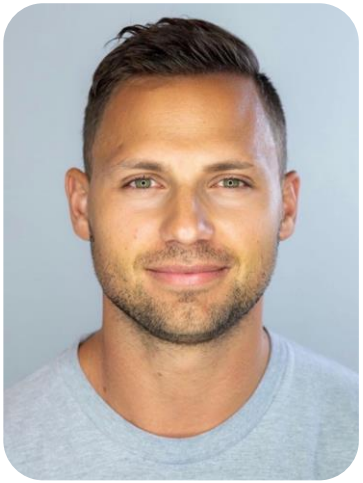
Meta

Haptics in the Metaverse

Nicholas Colonnese
Smart Haptics 2022
12/8/2022

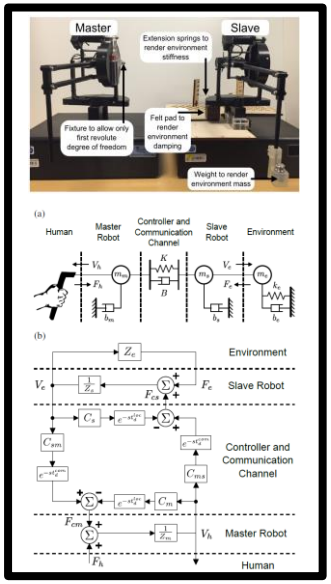
REALITY LABS

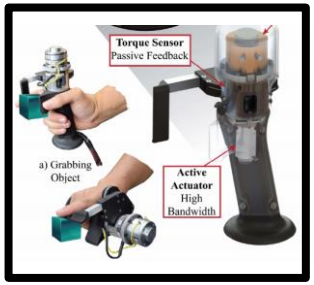


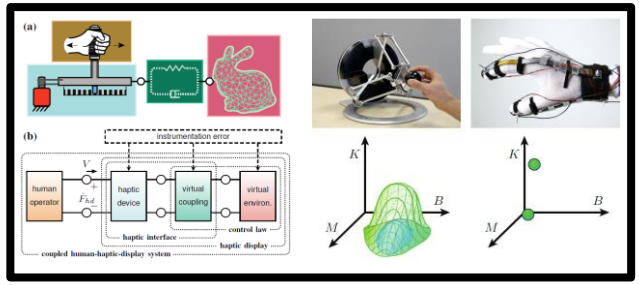
Nicholas Colonnese

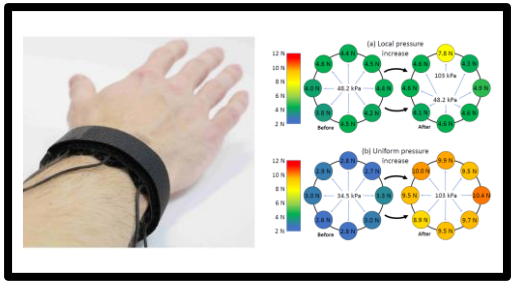
Research Science Director

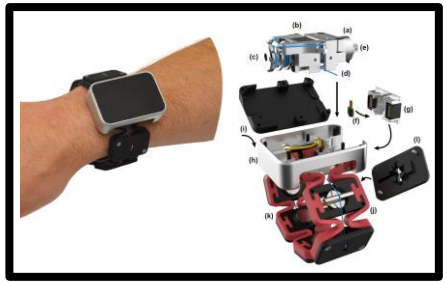
Reality Labs Research at Meta











Meta

We are in the midst of a human-computer interaction revolution


Temperature
Texture
Force
Slip
Location
& Configuration
Impact

haptic displays

grounded serial or parallel robots

handhelds

mid-air displays

wearables

active surfaces

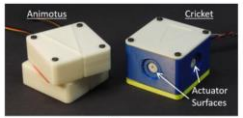
grounded serial or parallel robots

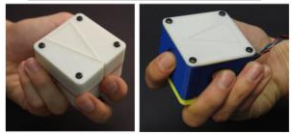

handhelds





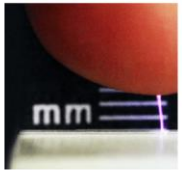




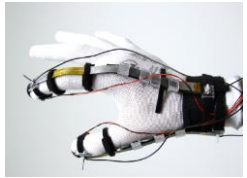


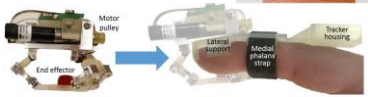
mid-air displays





wearables

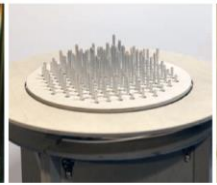


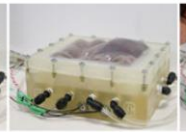







active surfaces

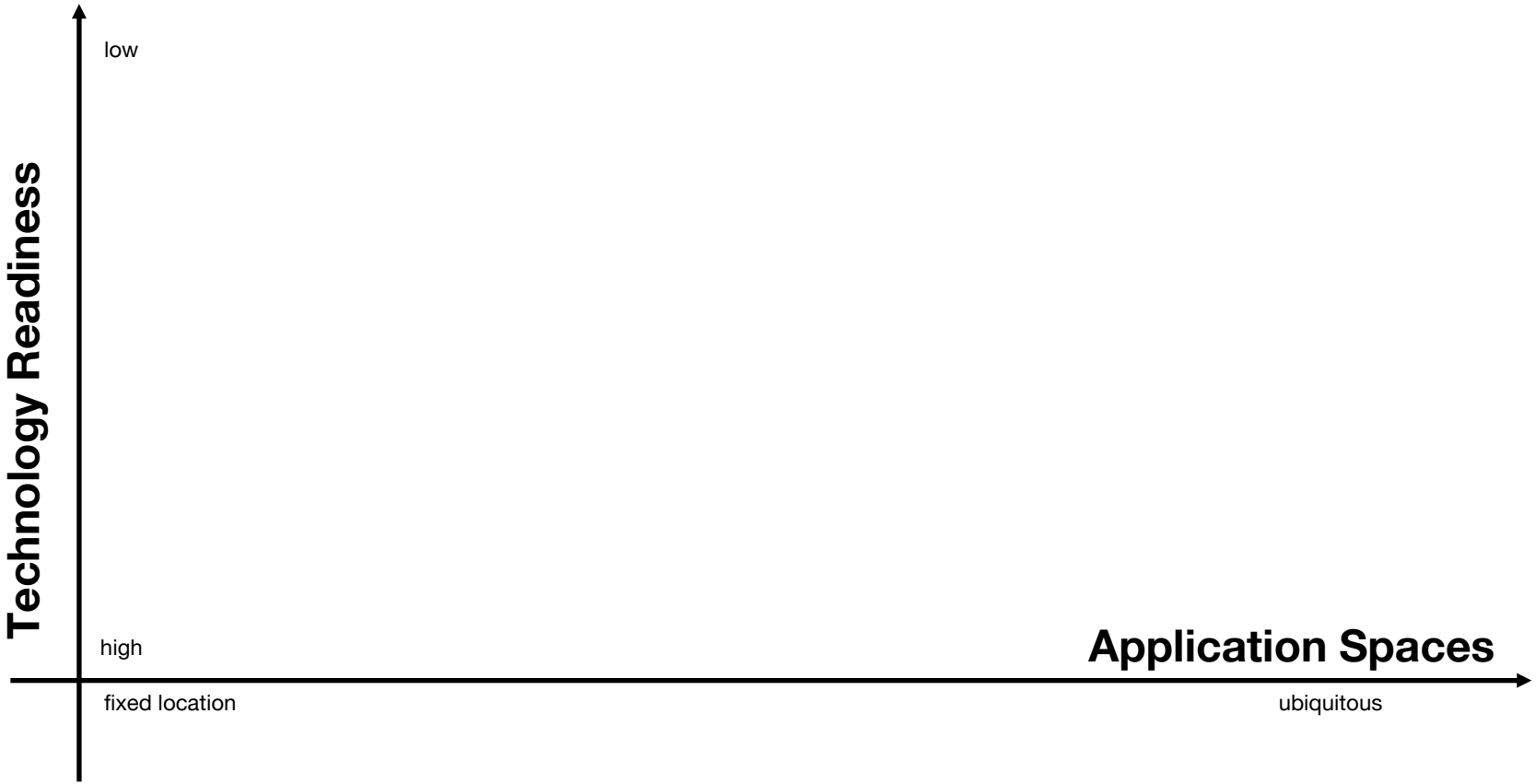
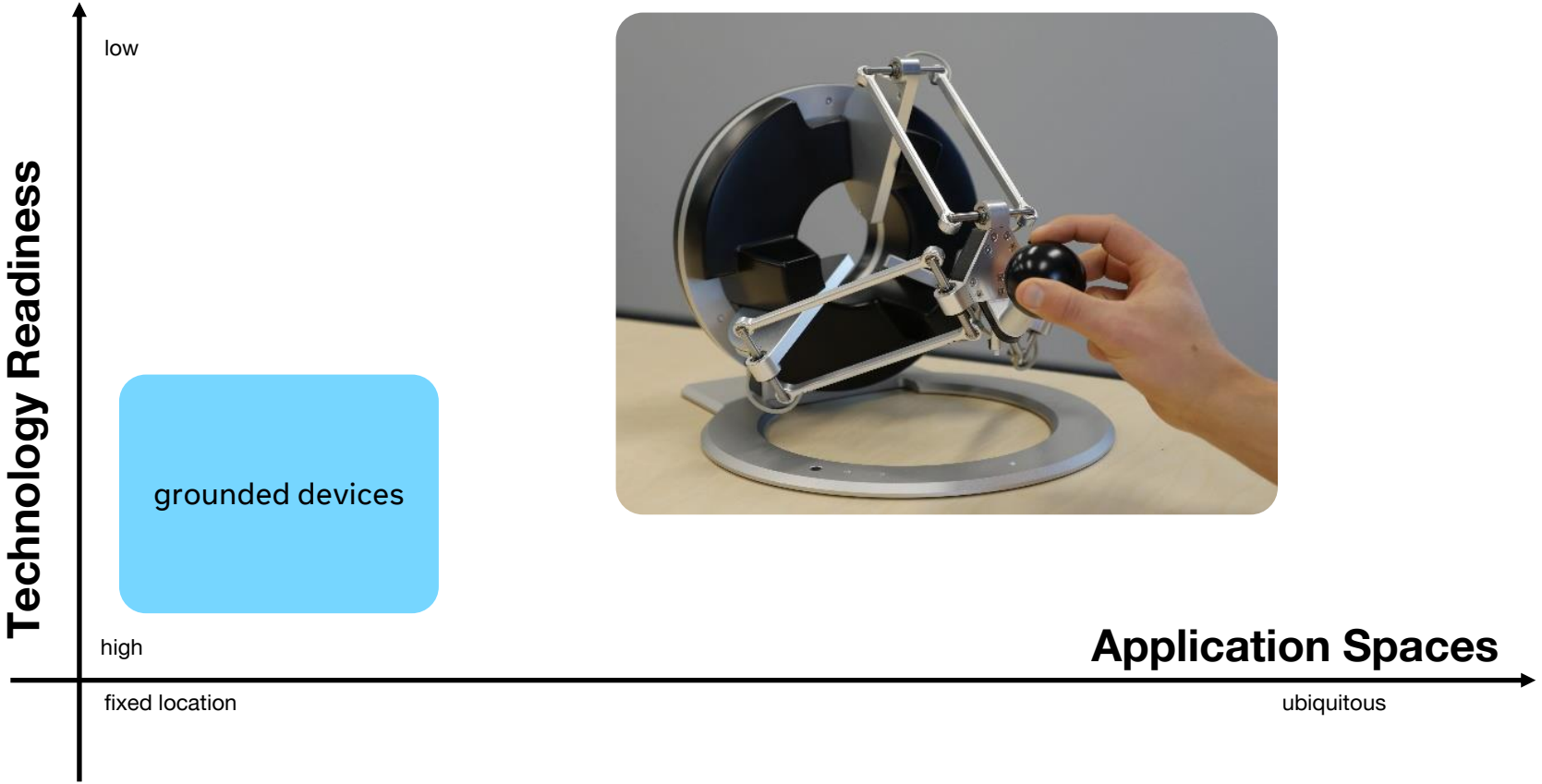
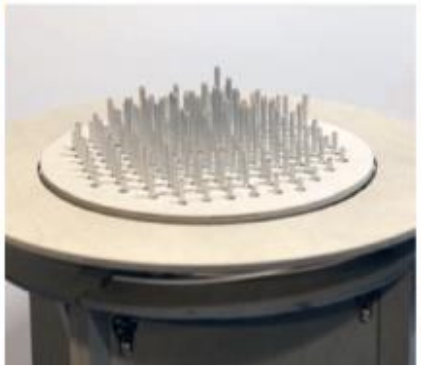



Figure Inspired by Ali Israr


Technology Readiness
low
high
grounded devices
Application Spaces
fixed location
ubiquitous

low

active surfaces



Technology Readiness

high

Application Spaces

fixed location

ubiquitous

Technology Readiness

low

high

mid-air displays

Application Spaces

fixed location

ubiquitous

Technology Readiness

low

high

handhelds

Application Spaces

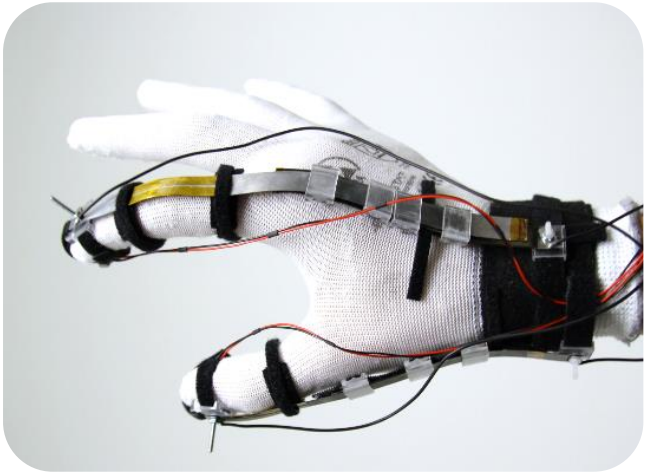
fixed location

ubiquitous

Technology Readiness

low

high

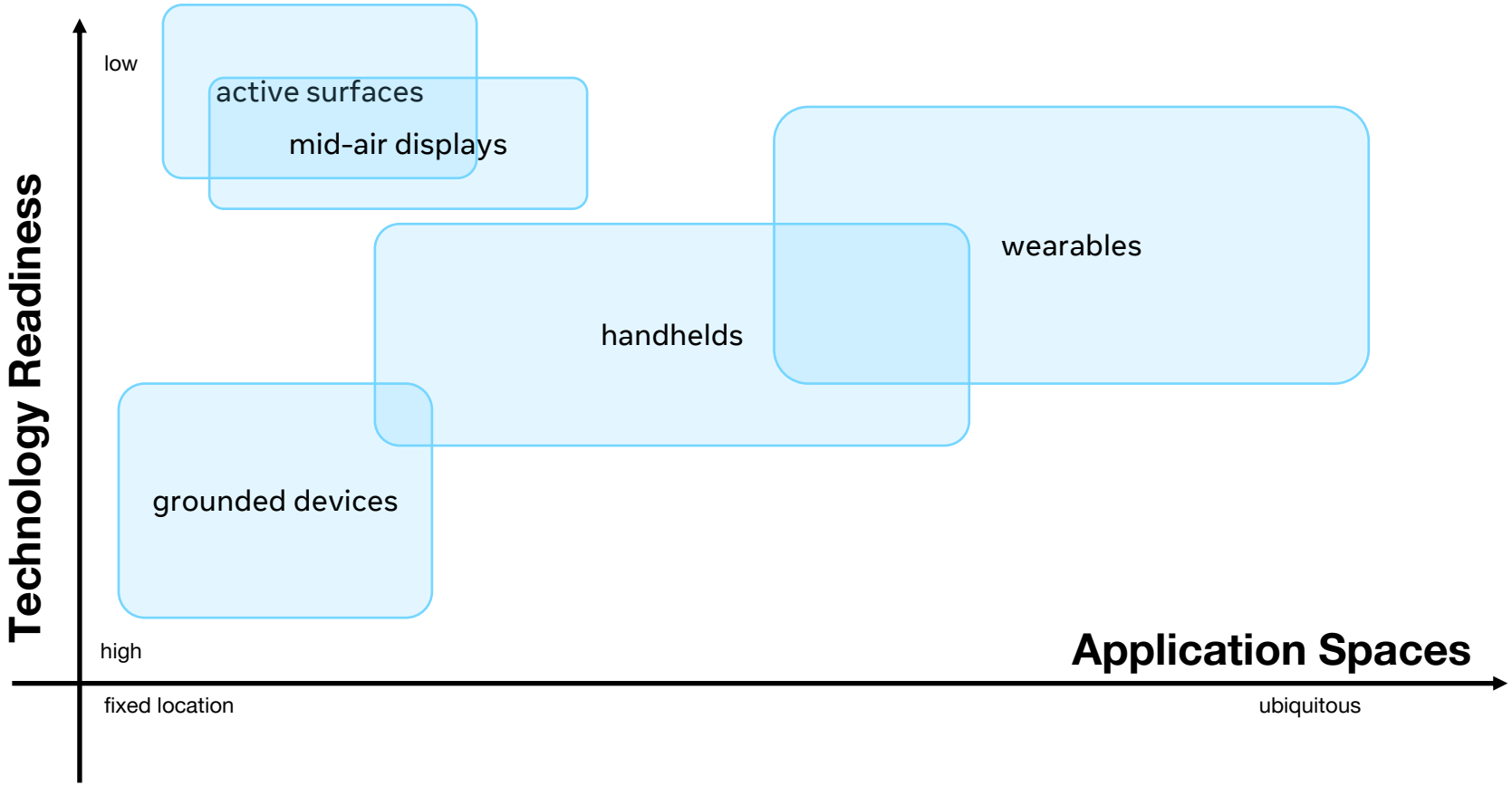


wearables

Application Spaces

fixed location

ubiquitous


low
active surfaces
mid-air displays
wearables
handhelds
grounded devices
Technology Readiness
high
Application Spaces
fixed location
ubiquitous

		grounded	handhelds	wearables
hardware	size, weight, volume, power			
	force, displacement, bandwidth, efficiency			
	manufacture, instrumentation, reliability			
software	I/O standards and frameworks			
	rendering algorithms			
	virtual world content			
user	haptic perception well understood			
	interaction abstractions, design tools			
market	demand			
	cost			

Table Inspired by Ali Israr

		grounded	handhelds	wearables
hardware	size, weight, volume, power			
	force, displacement, bandwidth, efficiency			
	manufacture, instrumentation, reliability			
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	virtual world content			
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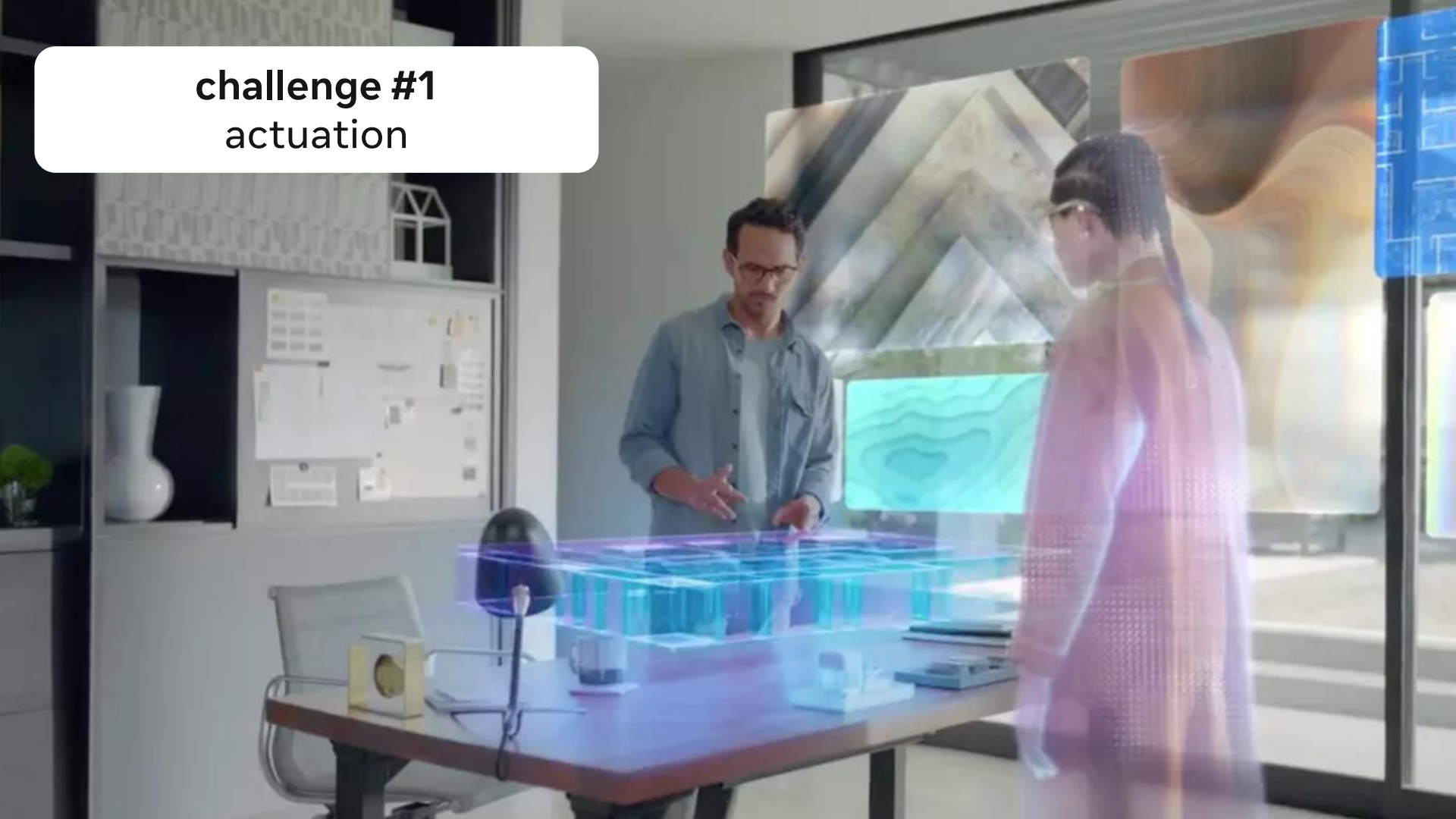
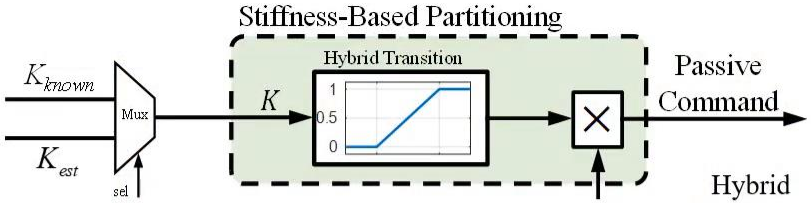
	cost			

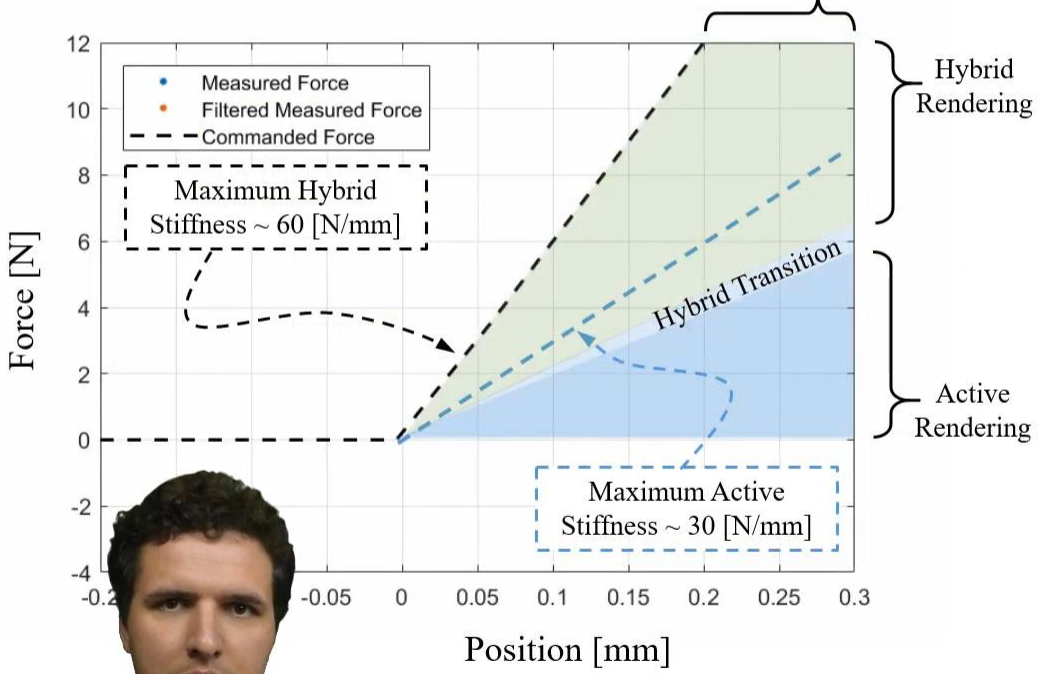
Table Inspired by Ali Israr

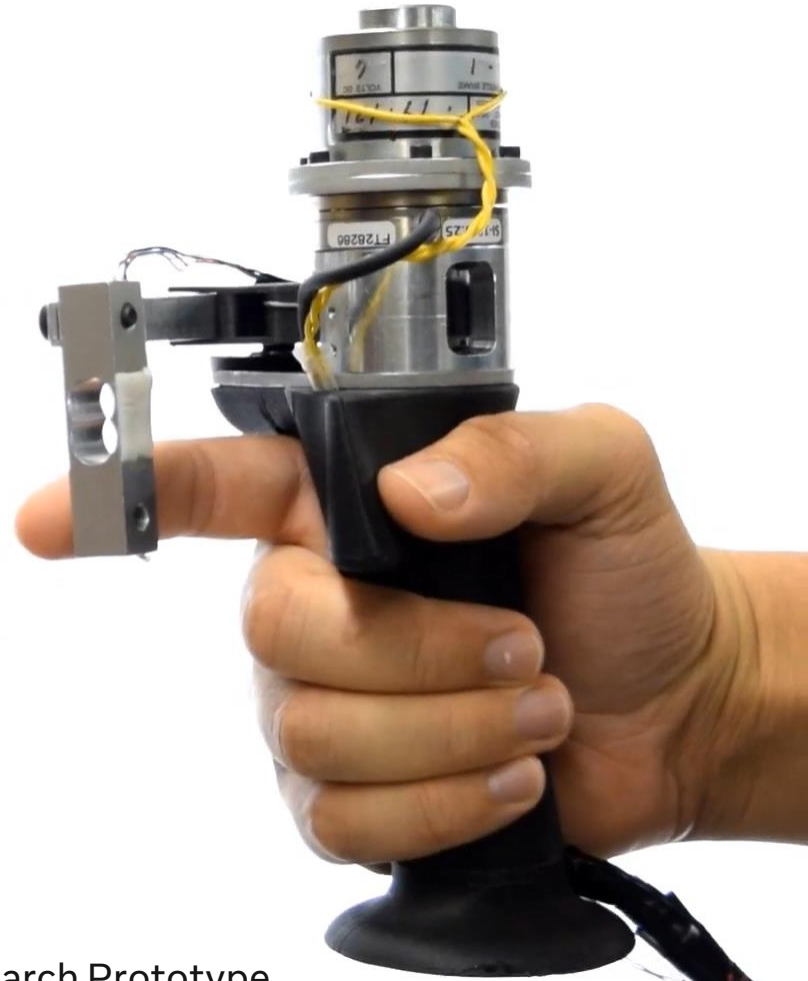
Meta

haptics technology is nascent today


challenge #1
actuation







Research Prototype

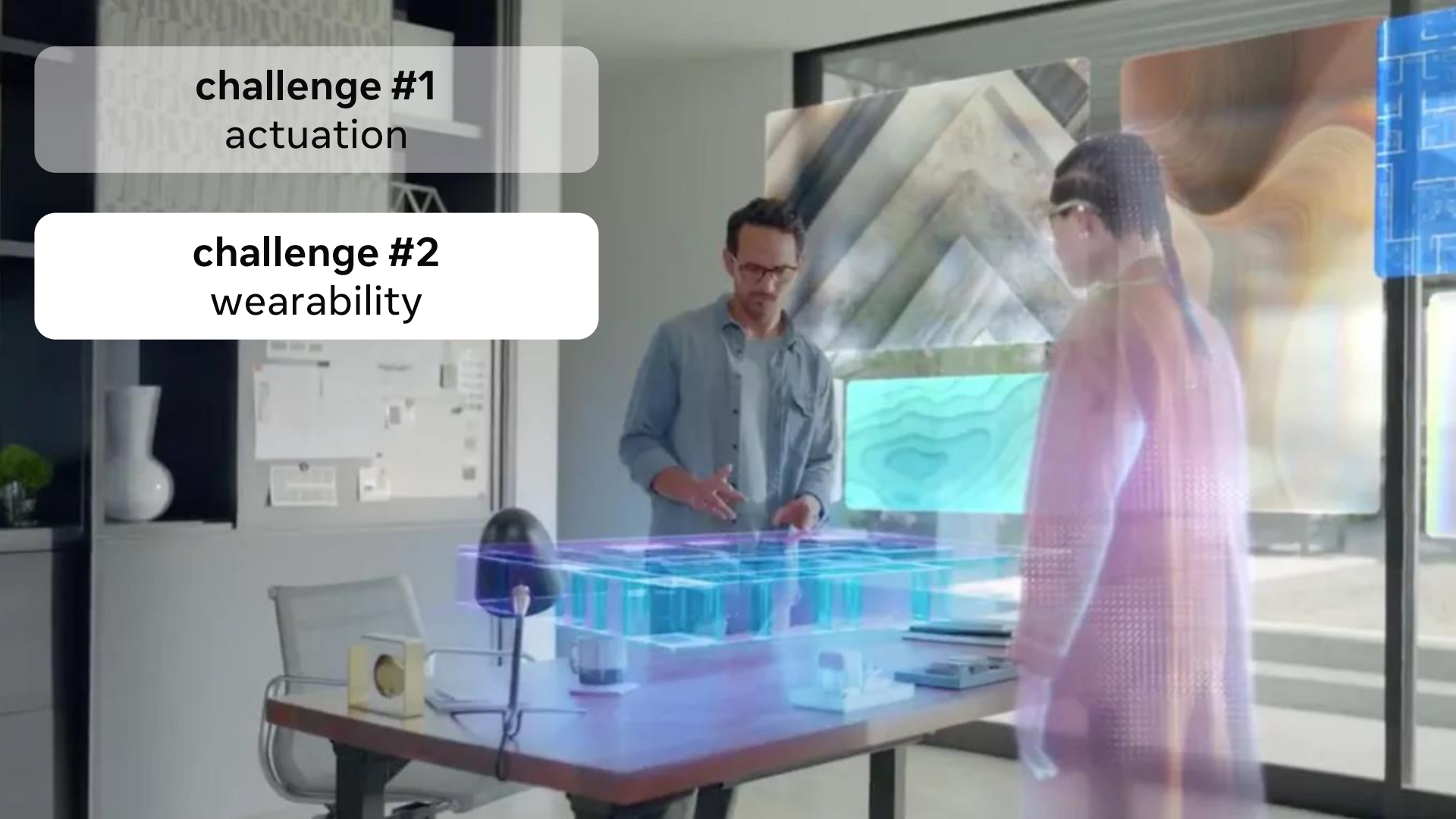
Research Prototype

Table 2. Summary of emerging material actuation methods for tactile displays.

Transduction technique	Mechanism	Advantages	Disadvantages
Pneumatic	Compressed air	Simple, lightweight, high power-to-weight ratio	Low bandwidth, stiff
Hydraulic	Compressed liquid	High bandwidth, high power	Bulky and heavy
Electronic EAP	Electric field driven	Fast, high actuation force, high mechanical energy density, long lifetime	High operating voltage
Ionic EAP	Ionic diffusion	Voltage control bidirectional, low operating voltage	Liquid electrolyte, slow response, low actuation force
Piezoelectric	Piezoelectric effect	Small dimension, large force, high resolution frequency, fast, low power consumption	Small motion, high driving voltage
Electrovibration	Coulomb force	Fast, low-powered, dynamic	Relatively high noise
Electromagnetic	Electromagnetism	Wide bandwidth	Heat generation
ERF	Change in viscosity by electric field	Very fast, high power	Liquid suspension, low breakdown voltage
MRF	Change in viscosity by magnetic field	Strong force	Liquid suspension, expensive
LCE	Phase transition	Wide bandwidth, well controlled	Liquid medium
Gel	Chemical reaction	Different stimulus, well controlled	Relatively low bandwidth, semiliquid medium
MEMS	Electromechanical	Miniature, wide range bandwidth	High-tech fabrication, rarely soft

Biswas and Visell. *Emerging Material Technologies for Haptics*. In Advanced Materials Technologies. 2019.

opportunity:
novel haptic actuation


challenge #1
actuation
challenge #2
wearability


Research Prototype

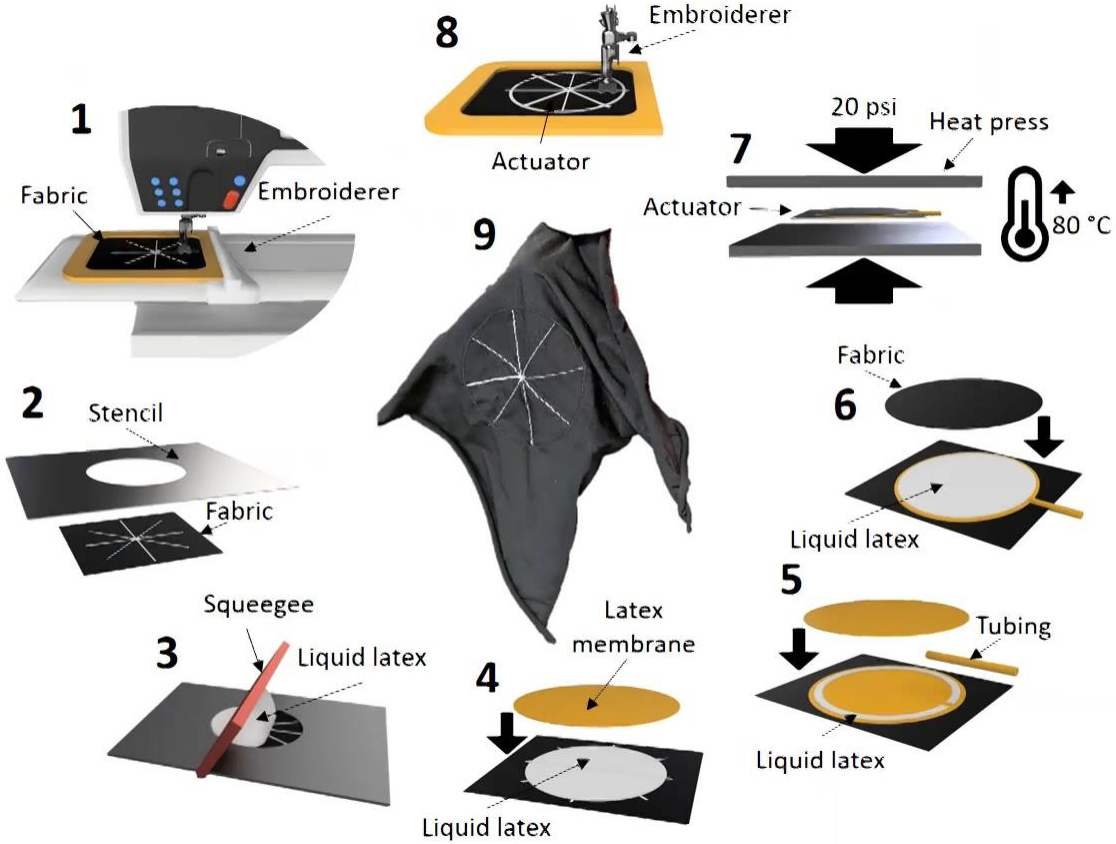
PneuSleeve: In-fabric Multimodal Actuation and Sensing in a Soft, Compact, and Expressive Haptic Sleeve

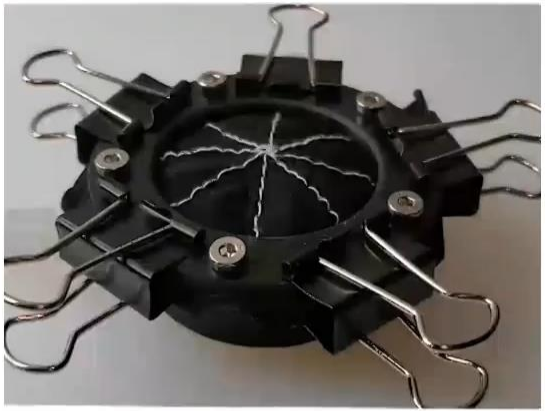
Mengjia Zhu[1,2], Amirhossein H. Memar[1], Aakar Gupta[1], Majed Samad[1], Priyanshu Agarwal[1], Sean J. Keller[1], Nicholas Colonnese[1]

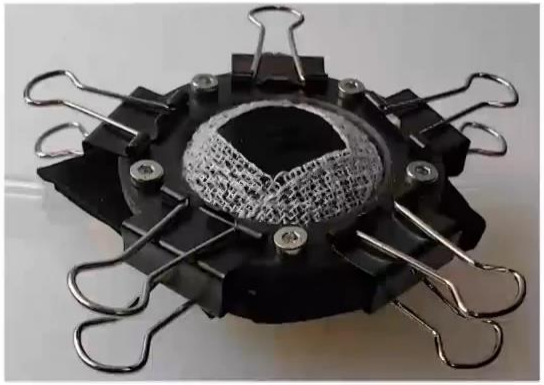
[1]Facebook Reality Labs, Redmond, WA, USA, [2]University of California, Santa Barbara, CA, USA

Music: https://www.bensound.com/royalty-free-music

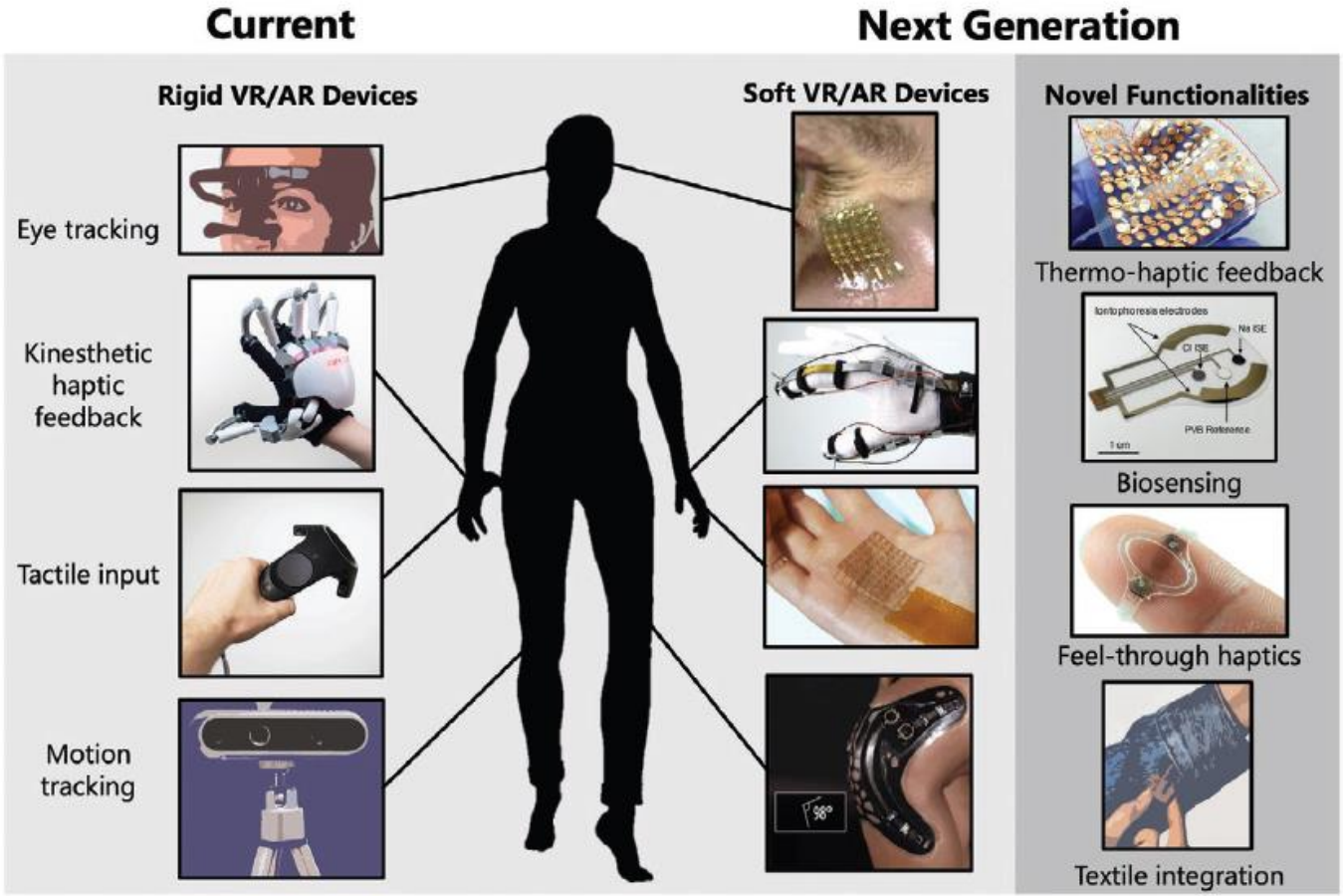
Research Prototype





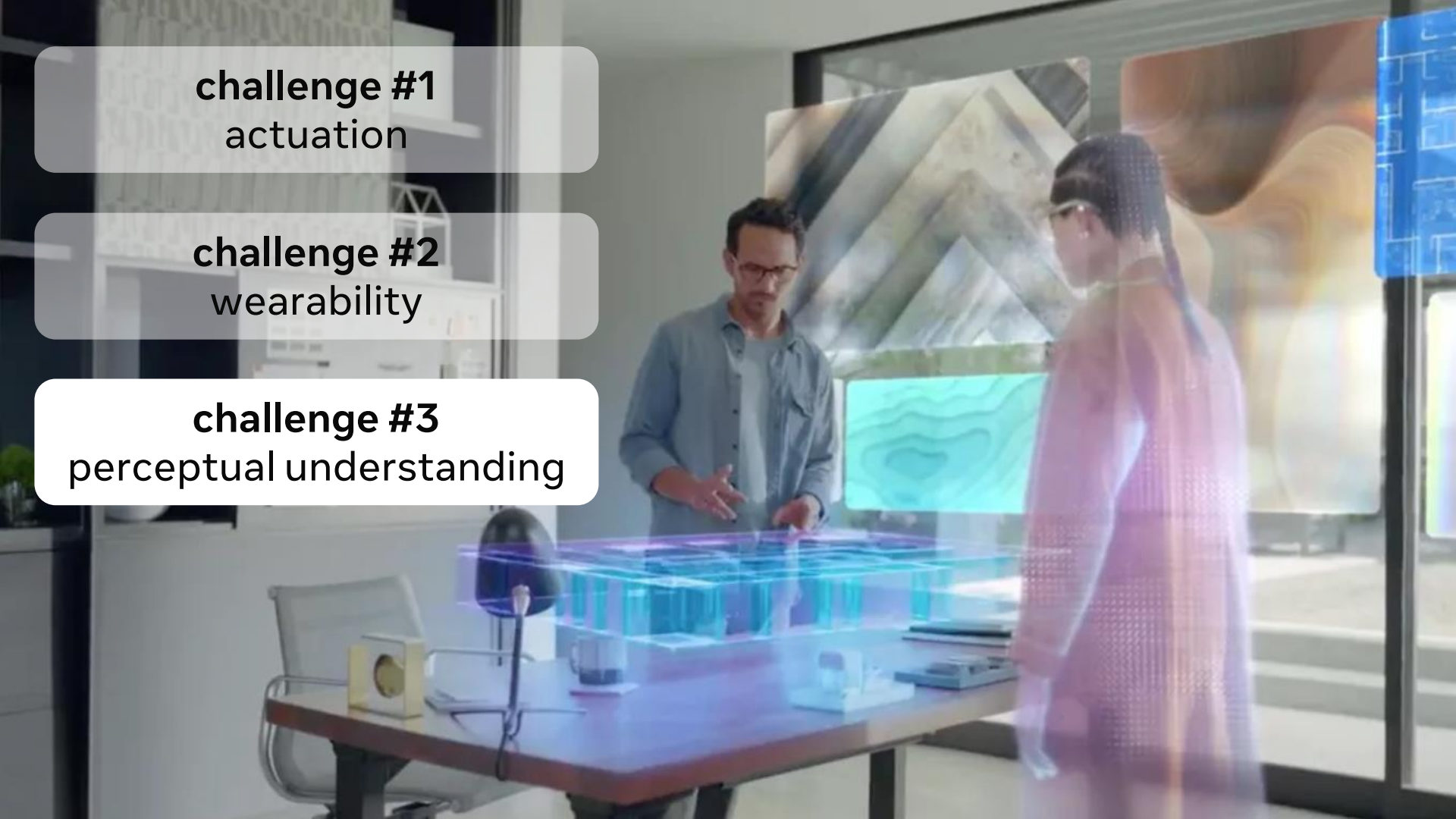


Research Prototype

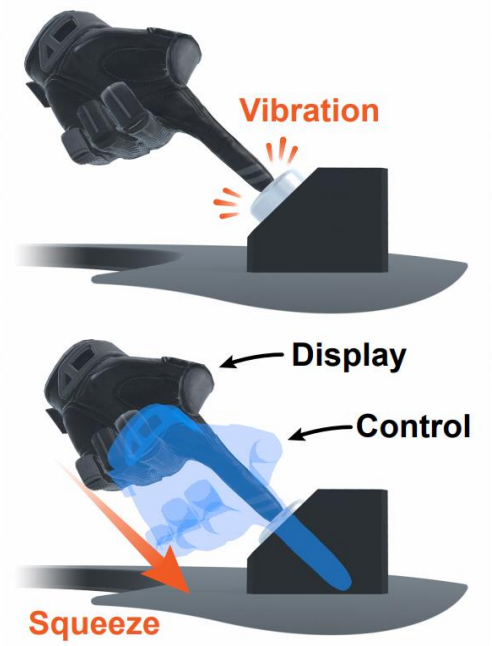


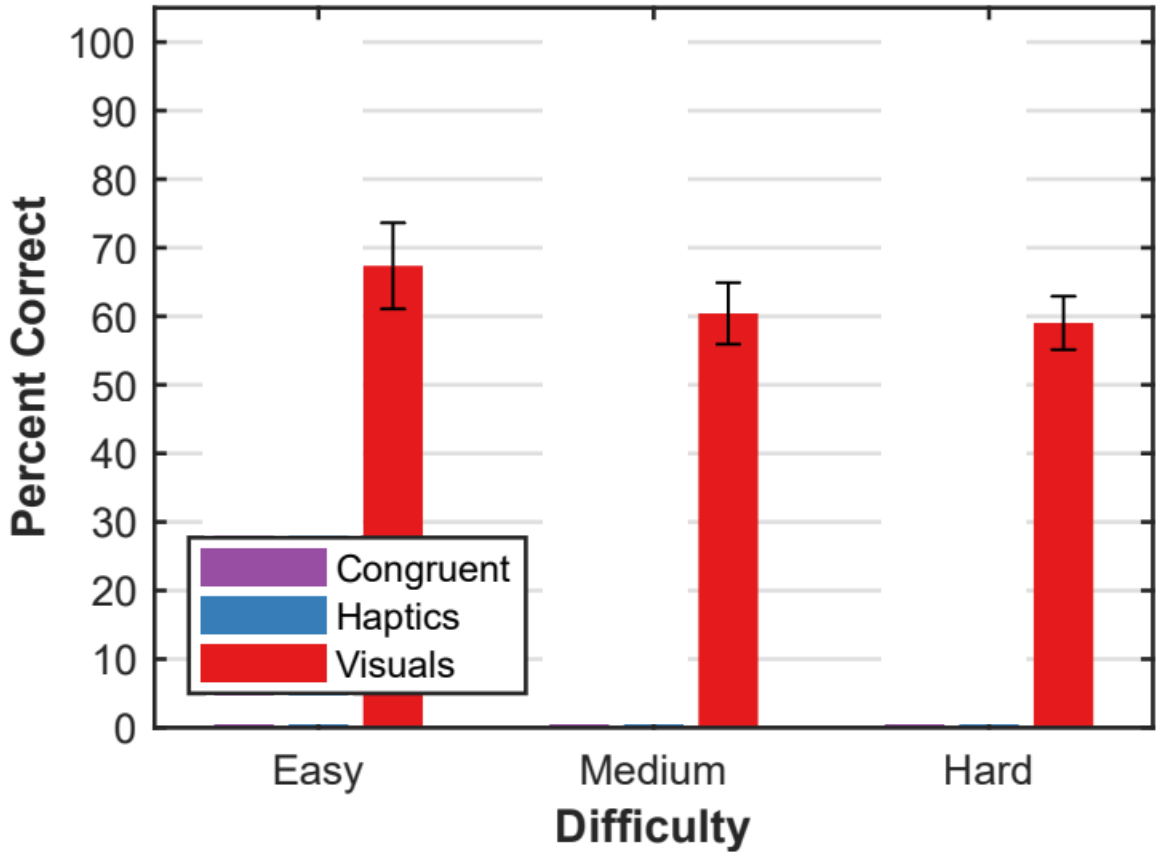
Yin et al. Wearable Soft Technologies for Haptic Sensing and Feedback. In Advanced Functional Materials 2021.

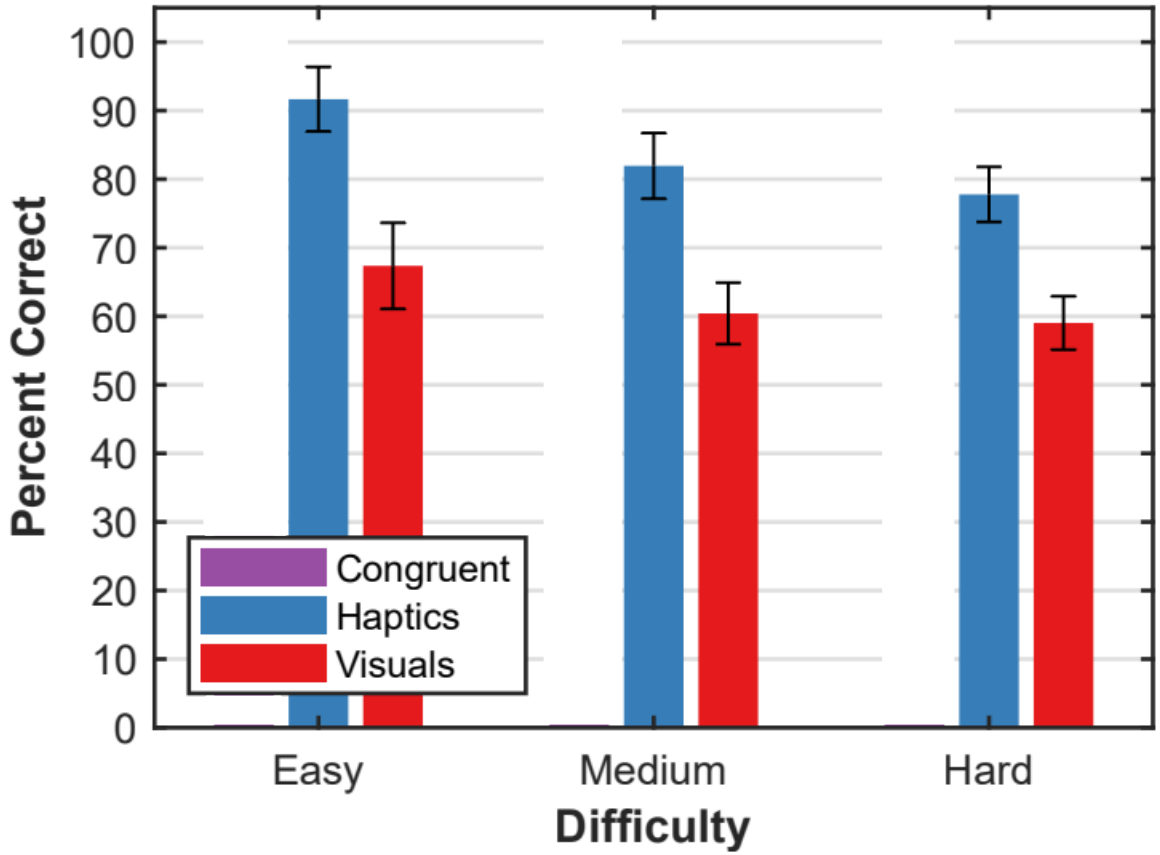
opportunity:
soft materials more closely matching the mechanical properties of the human body


challenge #1
actuation
challenge #2
wearability
challenge #3
perceptual understanding

Research Prototype


Vibration
Display
Control
Squeeze


Percent Correct
100
90
80
70
60
50
40
30
20
10
0
Congruent
Haptics
Visuals
Easy
Medium
Hard
Difficulty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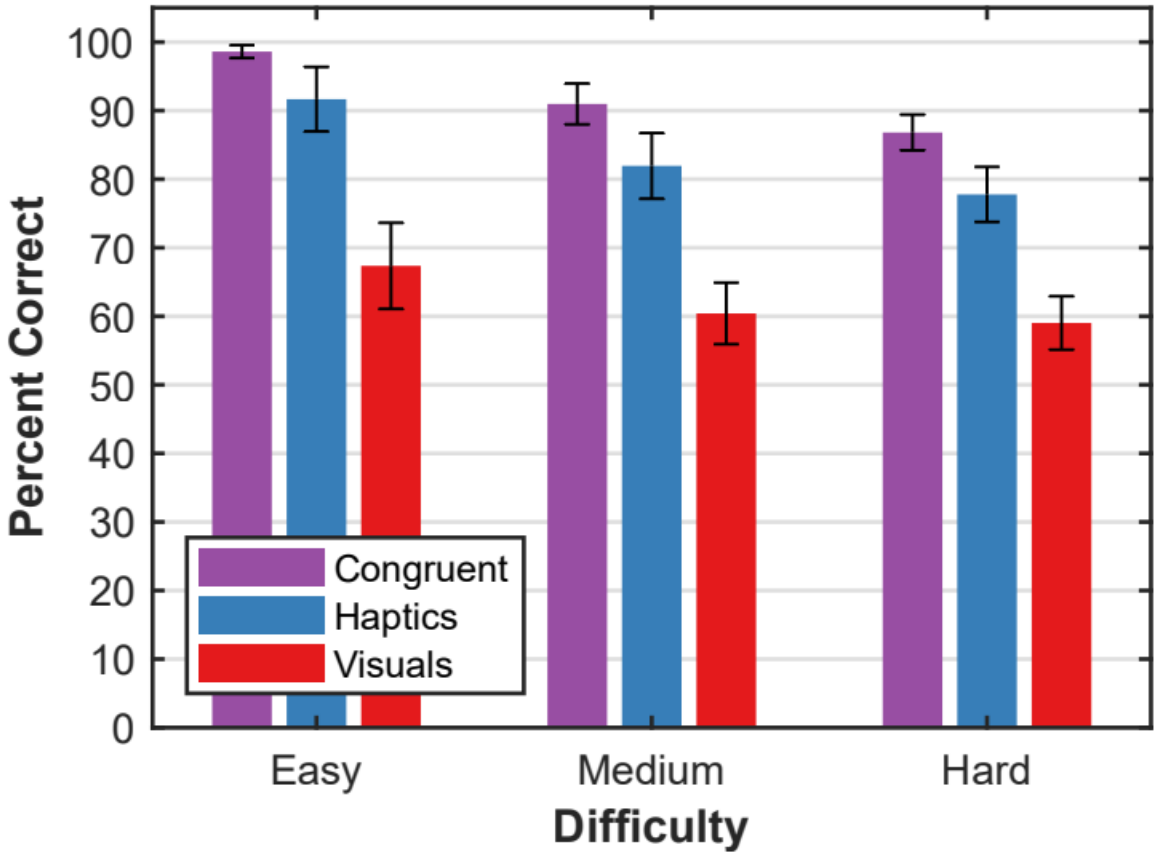
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Hard
Difficulty

Soft
Medium
Hard
Vibration Squeeze
Squeeze
Vibration
VT5
VT0
VT4
VT1
VT3
VT2
Squeeze
VT5
VT0
VT4
VT1
VT3
VT2
Squeeze

Opportunity:
clever design leveraging haptic and multisensory perception

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Nur Al-huda Hamdan, Adrian Wagner, Simon Voelker, Jürgen Steimle, and Jan Borchers. 2019. Springlets: Expressive, Flexible and Silent On-Skin Tactile Interfaces. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. ACM, 488.

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N. Colonnese and A. M. Okamura, "Propagation of joint space quantization error to operational space coordinates and their derivatives," *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Vancouver, BC, 2017, pp. 2054-2061.

N. Colonnese, A. F. Siu, C. M. Abbott and A. M. Okamura, "Rendered and Characterized Closed-Loop Accuracy of Impedance-Type Haptic Displays," in *IEEE Transactions on Haptics*, vol. 8, no. 4, pp. 434-446, 1 Oct.-Dec. 2015.

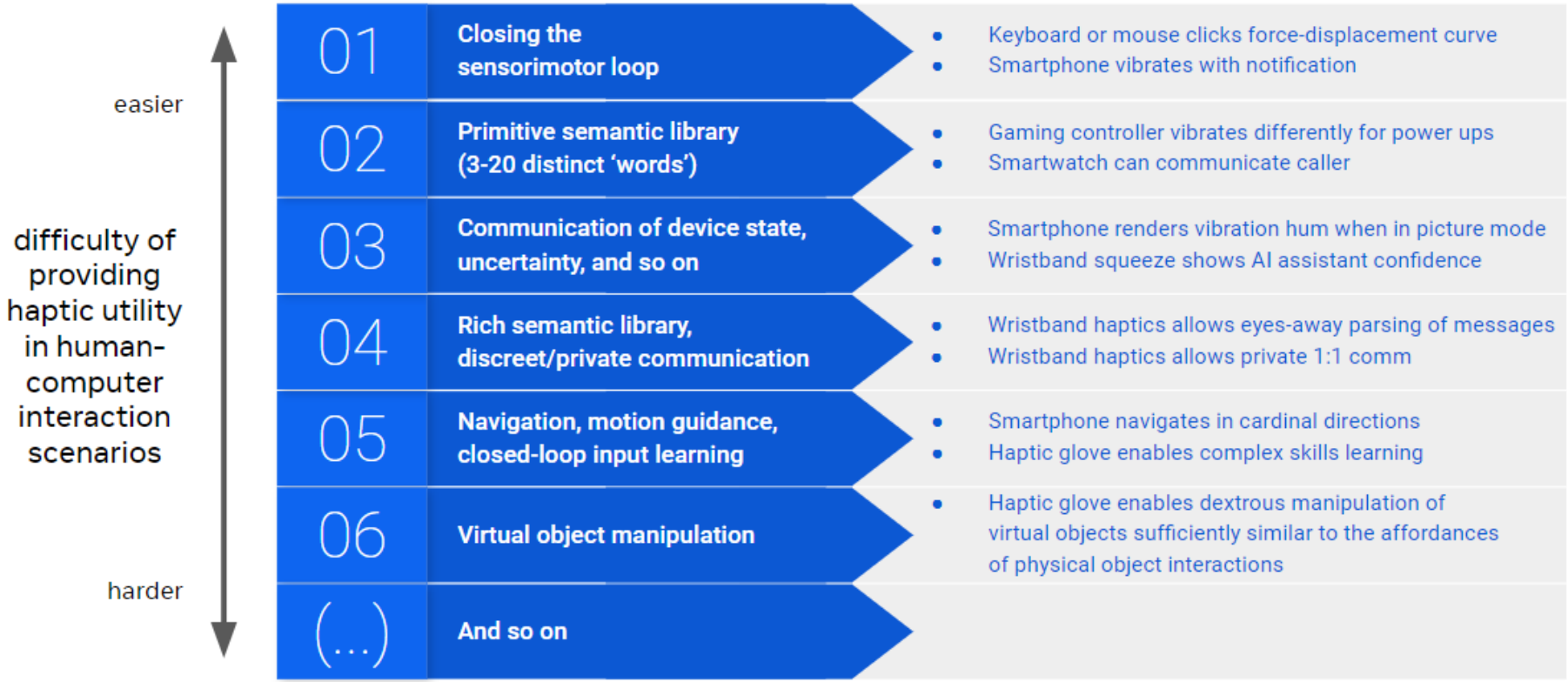
Summary

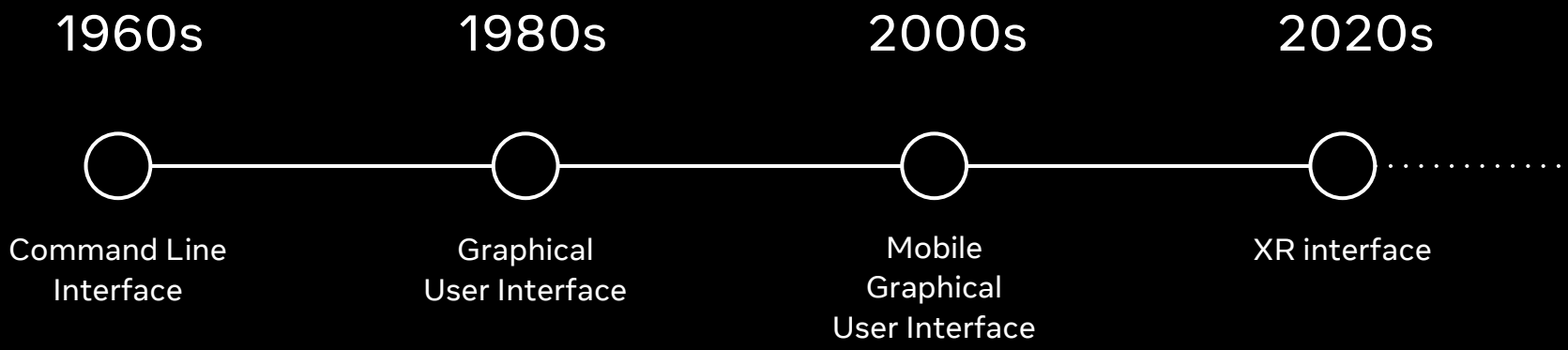
- haptics will be essential to AR/VR and the metaverse
- haptics tech is nascent today
- biggest opportunities:

  1) novel actuation

  2) soft materials for increased wearability

  3) clever rendering leveraging human perception

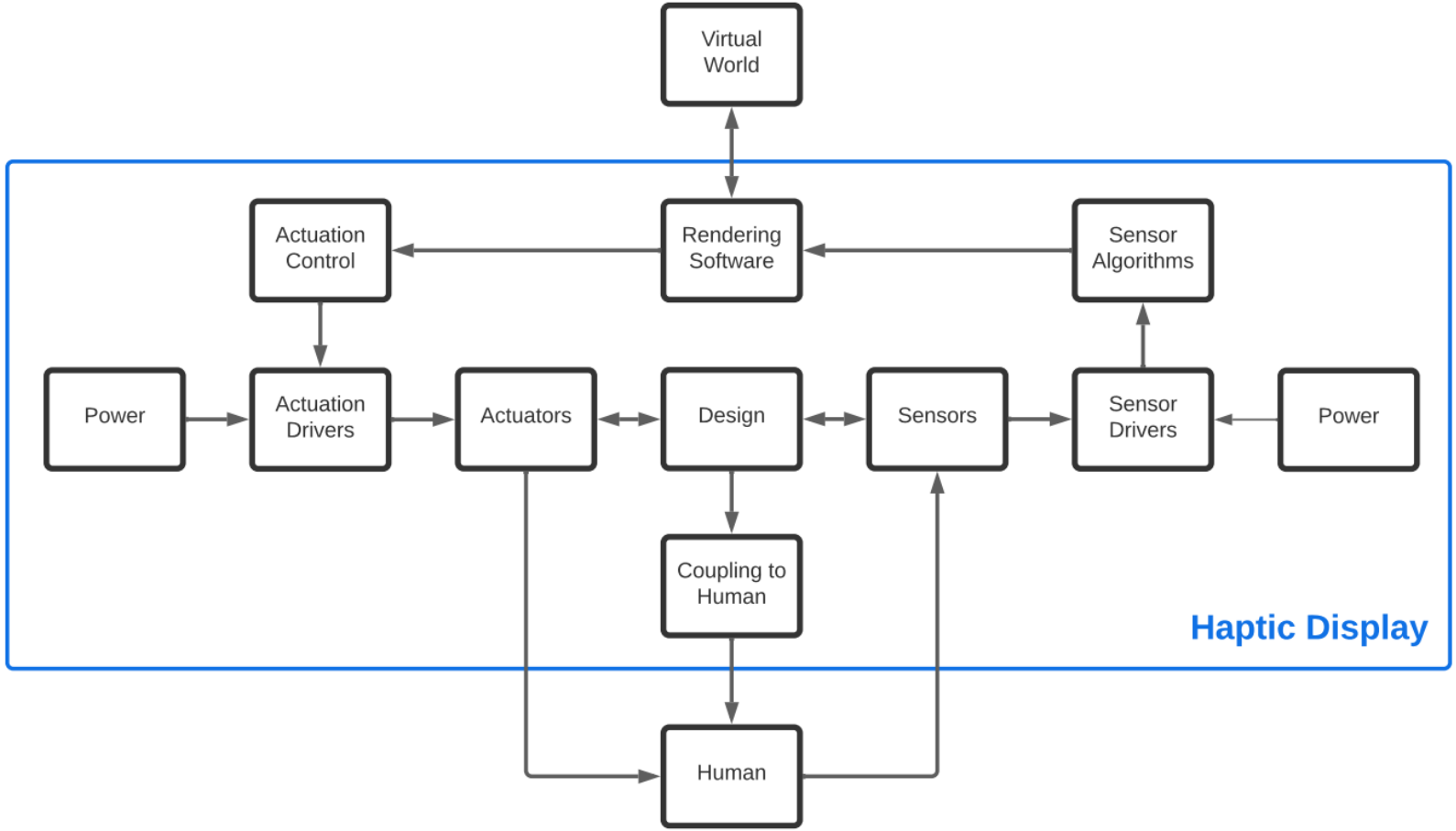

easier
difficulty of providing haptic utility in human-computer interaction scenarios
harder
01
Closing the sensorimotor loop
Keyboard or mouse clicks force-displacement curve
Smartphone vibrates with notification
02
Primitive semantic library (3-20 distinct 'words')
Gaming controller vibrates differently for power ups
Smartwatch can communicate caller
03
Communication of device state, uncertainty, and so on
Smartphone renders vibration hum when in picture mode
Wristband squeeze shows AI assistant confidence
04
Rich semantic library, discreet/private communication
Wristband haptics allows eyes-away parsing of messages
Wristband haptics allows private 1:1 comm
05
Navigation, motion guidance, closed-loop input learning
Smartphone navigates in cardinal directions
Haptic glove enables complex skills learning
06
Virtual object manipulation
Haptic glove enables dextrous manipulation of virtual objects sufficiently similar to the affordances of physical object interactions
(...)
And so on


1960s
1980s
2000s
2020s
Command Line Interface
Graphical User Interface
Mobile Graphical User Interface
XR interface

		Command Line Interface	Graphical User Interface	Mobile Graphical User Interface	AR/VR Interface (Metaverse)
		1960s	1980s	2000s	2020s
Output	**visual**				
	audio			voice	voice
	haptic	keyboard	keyboard, mouse	multi-touch 2d touch screen	
Input	**visual**	monocolor terminal	low res. 2d color screen	high res. 2d color screen	high res. 3d, color, world locked
	audio	beeps	8bit	stereo	custom spatialized
	haptic	keyboard	keyboard, mouse	multi-touch 2d screen, vibration	
processing power (switches)	**Brain[1]**	10^{14}	10^{14}	10^{14}	10^{14}
	Computer[2]	10^{1}	10^{5}	10^{9}	10^{11}
mobile		no	no	yes	yes

[1] Total Number of Synapses in the Adult Human Neocortex. Thai Nguyen. Undergraduate Journal of Mathematical Modeling: 2013.

[2] Server Engineering Insights for Large-Scale Online Services, Kozyrakis et al. 2010


Virtual World
Rendering Software
Actuation Control
Sensor Algorithms
Power
Actuation Drivers
Actuators
Design
Sensors
Sensor Drivers
Power
Coupling to Human
Haptic Display
Human

1	2	3	4	5	6
chemistry and materials, substrate design	actuator design, manufacturing	display design, I/O, control	haptic rendering algorithms	haptic and multisensory perception	user interaction design and value evaluation