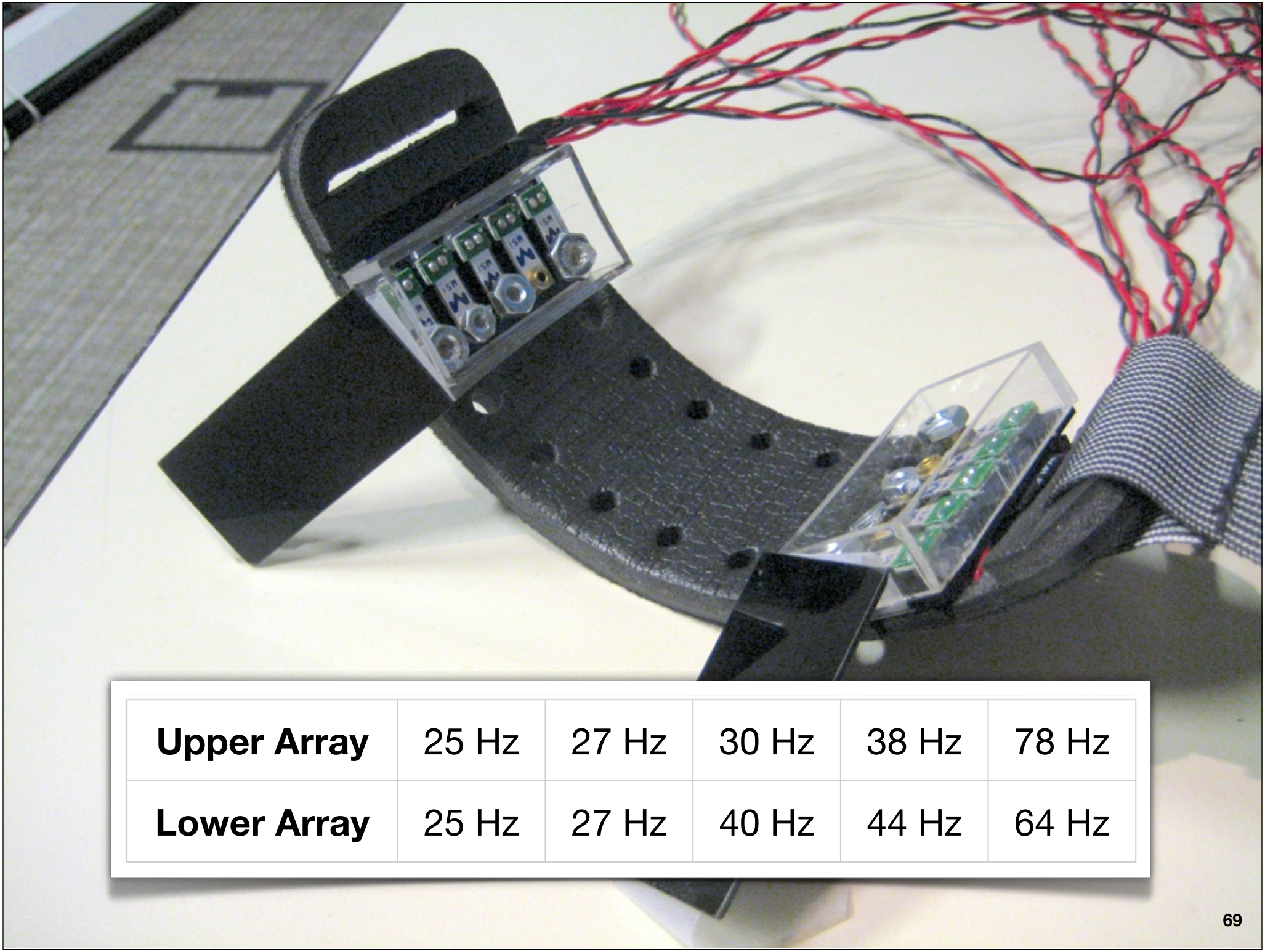
Transverse surface distortions (ripples)

Sensing

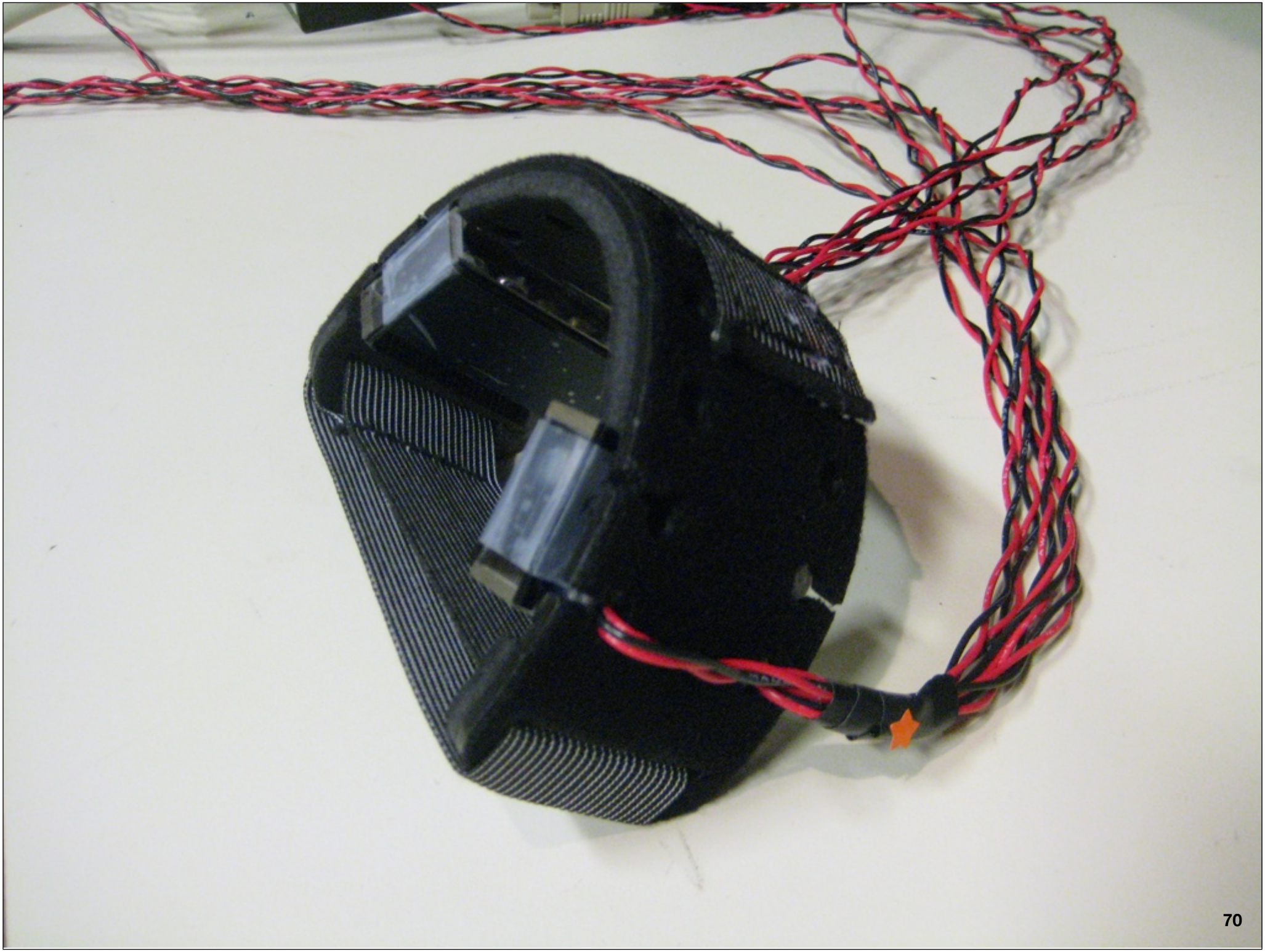
- Cantilevered mass on piezo film
  - Mass alters resonant frequency
  - Resonant frequency amplifies energy
  - Natural band pass filter
- We use 10 sensing elements
  - In two arrays of five
  - Acoustic spectrum from 25 to 78 Hz
- Constructed prototype Armband

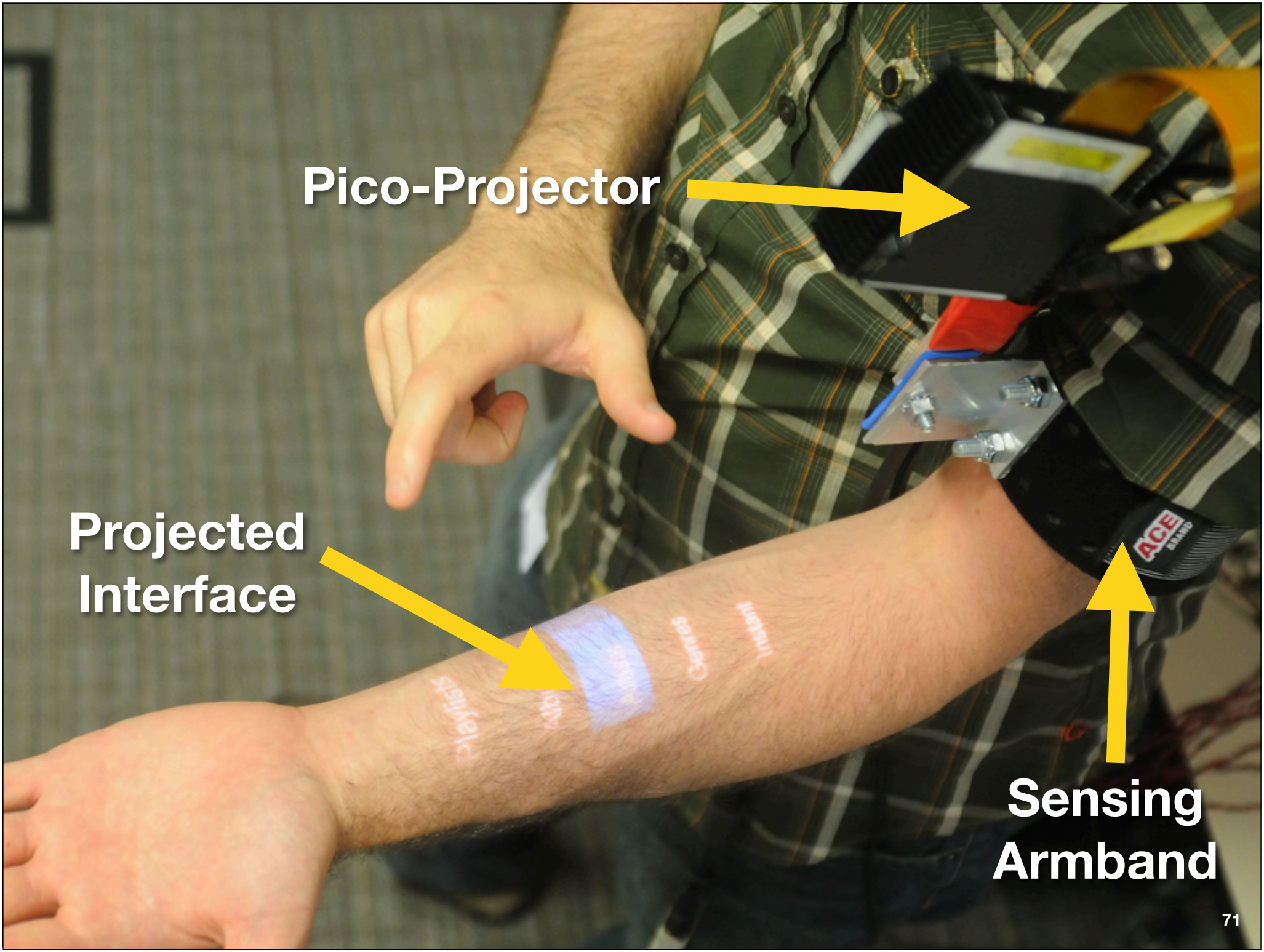


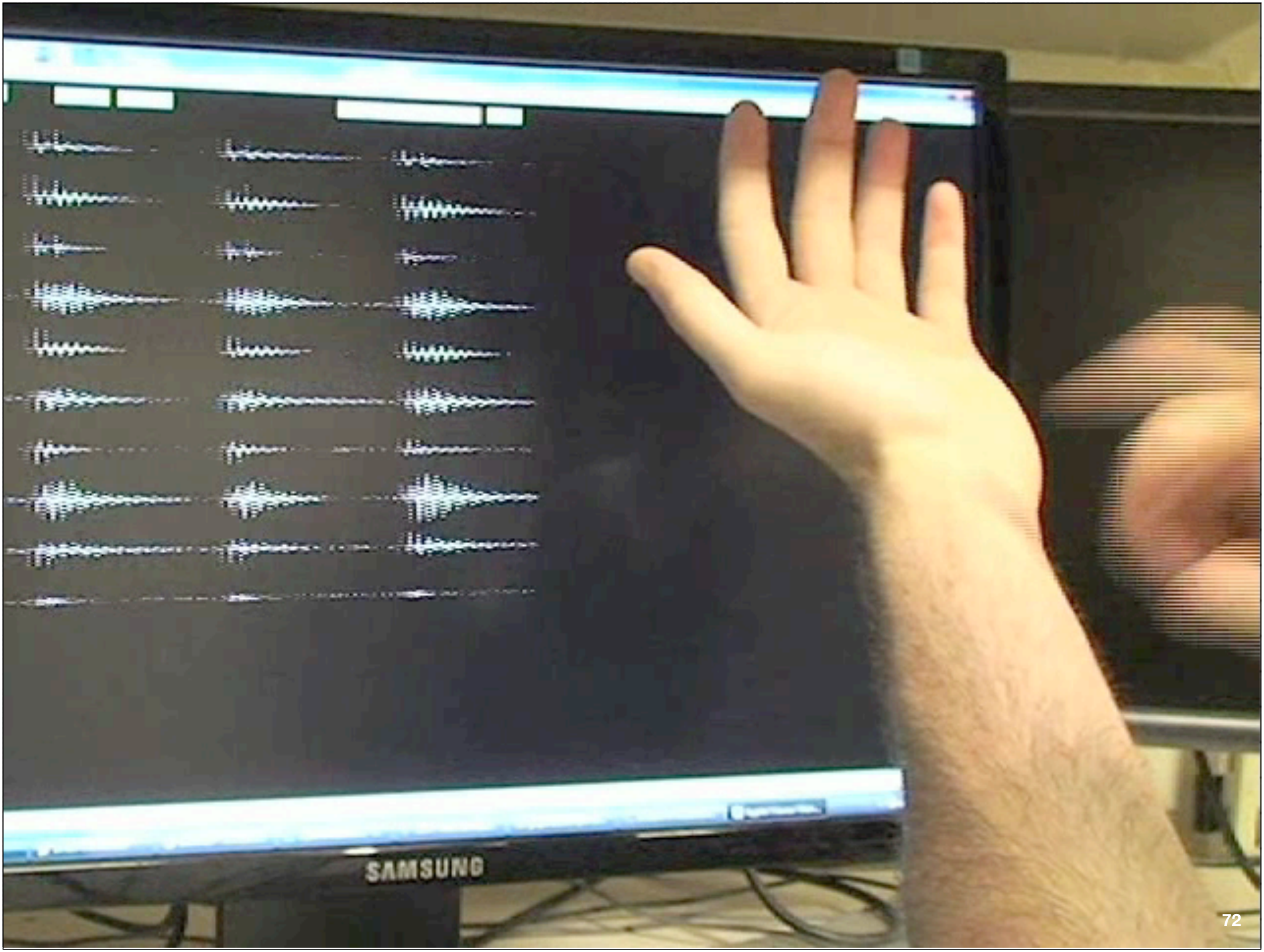

Tacoma Narrows Bridge
1940



Upper Array	25 Hz	27 Hz	30 Hz	38 Hz	78 Hz
Lower Array	25 Hz	27 Hz	40 Hz	44 Hz	64 Hz




Pico-Projector
Projected Interface
Sensing Armband
ACE BRAND

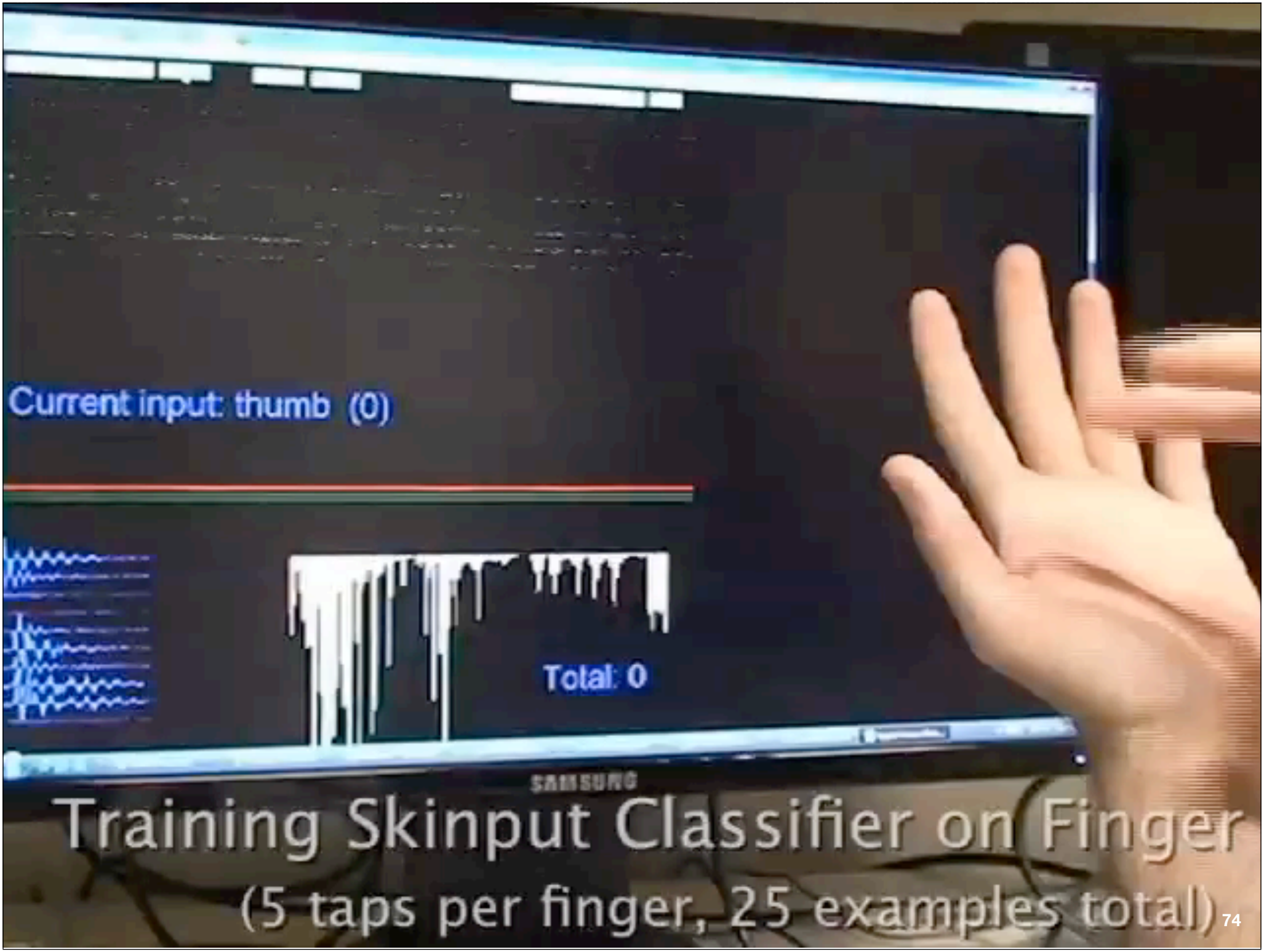

SAMSUNG

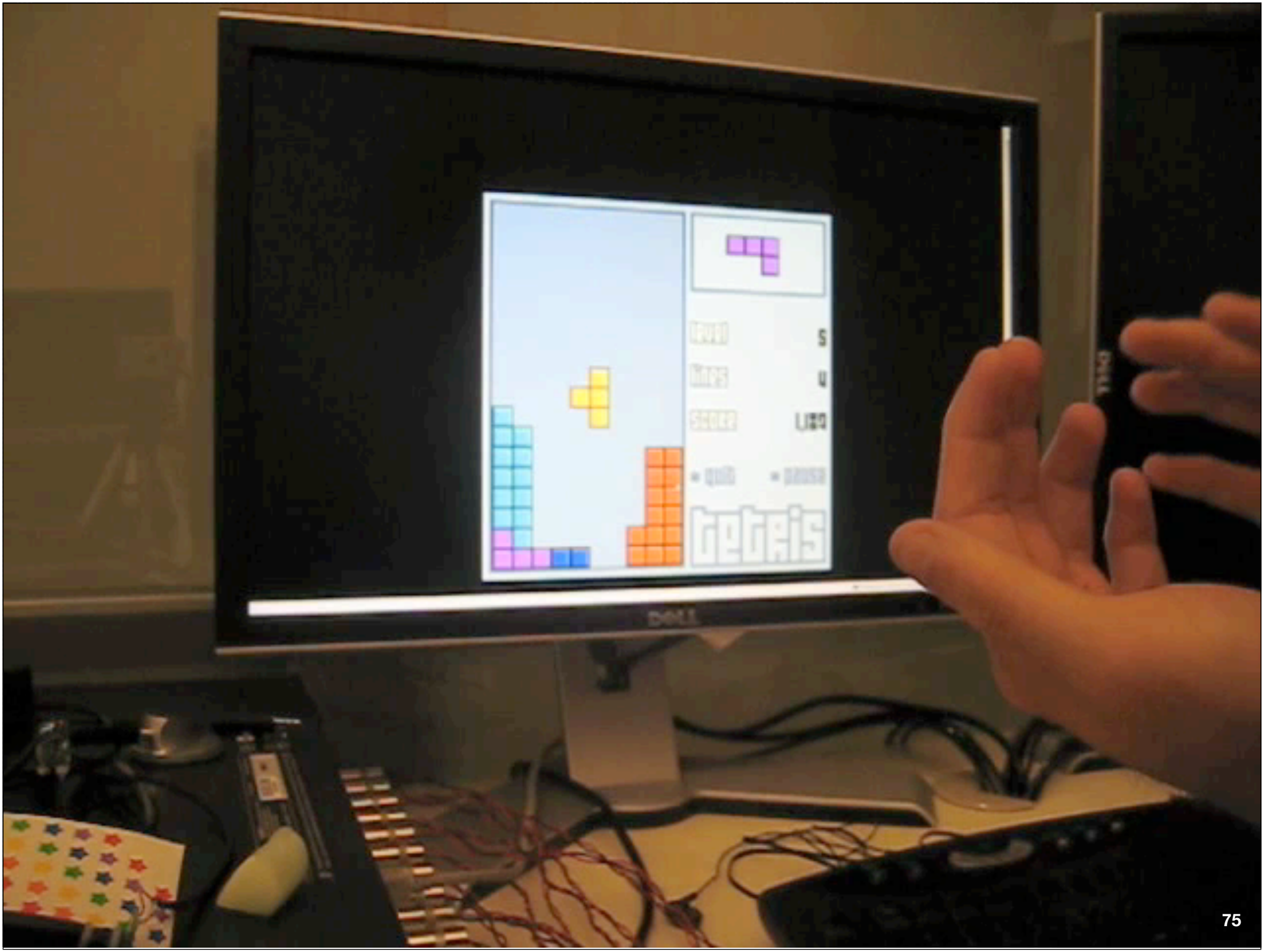
Segmentation and Processing

- Sensors provide high level of noise suppression
  - Segment using fixed thresholds on the exponential average
- Sensors provide acoustic information in different bands
  - Derive band ratios, frequency distributions, other features
- Train SVM classifier; use to determine location of tap

[Witten '05]

- Bind functions to different locations


Current input: thumb (0)
Total: 0
SAMSUNG
Training Skinput Classifier on Finger
(5 taps per finger, 25 examples total)


tetris

Carnegie Mellon

Experiment

- 13 Participants (7 female)
- Age ranged from 20 to 56 (mean 38)
- BMI ranged from 20.5 (normal) to 31.9 (obese)
- Three input location sets
  - Fingers (5 locations)
  - Whole arm (5 locations)
  - Forearm (10 locations)

Procedure

- Users provided 3 rounds of example input
  - 10 taps to each input location
  - Next round started after all locations were tapped
- Accuracy evaluated:
  - Presented users a simple text stimuli (e.g., “tap your wrist”)
  - Each input location appeared 10 times, random order
  - Live segmentation and classification accuracy

Carnegie Mellon

Fingers (5 locations)

- We have exceptional dexterity with our fingers
- Discrete and named (e.g., thumb, ring)
- Linearly ordered
- Downside: Hard to sense

- Mean accuracy: **87.7%** (SD=10.0%)
- Segmentation accuracy: **~100%**

Carnegie Mellon

Fingers (5 locations)

- We have exceptional dexterity with our fingers
- Discrete and named (e.g., thumb, ring)
- Linearly ordered
- Downside: Hard to sense

- Mean accuracy: **87.7%** (SD=10.0%)
- Segmentation accuracy: **~100%**

Carnegie Mellon

Whole Arm (5 locations)

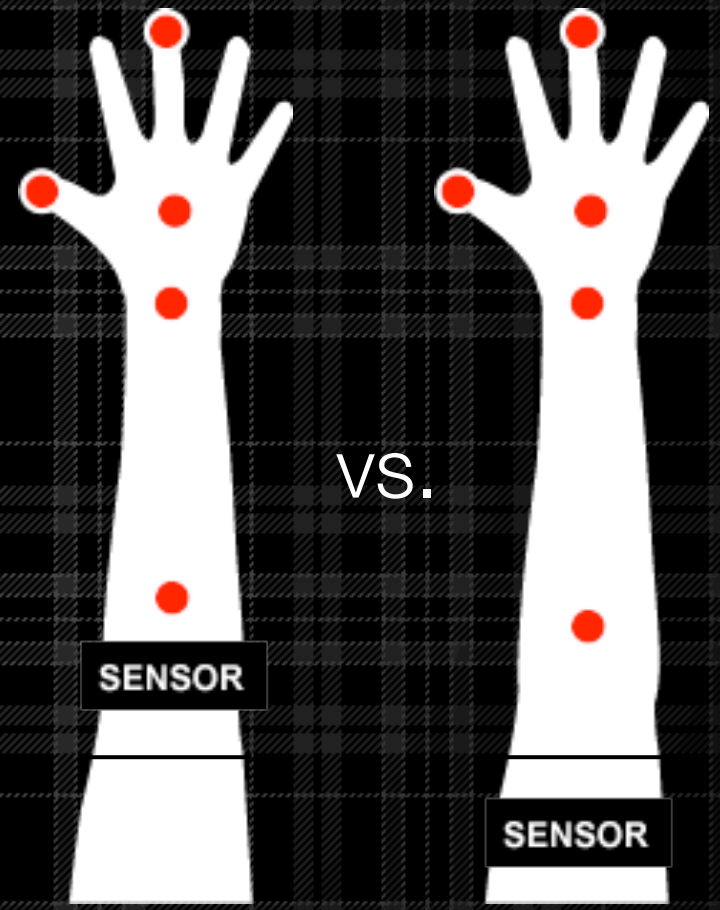
- Discrete and well named (e.g., wrist, palm)
- Acoustically unique

- Mean accuracy: **95.5%** (SD=5.1%)
- Eyes-free mean accuracy: **85.0%** (SD=9.4%)

Carnegie Mellon

Whole Arm (5 locations)

- Below-elbow mean accuracy:
  95.5% (SD=5.1%)
- Above-elbow mean accuracy:
  88.3% (SD=7.8%)



Carnegie Mellon

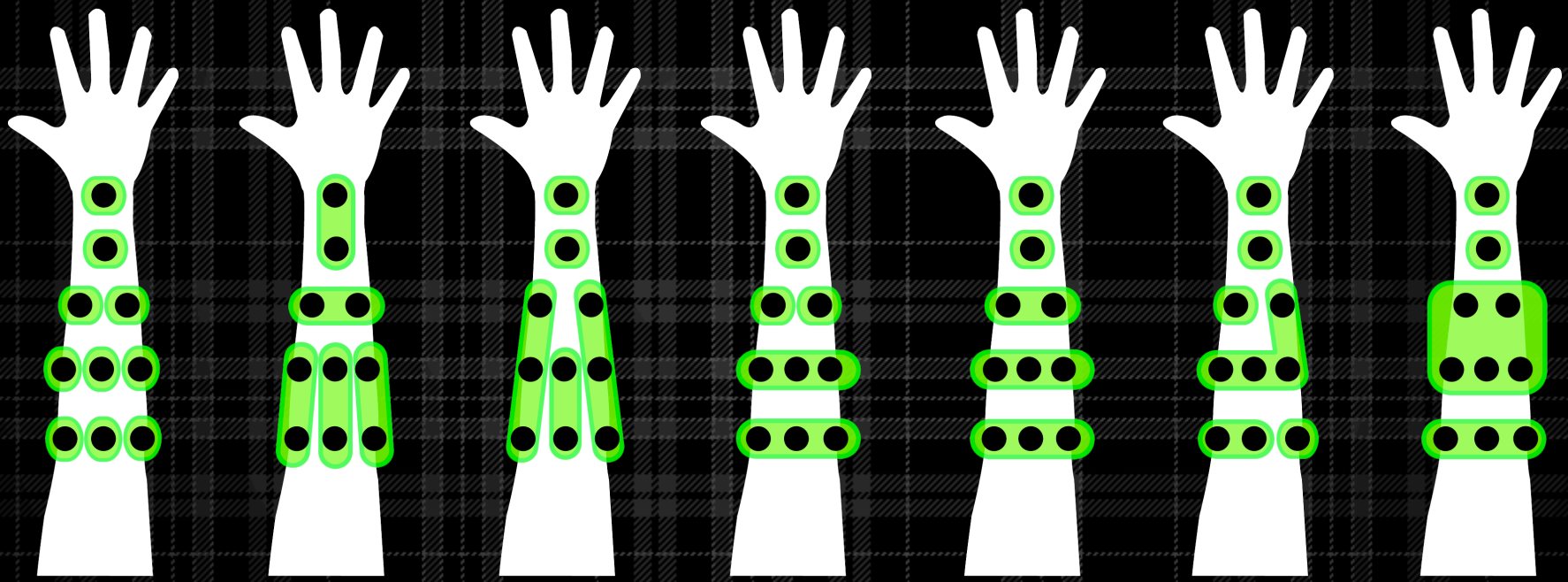
Forearm (10 locations)

- Attempt to tax system accuracy
- Used stickers instead of names
- Two training rounds (due to time)

- Mean accuracy: **81.5%** (SD=10.5%)

Carnegie Mellon

Forearm Groupings & Accuracies



81.5% (10 locations)

84.0% (5 locations)

86.3% (5 locations)

87.1% (6 locations)

87.4% (5 locations)

88.8% (6 locations)

91.2% (4 locations)

Walking and Jogging

- Male participant
  - 2.3 mph walking
  - 4.3 mph jogging
- Female participant
  - 1.9 mph walking
  - 3.9 mph jogging
- Three Input locations:
  - Arm | Wrist | Palm
  - Provided 10 input examples per location while walking/jogging

Walking and Jogging

Walking

- No false positive inputs
- **100%** true positive segmentation
- Mean classification accuracy **93.4%**

Jogging

- Four false positives (over six minutes)
- **100%** true positive segmentation
- Mean classification accuracy **71.7%**

MENU

Address Book
Music Player

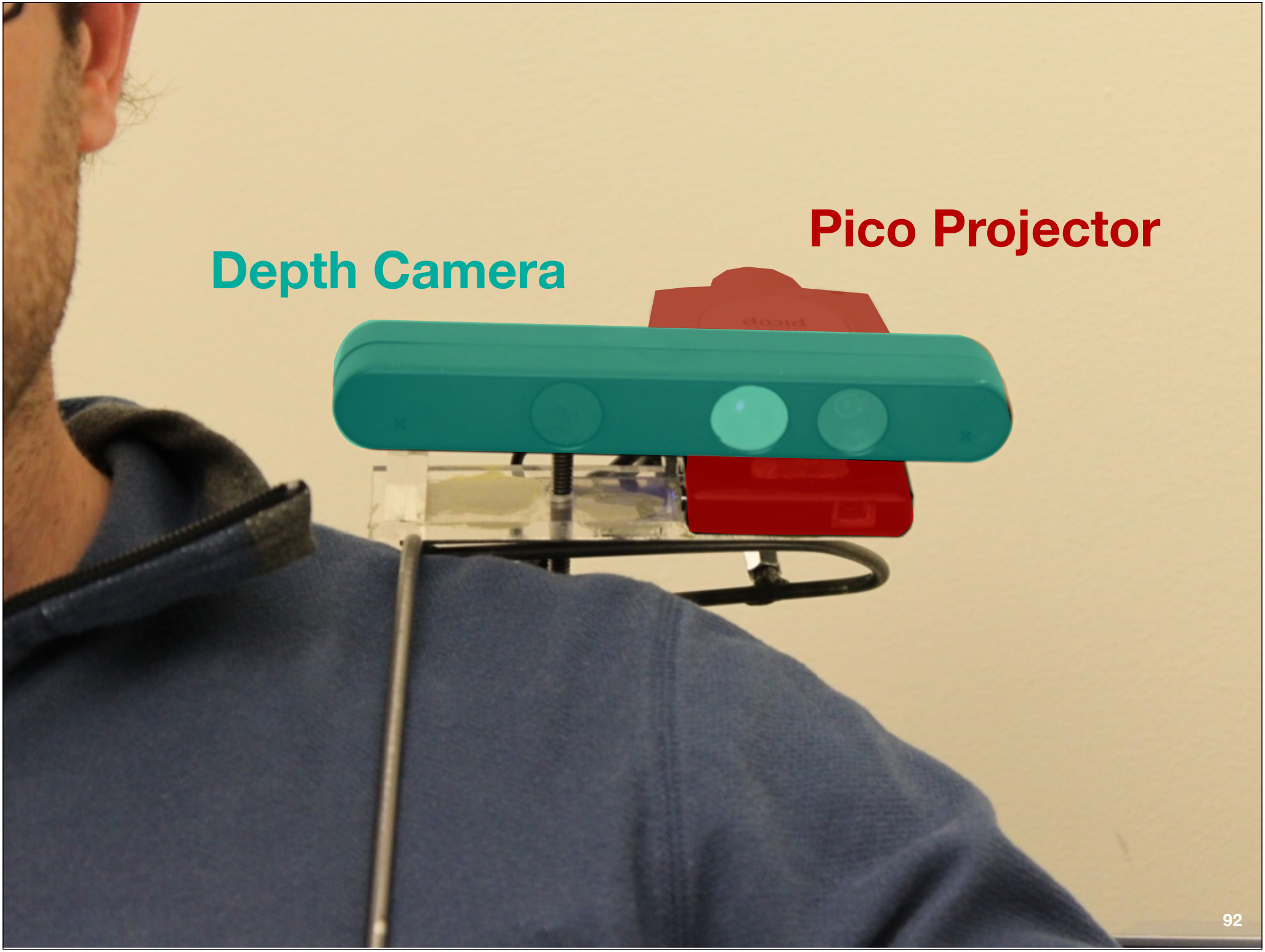
Carnegie Mellon

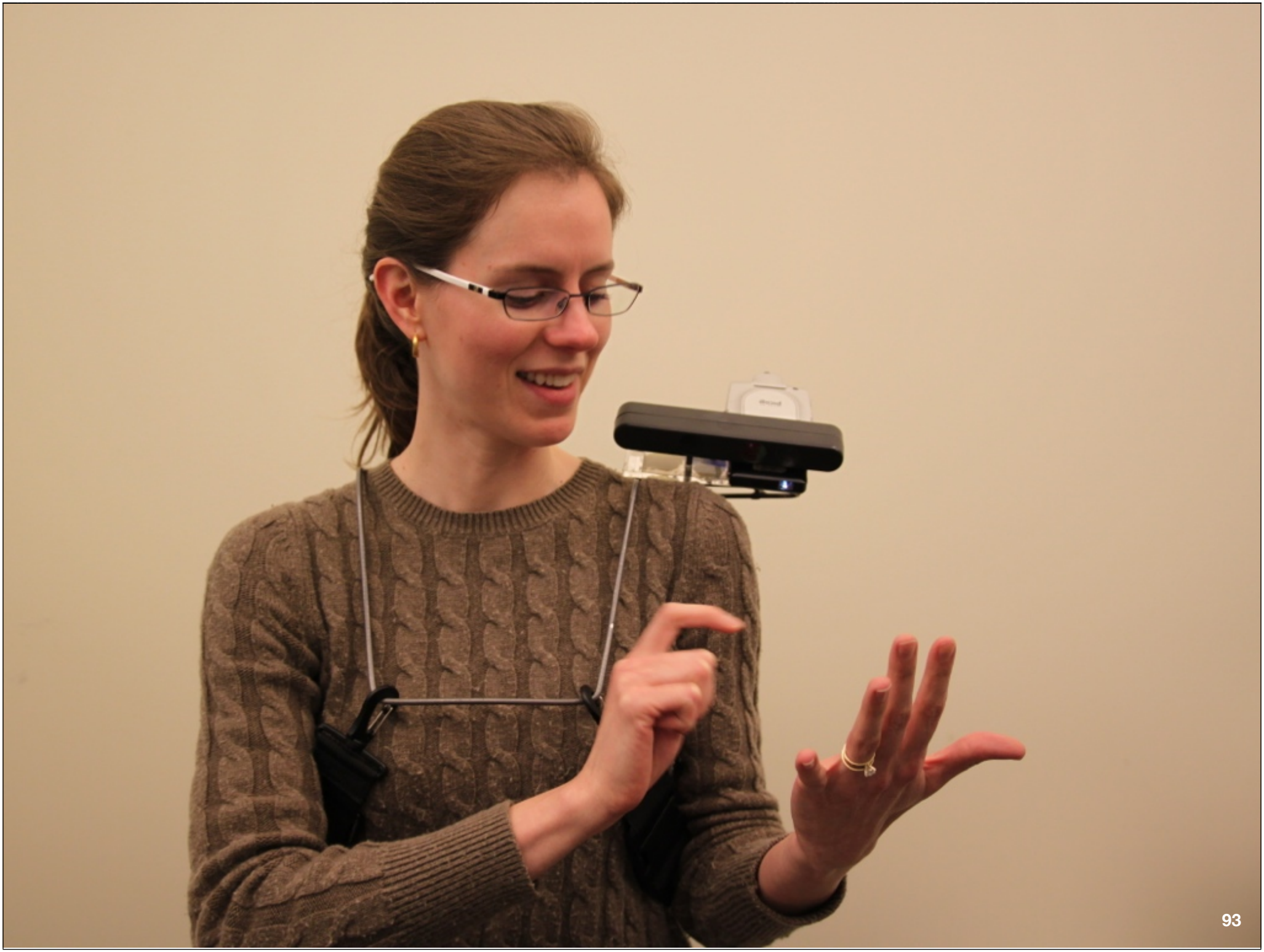
OmniTouch

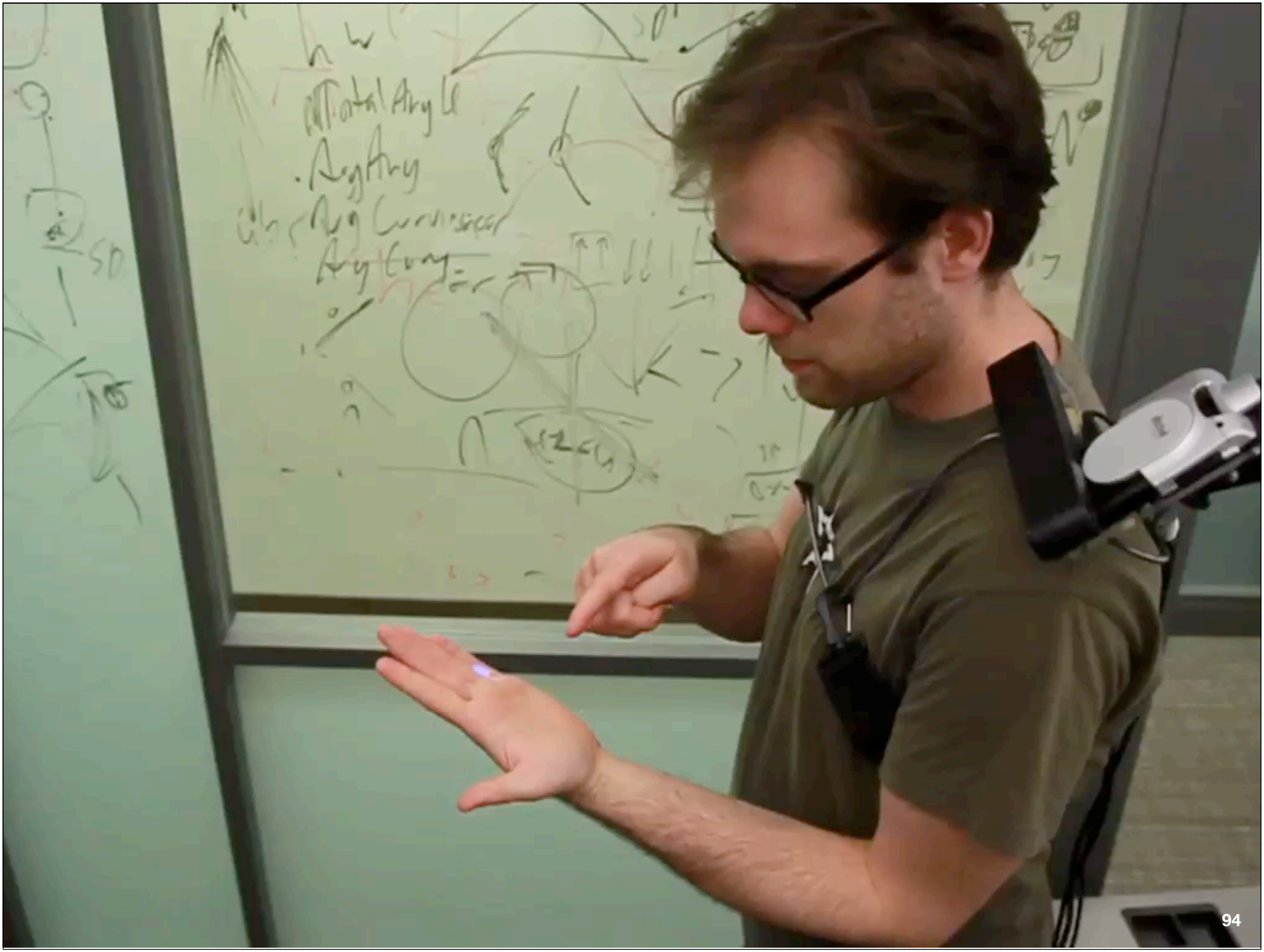
UIST 2011

Chris Harrison Hrvoje Benko Andy Wilson

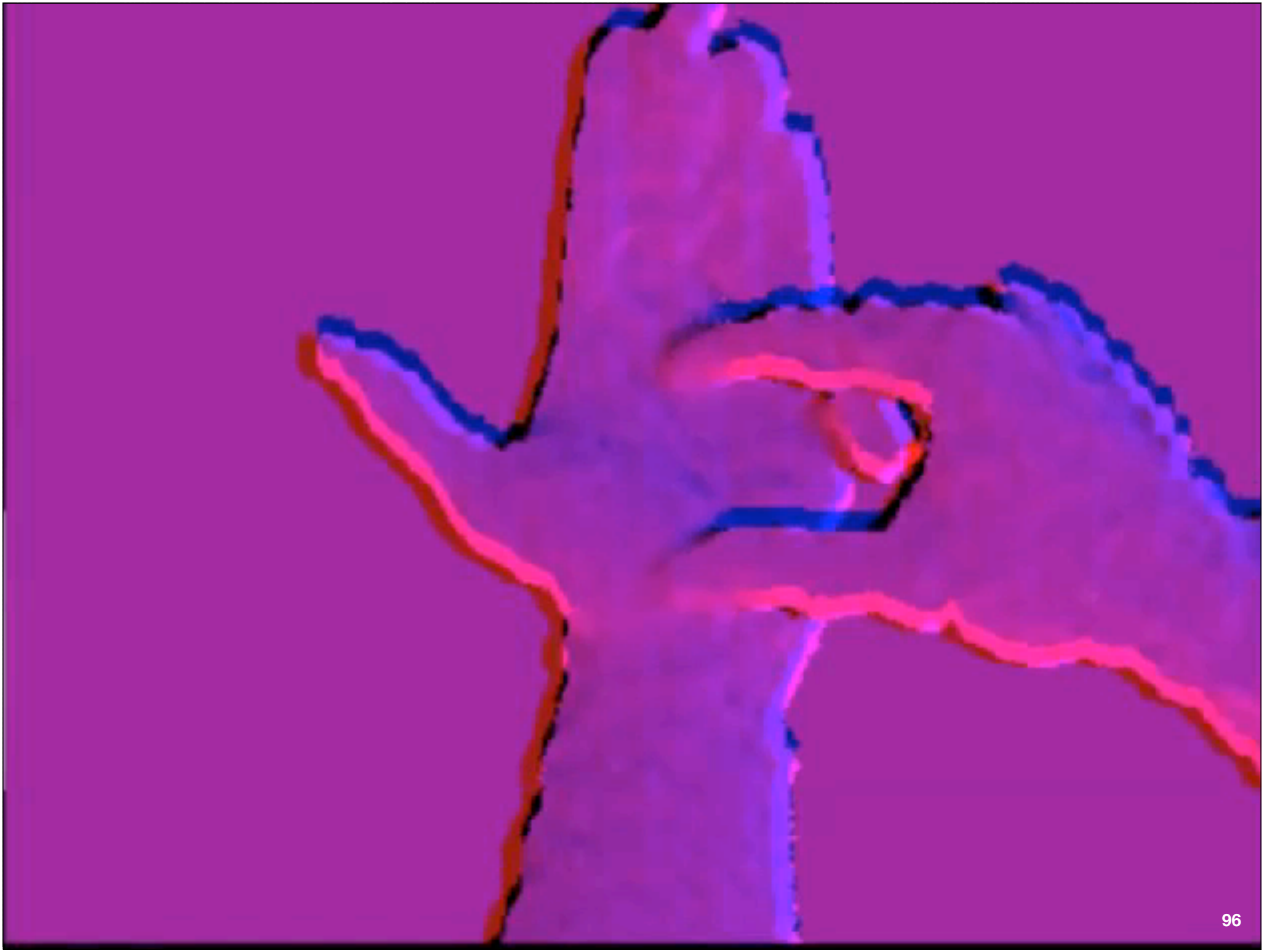
picoP

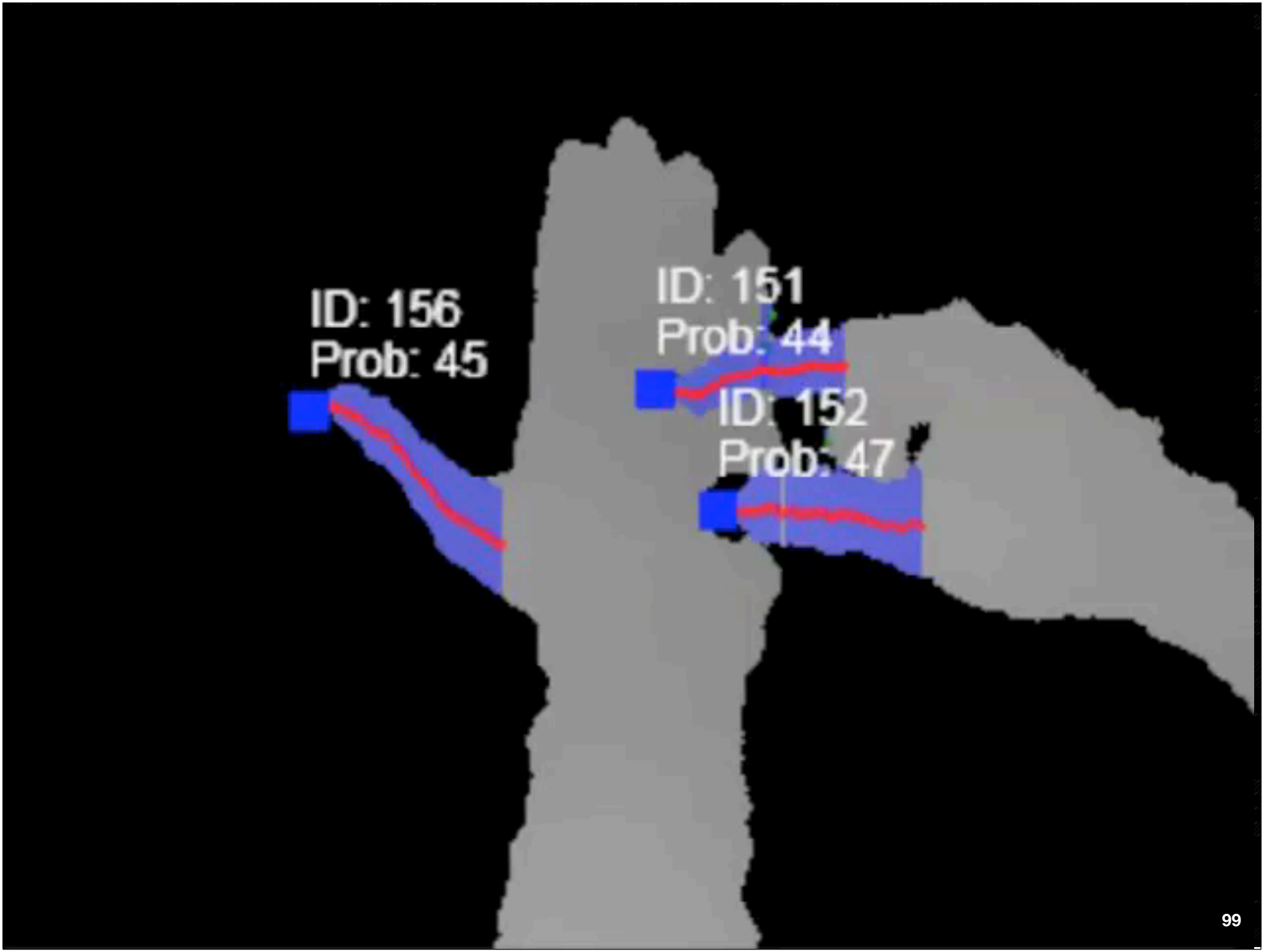

Depth Camera
Pico Projector





FPS: 29.95

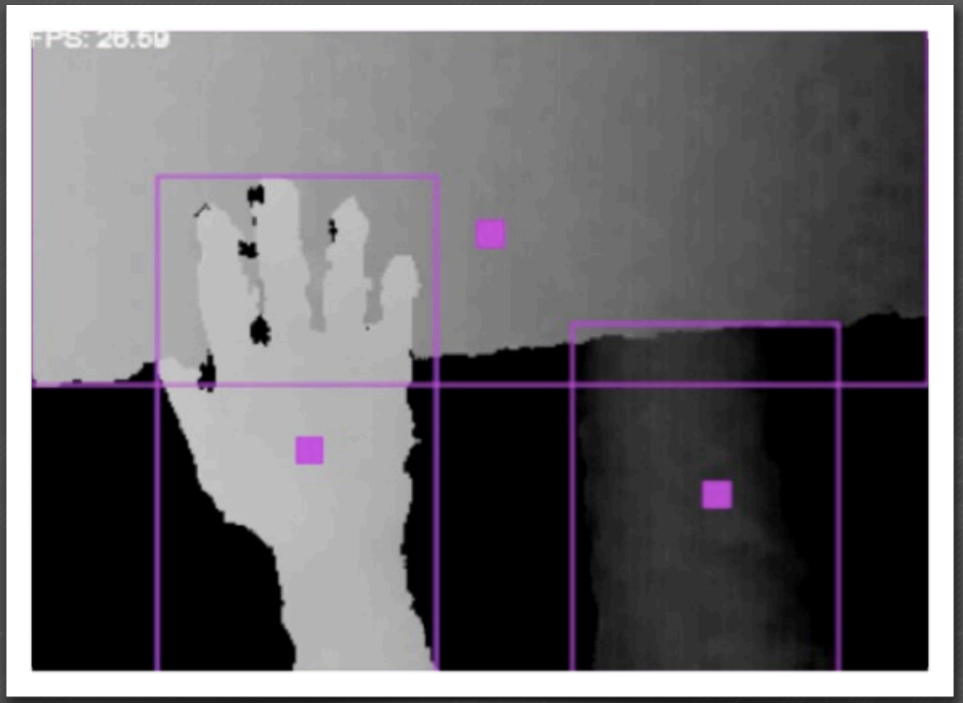



ID: 156
Prob: 45
ID: 151
Prob: 44
ID: 152
Prob: 47

Identifying Surfaces

- Find candidate surfaces for projection
- 3D connected components
- Compute real world size
  - Surfaces smaller than a hand are discarded
- Compute surface X/Y/Z position and orientation

Identifying Surfaces

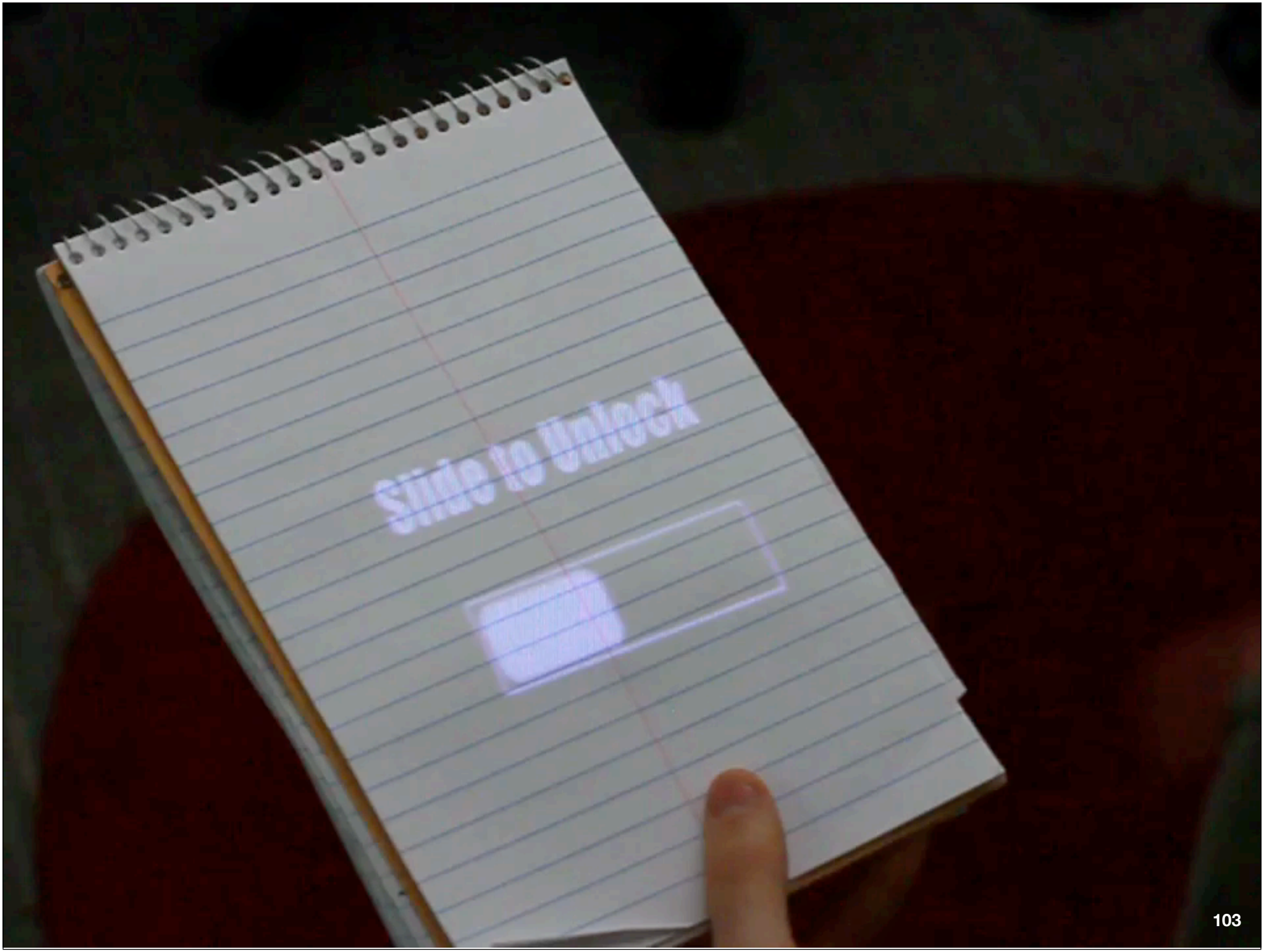


Depth Map

3D Connected Components

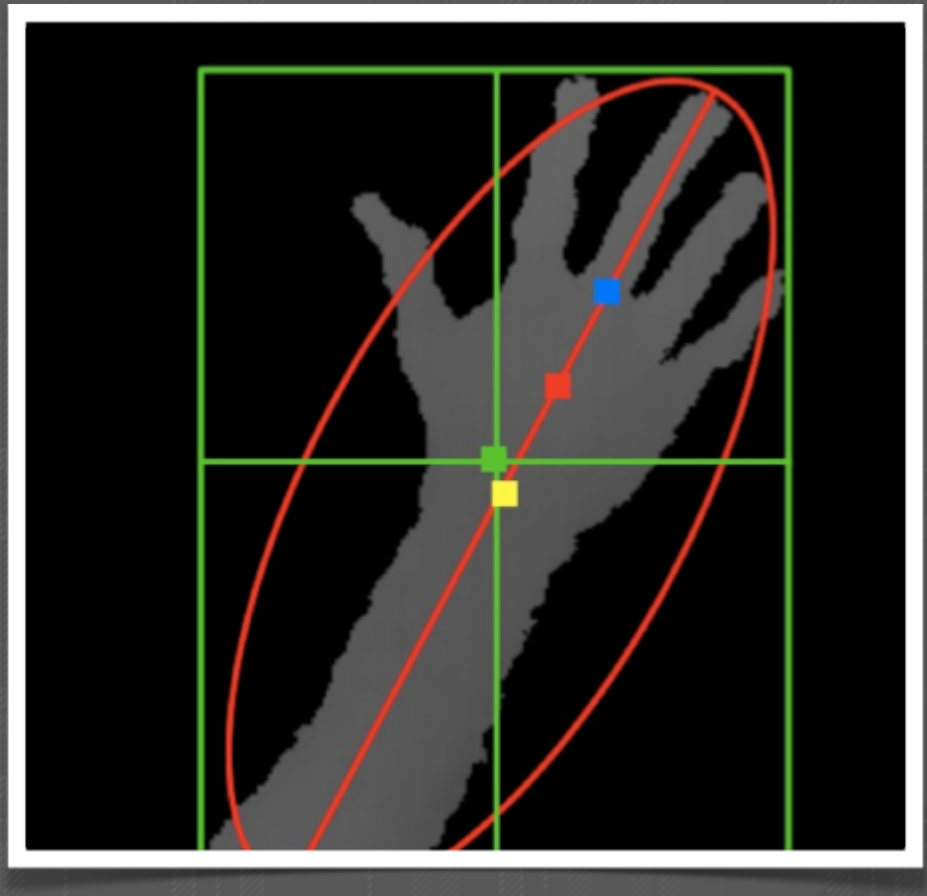
Projected Interfaces

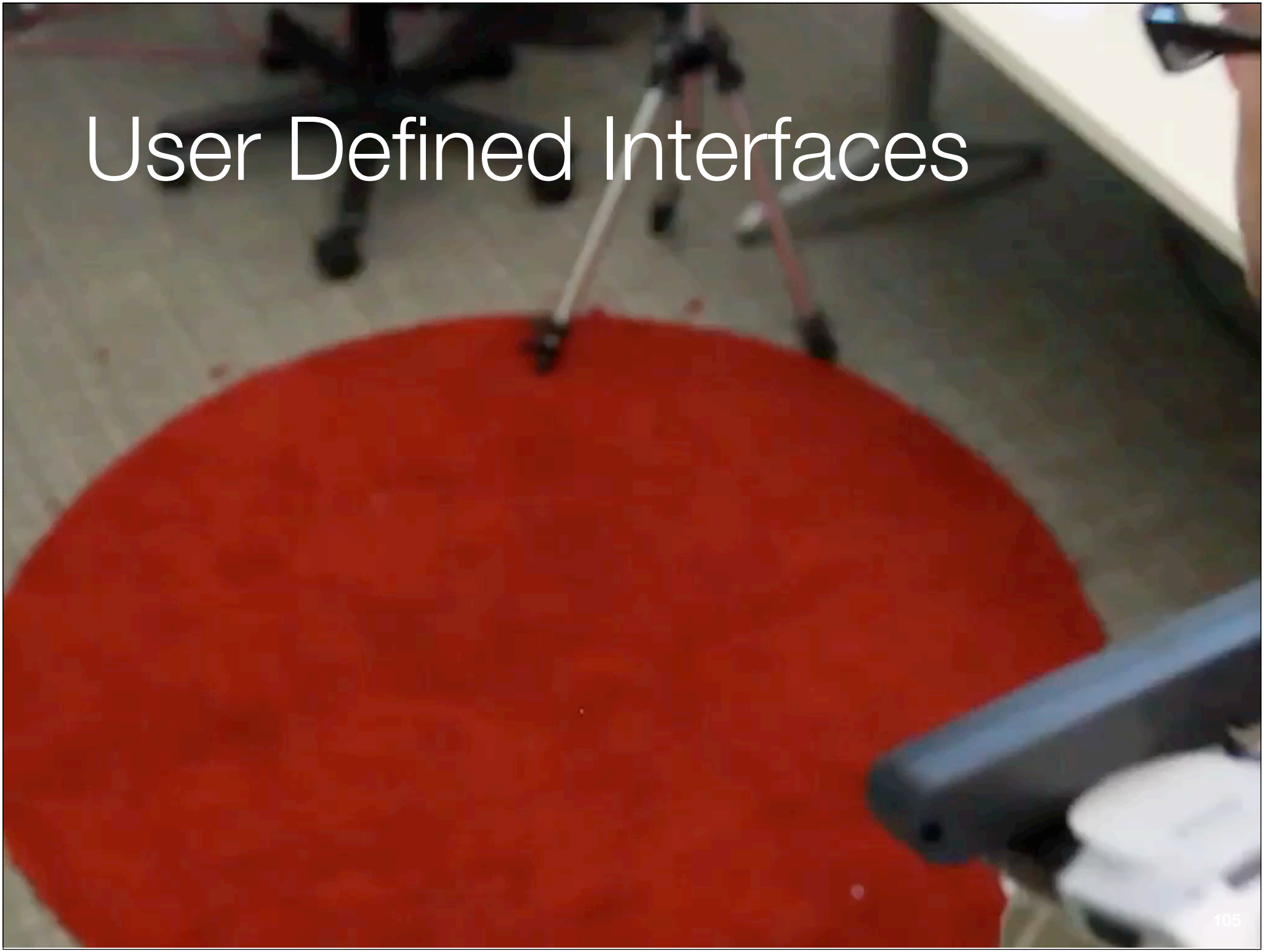
- Compositing interfaces in virtual 3D scene
  - Treat interfaces as planes in 3D space
  - Treat projector like a virtual camera; project viewport image
  - Scaling, z-ordering, perspective transformation, etc. comes for free
  - Ray cast fingers as input points onto active interfaces
- Requires projector/camera calibration
  - Convert 3D spatial coordinates to 2D projected points
    [DeMenthon '95, Wilson '10]
- Interfaces can be authored in real-world units and coordinates


Slide to Unlock

Defining Interactive Areas

- Projected interfaces
  - Where to center?
  - How tall/wide?
- Approaches
  - One-size fits all
  - Classification driven
  - User defined




User Defined Interfaces

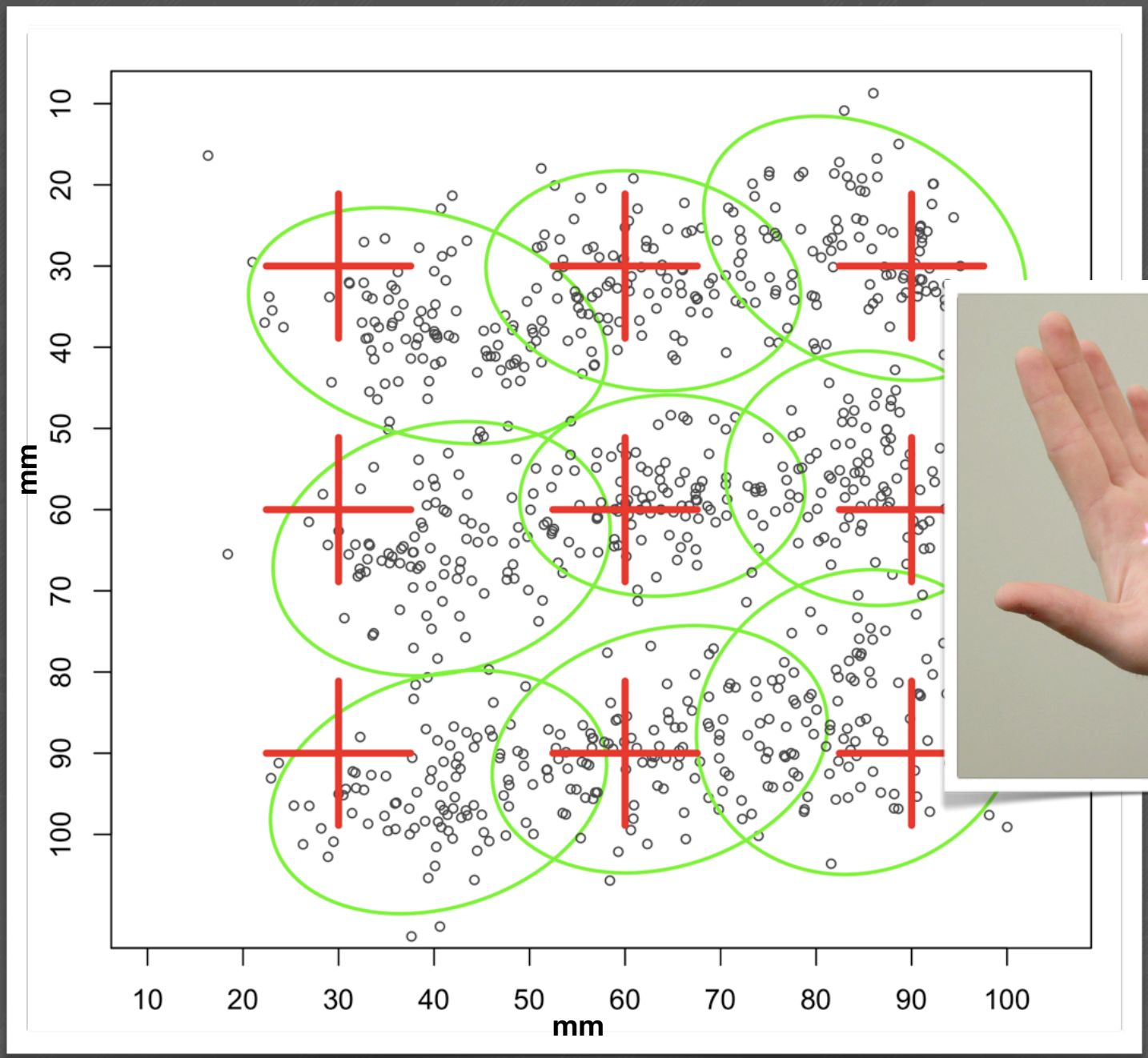
Carnegie Mellon

Evaluation

12	Participants (6 female)
9	Targets (3x3 pattern); random order
4	Surfaces (hand, arm, pad, wall)
3	Distances (hand, pad conditions)
6048	“Clicks” collected

Evaluation

Hand on body
Arm curved, additional on body surface
Pad object held in hand
Wall fixed surface in the environment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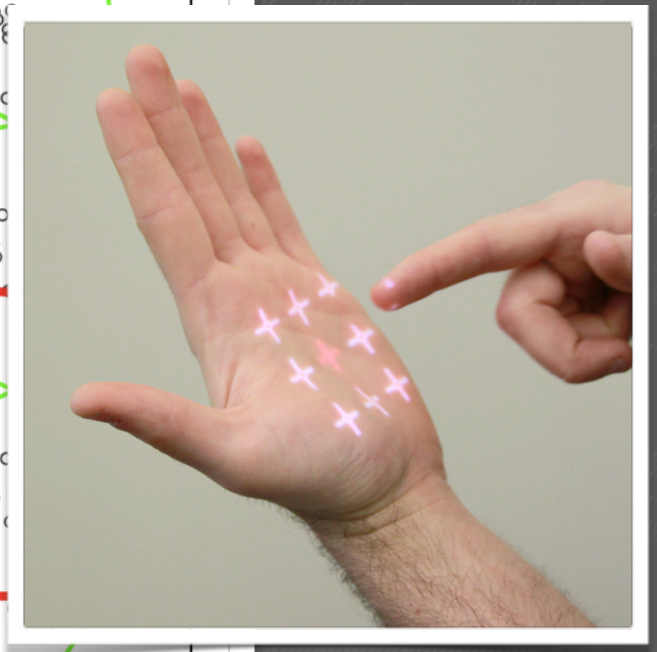

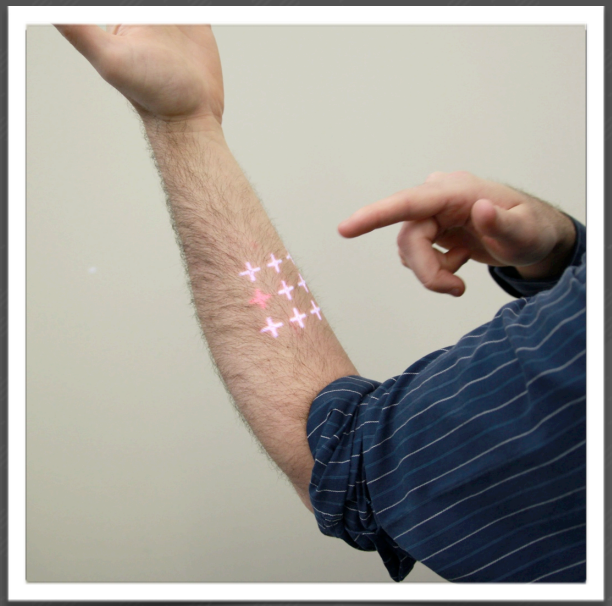

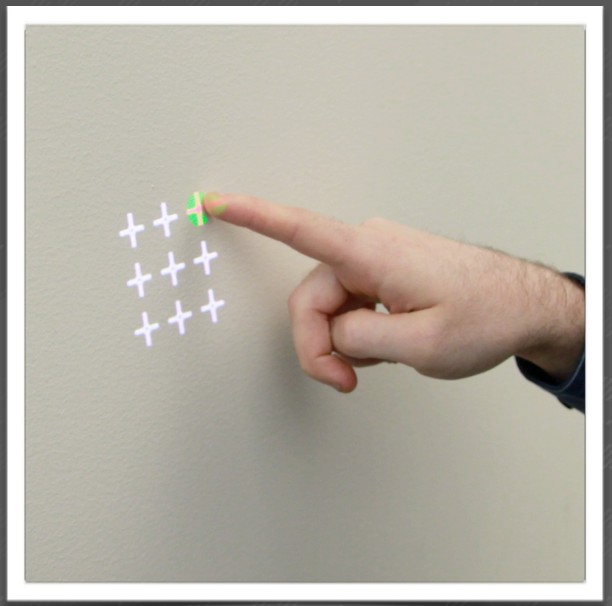

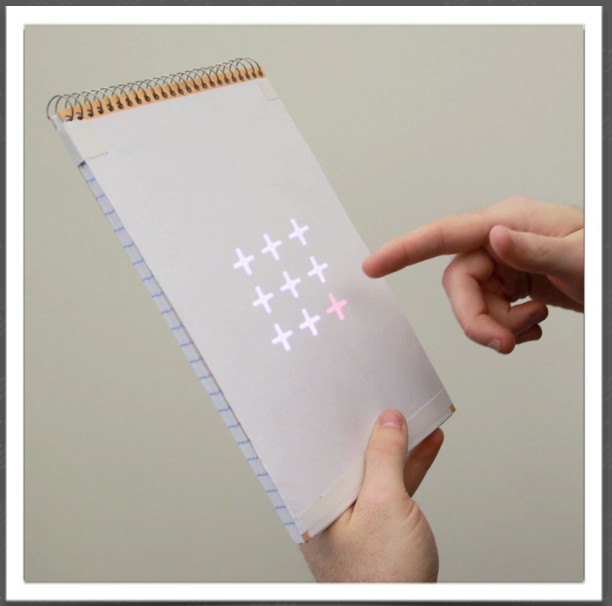

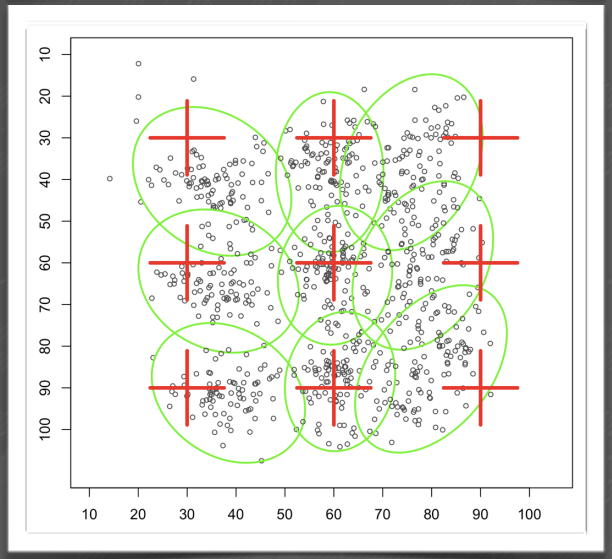
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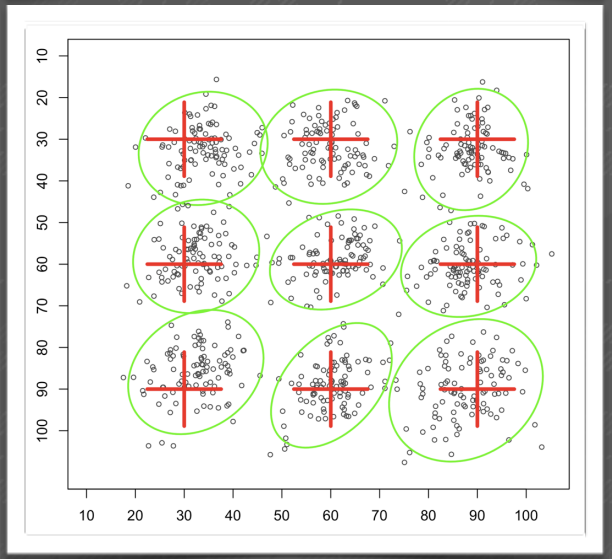
10 20 30 40 50 60 70 80 90 100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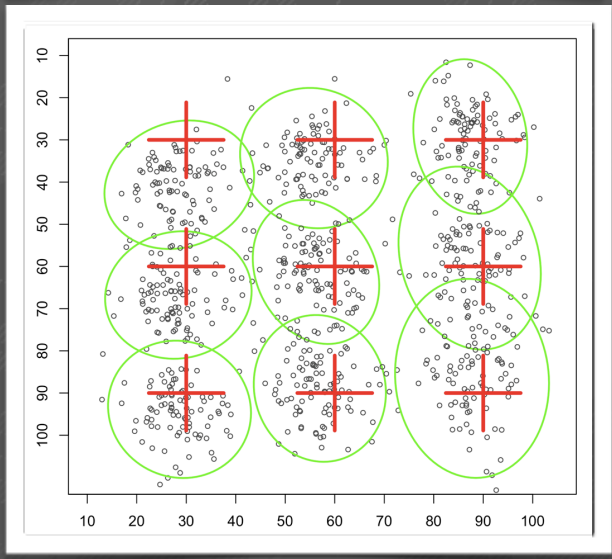
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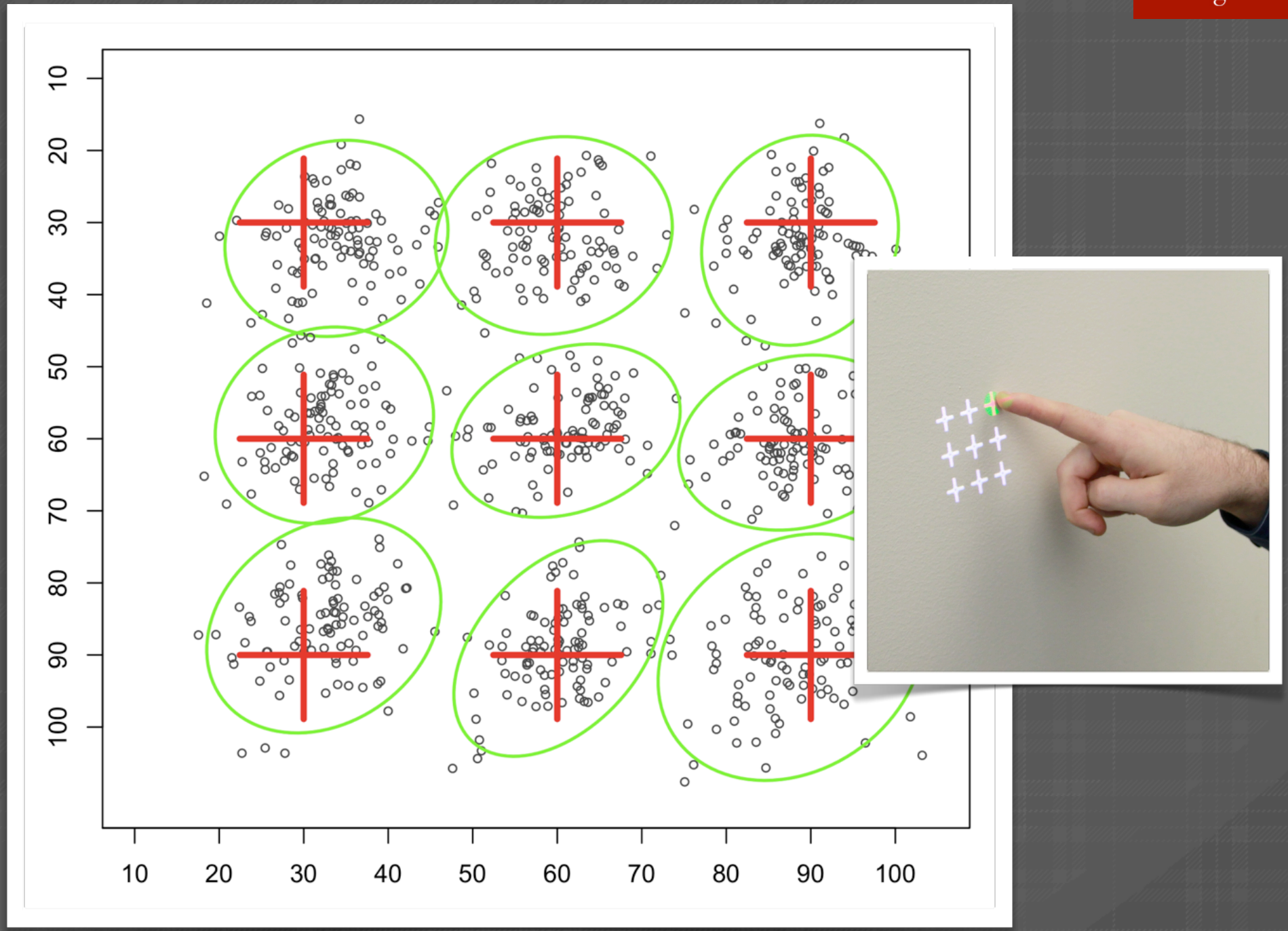
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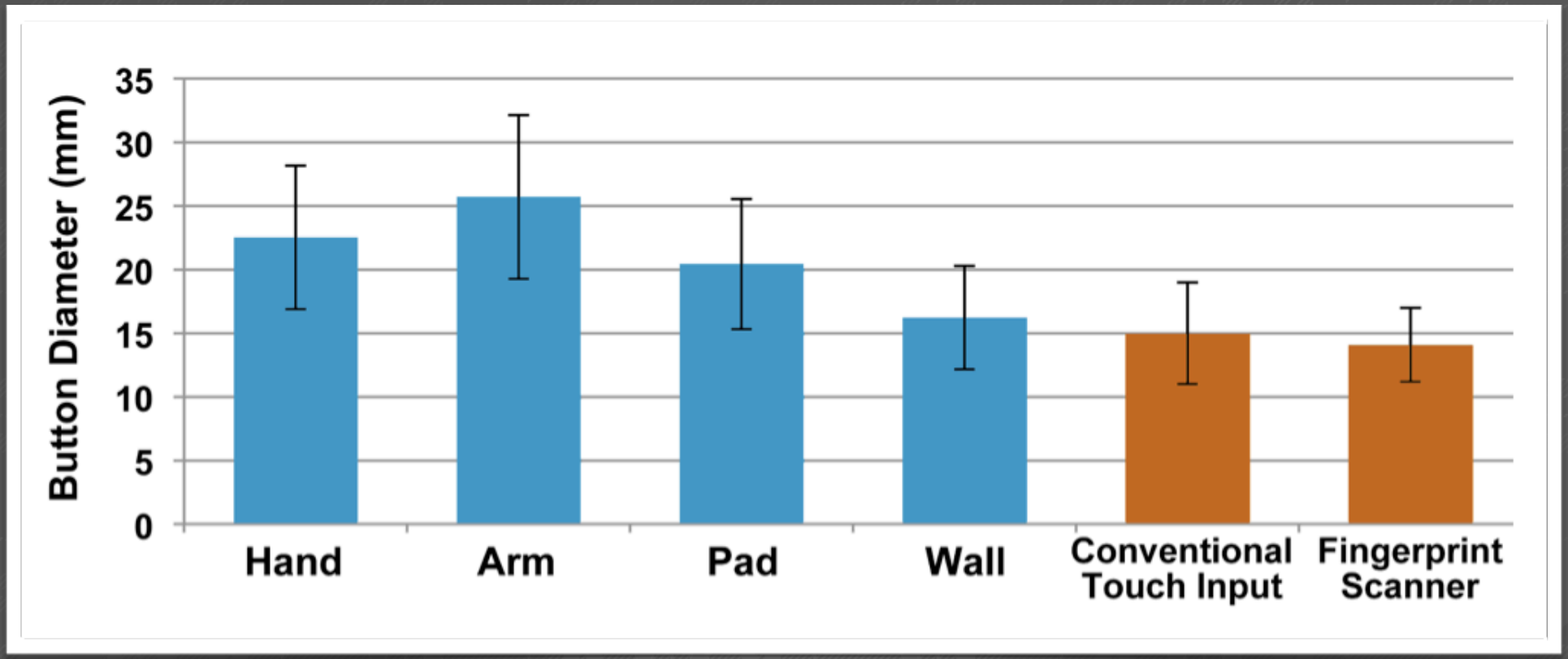
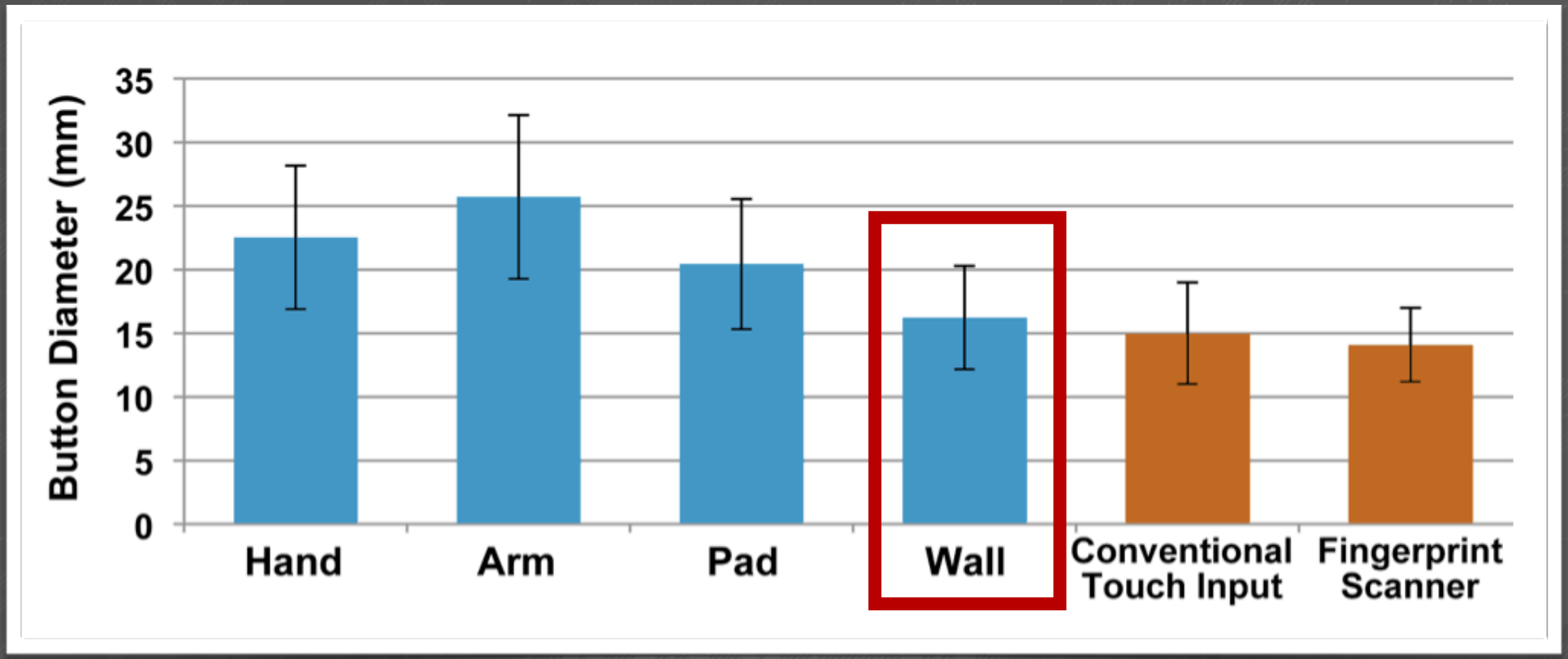
“Click” Precision



OmniTouch

[Holz and Baudisch '10]

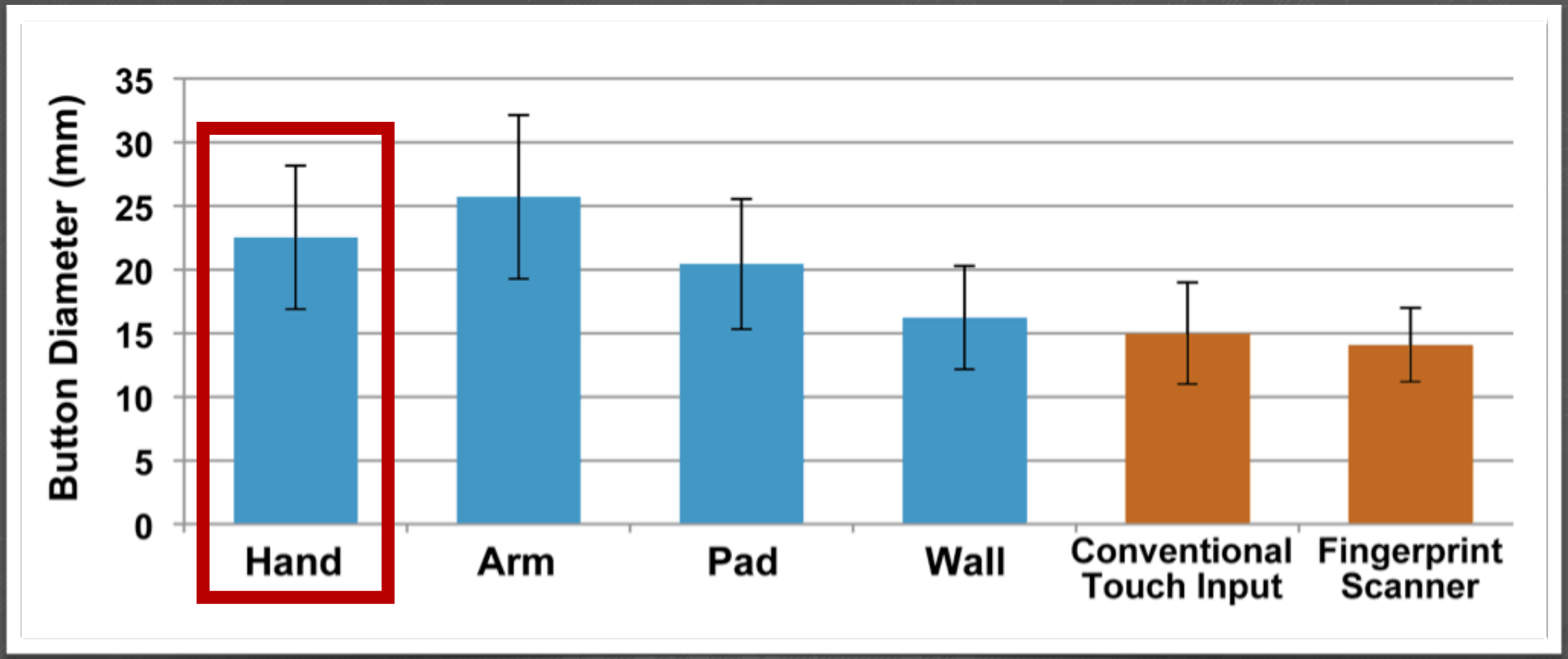
“Click” Precision



OmniTouch

[Holz and Baudisch '10]

“Click” Precision



OmniTouch

[Holz and Baudisch '10]

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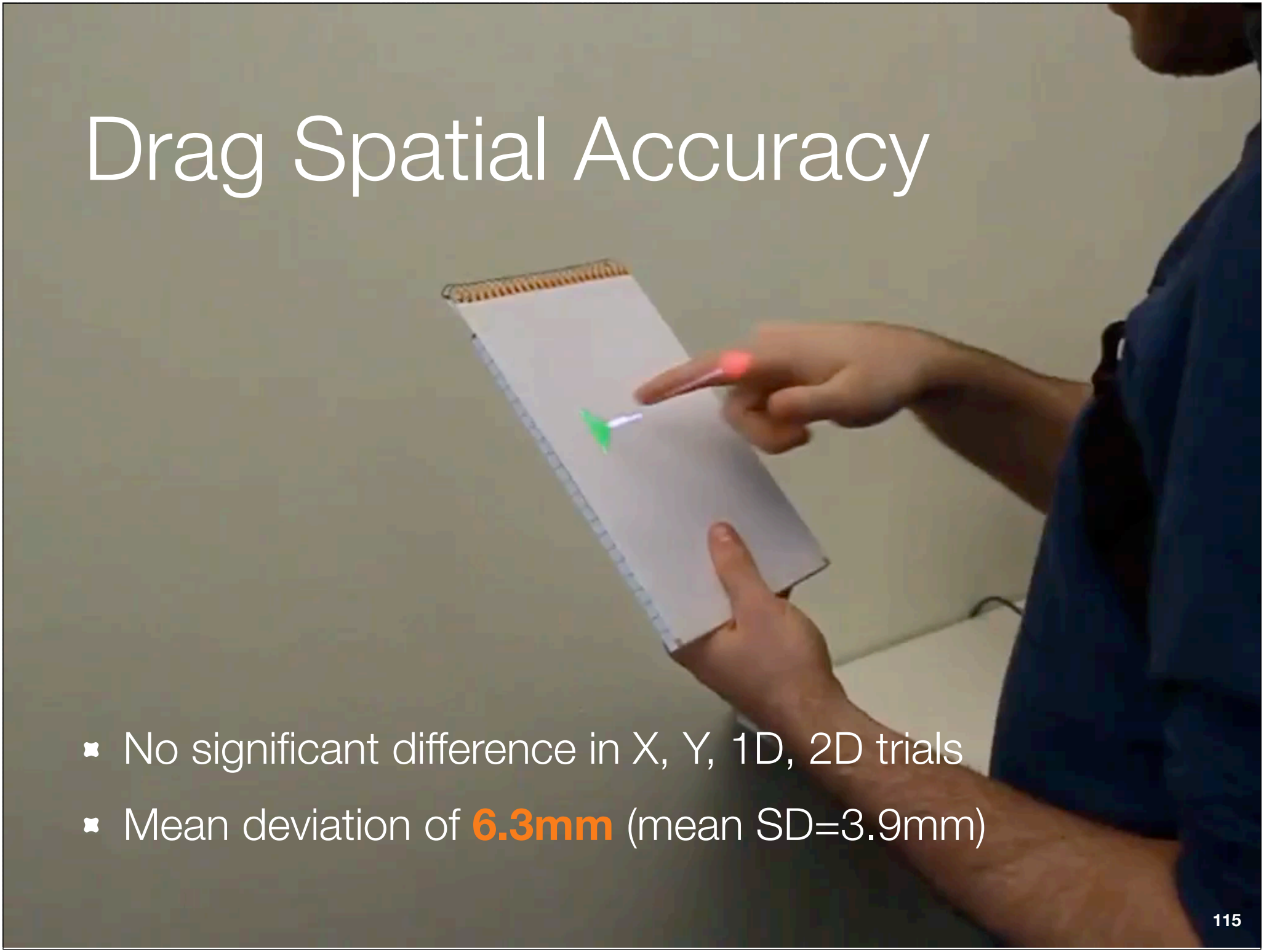
“Click” Detection

- Of our 6048 crosshair “click” trials:
  - **96.5%** correctly had one click event
  - **0.8%** had no click event (i.e., system missed click)
  - **2.5%** had two click events
  - **0.1%** had three click events

- With a 500ms timeout click rejection:
  - **98.9%** click detection accuracy

Drag Spatial Accuracy



- No significant difference in X, Y, 1D, 2D trials
- Mean deviation of **6.3mm** (mean SD=3.9mm)

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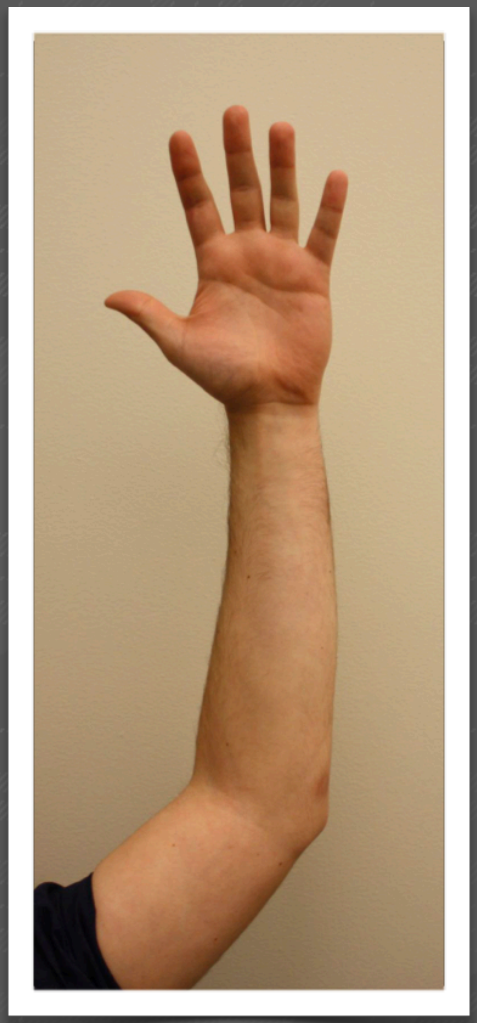
Armura

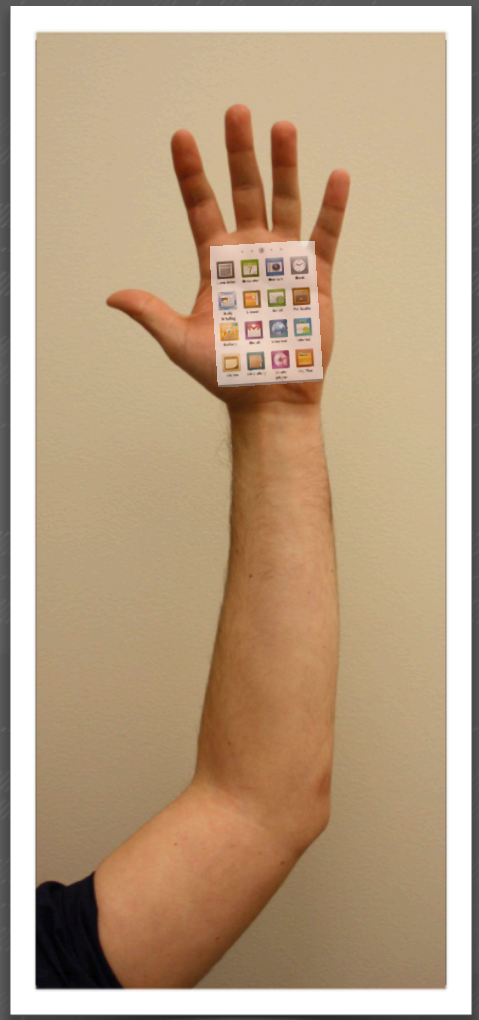
TEI 2012

Chris Harrison Shilpa Ramamurthy Scott Hudson

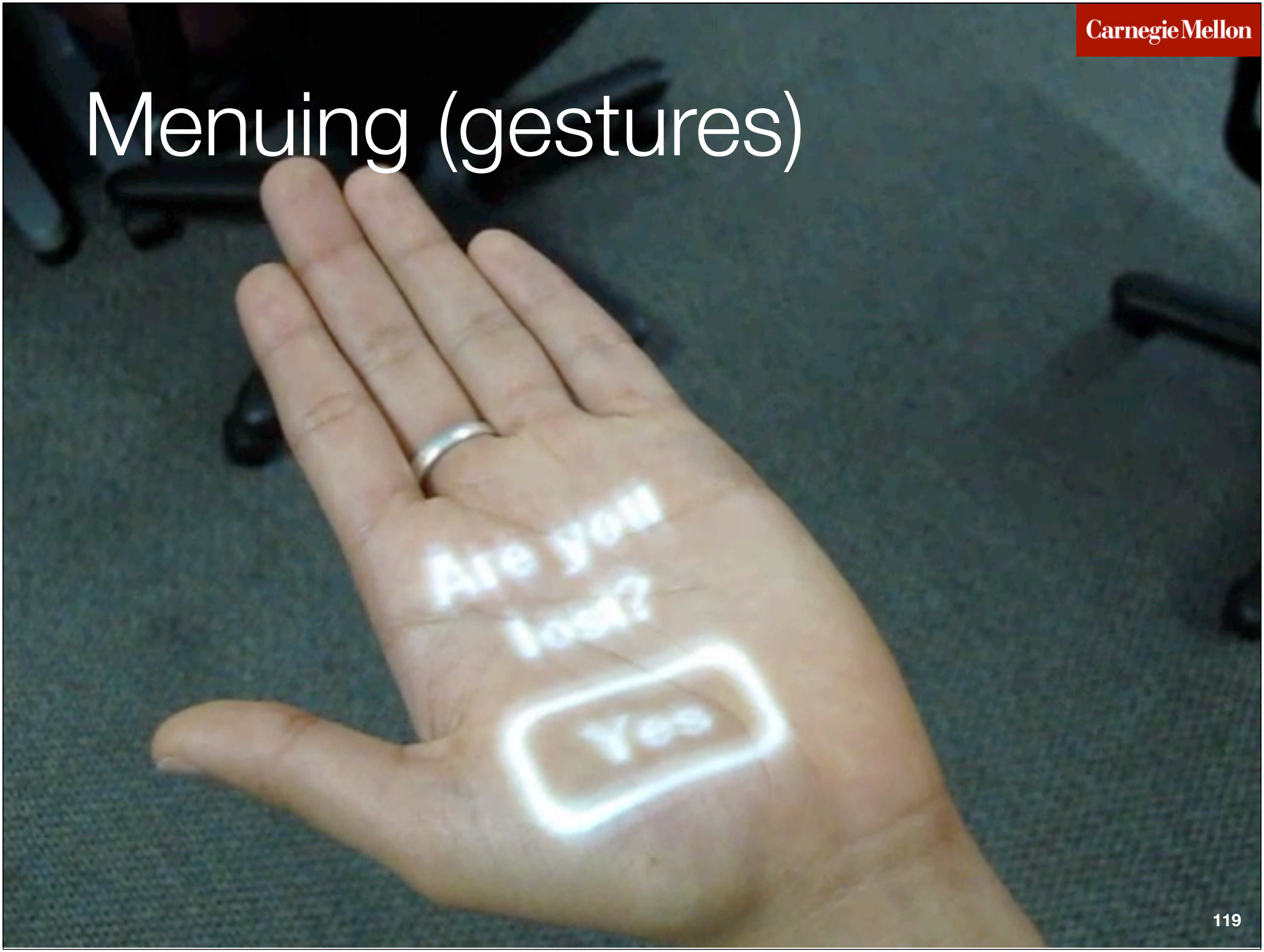
Interface Design



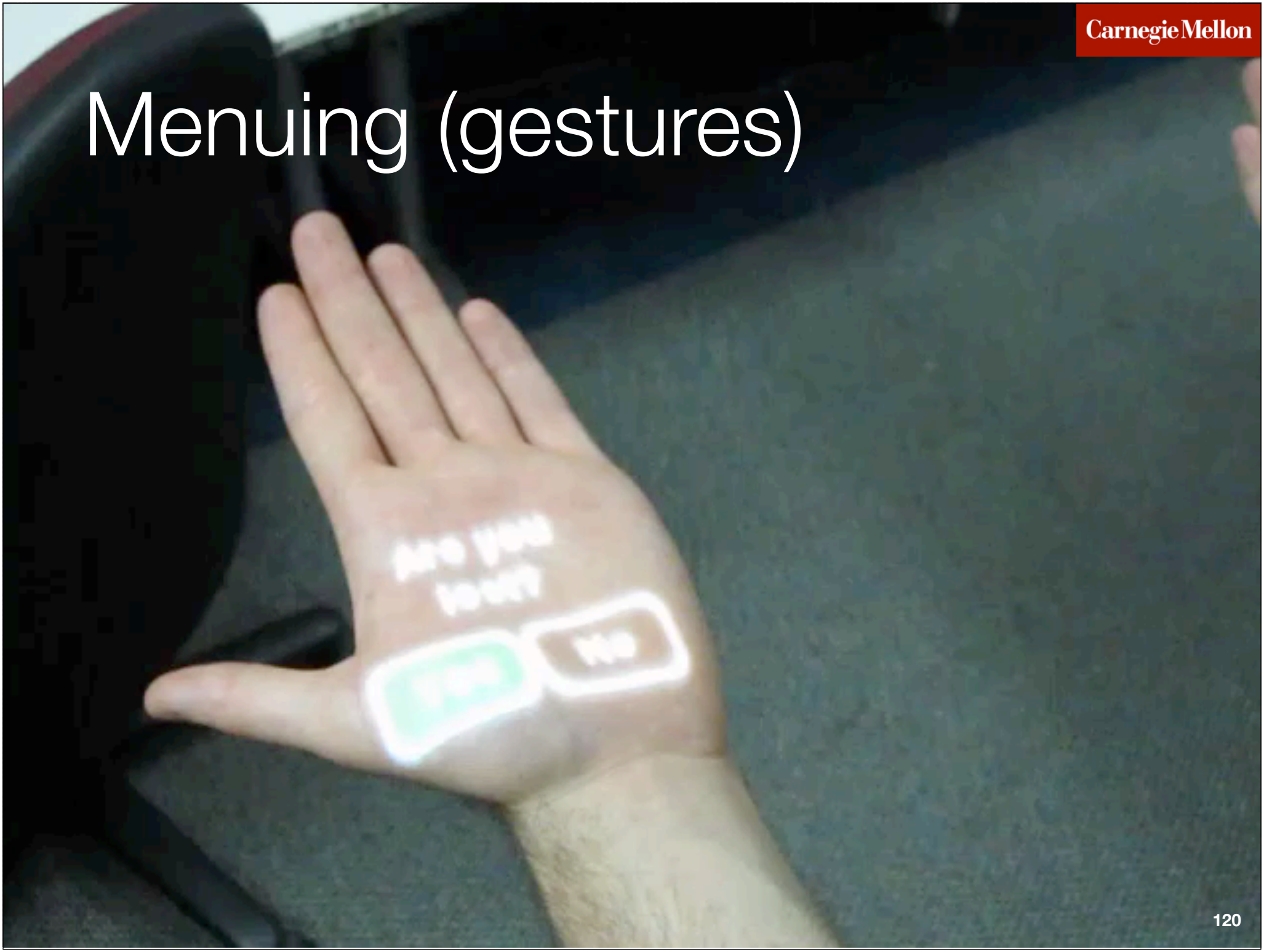
Interface Design



Menuing (gestures)

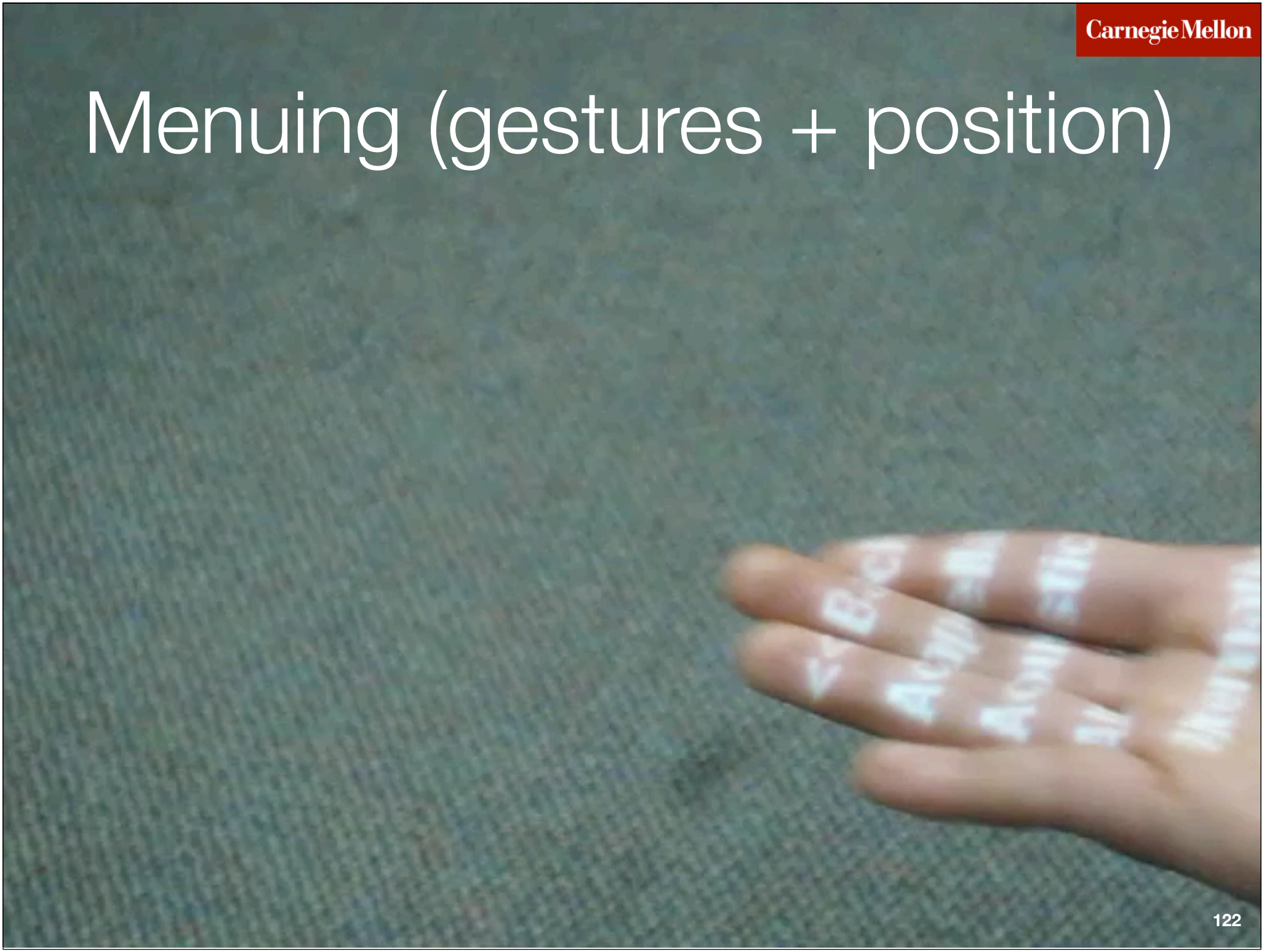


Menuing (gestures)

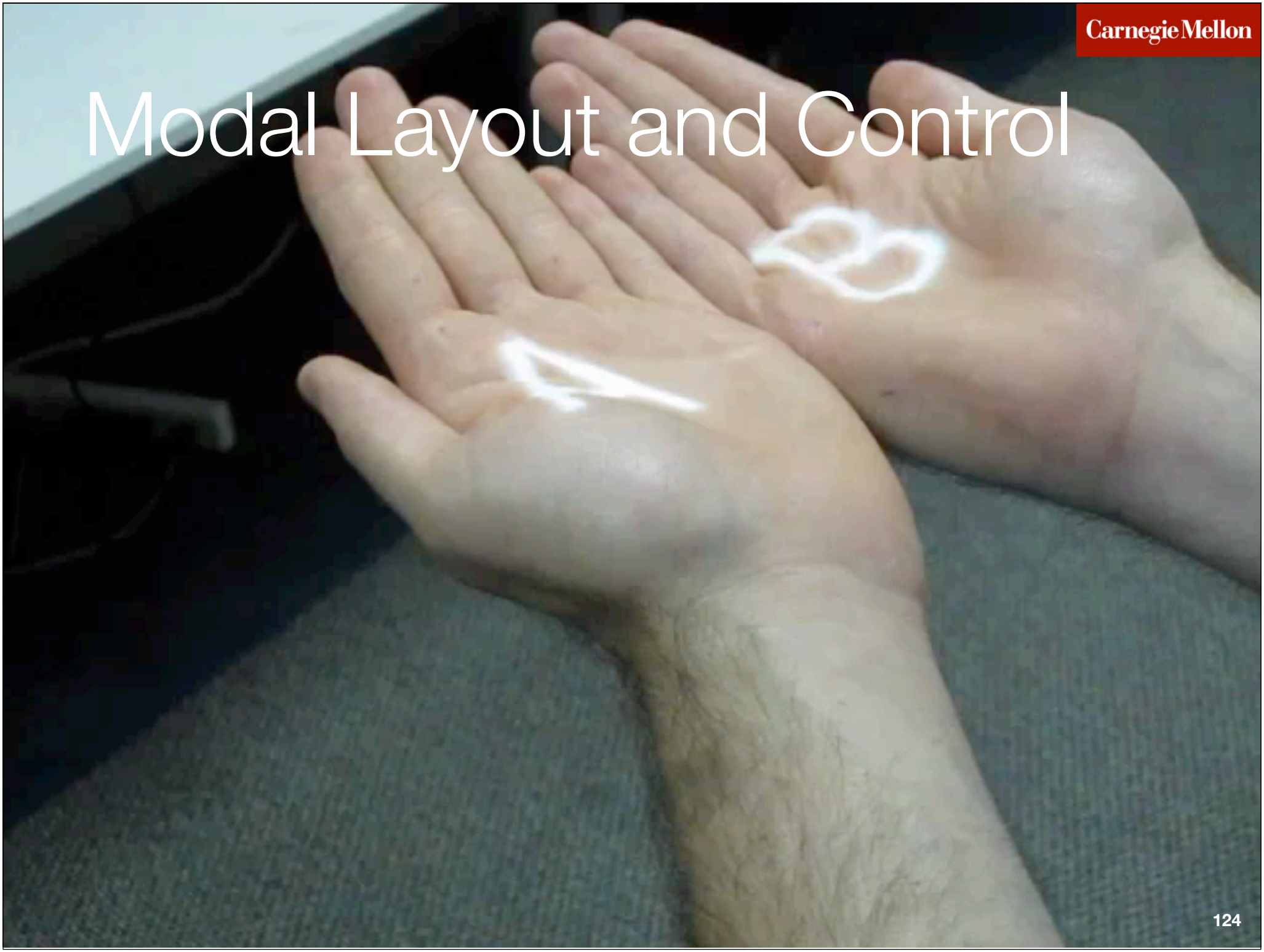


Carnegie Mellon
Menuing (gestures + position)

Menuing (gestures + position)



Carnegie Mellon
Menuing (gestures + position)
123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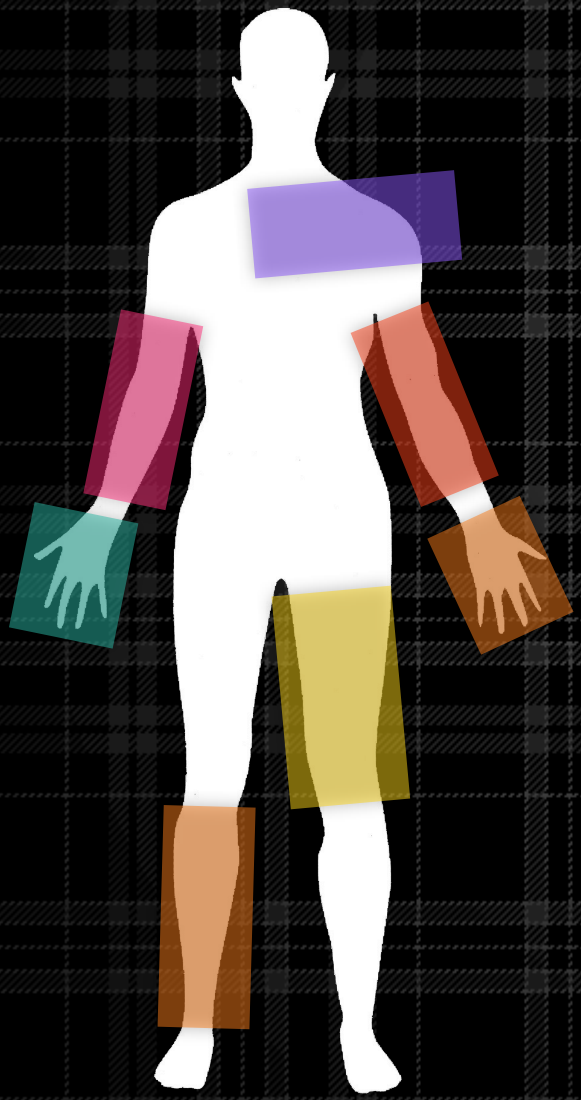
Modal Layout and Control

Next steps



- What are ideal on-body surfaces?
- Friends/strangers using on-body interfaces?
- How do users feel about projected Interfaces?
- Where is it appropriate to touch own body?
- Where should interfaces be located?
- How should they be laid out?

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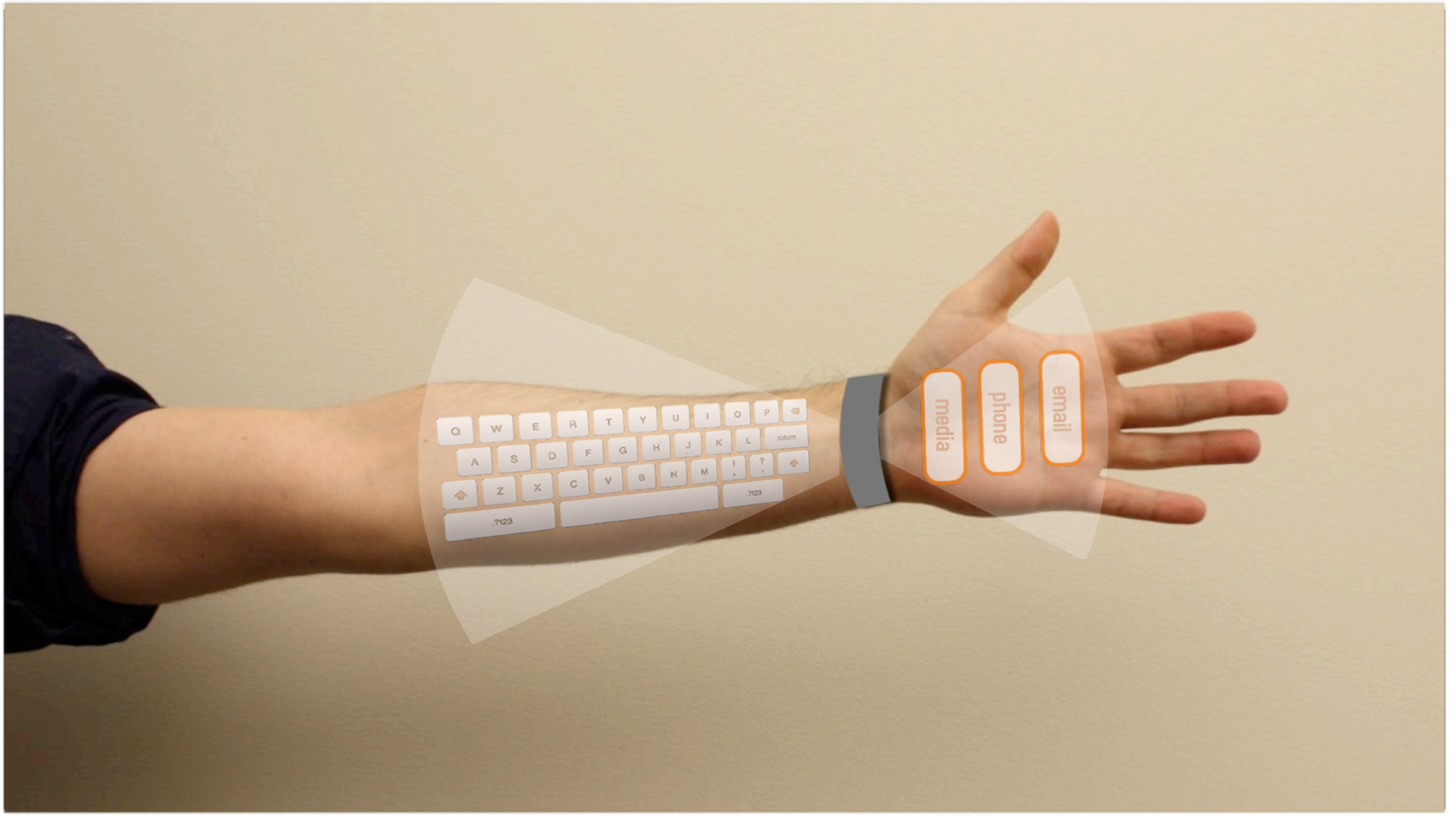
Next steps



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Thank You

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chris.harrison@cs.cmu.edu
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