Augmenting Embodied Interactions with the Physical World from Objects to Environments

Daniel Campos Zamora

University of Washington





Richard Serra's *Verb List* (1967)

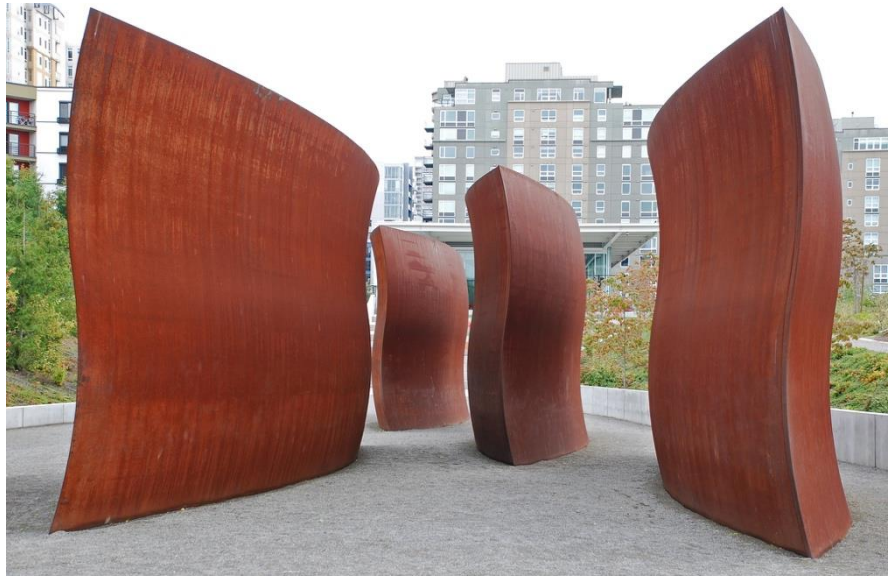


to roll
to crease
to fold
to store
to bend
to shorten
to twist
to dapple
to crumple
to shave
to tear
to chip
to split
to cut
to sever
to drop
to remove
to simplify
to differ
to disarrange
to open
to mix
to splash
to knot
to spill
to droop
to flow

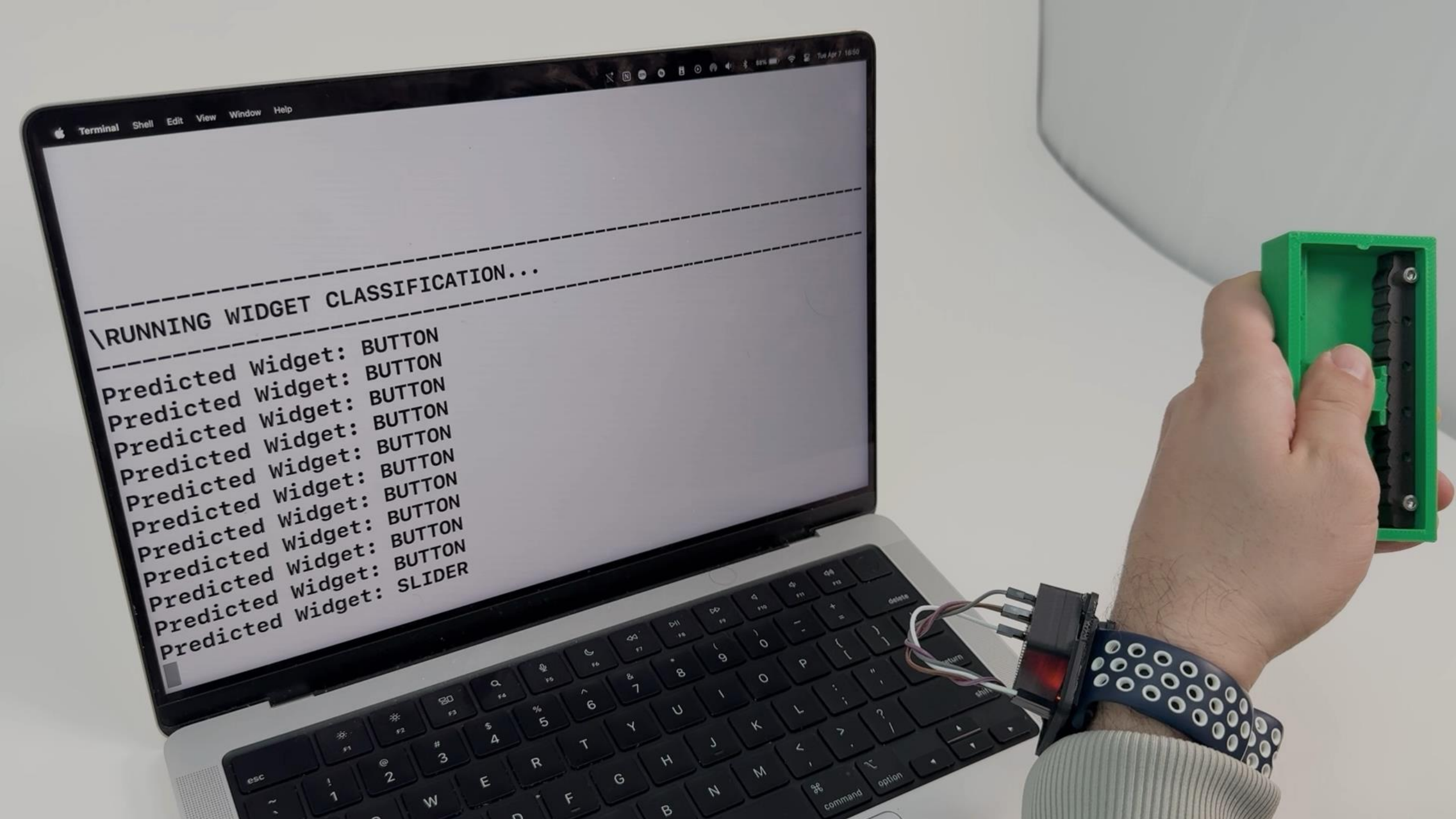
to curve
to lift
to inlay
to impress
to fire
to flood
to smear
to rotate
to swirl
to support
to hook
to suspend
to spread
to hang
to collect
of tension
of gravity
of entropy
of nature
of grouping
of layering
of felting
to grasp
to tighten
to bundle
to heap
to gather

to scatter
to arrange
to repair
to discard
to pair
to distribute
to surfeit
to compliment
to enclose
to surround
to encircle
to hole
to cover
to wrap
to dig
to tie
to bind
to weave
to join
to match
to laminate
to bond
to hinge
to mark
to expand
to dilute
to light

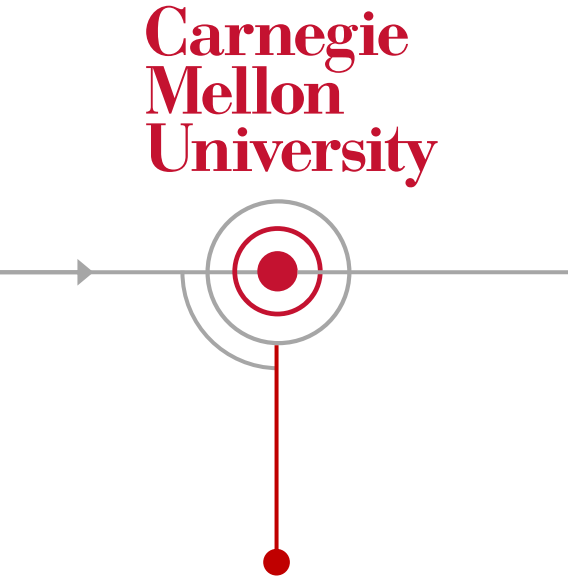
to modulate
to distill
of waves
of electromagnetic
of inertia
of ionization
of polarization
of refraction
of tides
of reflection
of equilibrium
of symmetry
of friction
to stretch
to bounce
to erase
to spray
to systematize
to refer
to force
of mapping
of location
of context
of time
of cabonization
to continue






Terminal Shell Edit View Window Help
\RUNNING WIDGET CLASSIFICATION...
Predicted Widget: BUTTON
Predicted Widget: BUTTON
Predicted Widget: BUTTON
Predicted Widget: BUTTON
Predicted Widget: BUTTON
Predicted Widget: BUTTON
Predicted Widget: BUTTON
Predicted Widget: BUTTON
Predicted Widget: SLIDER

Background



Undergrad

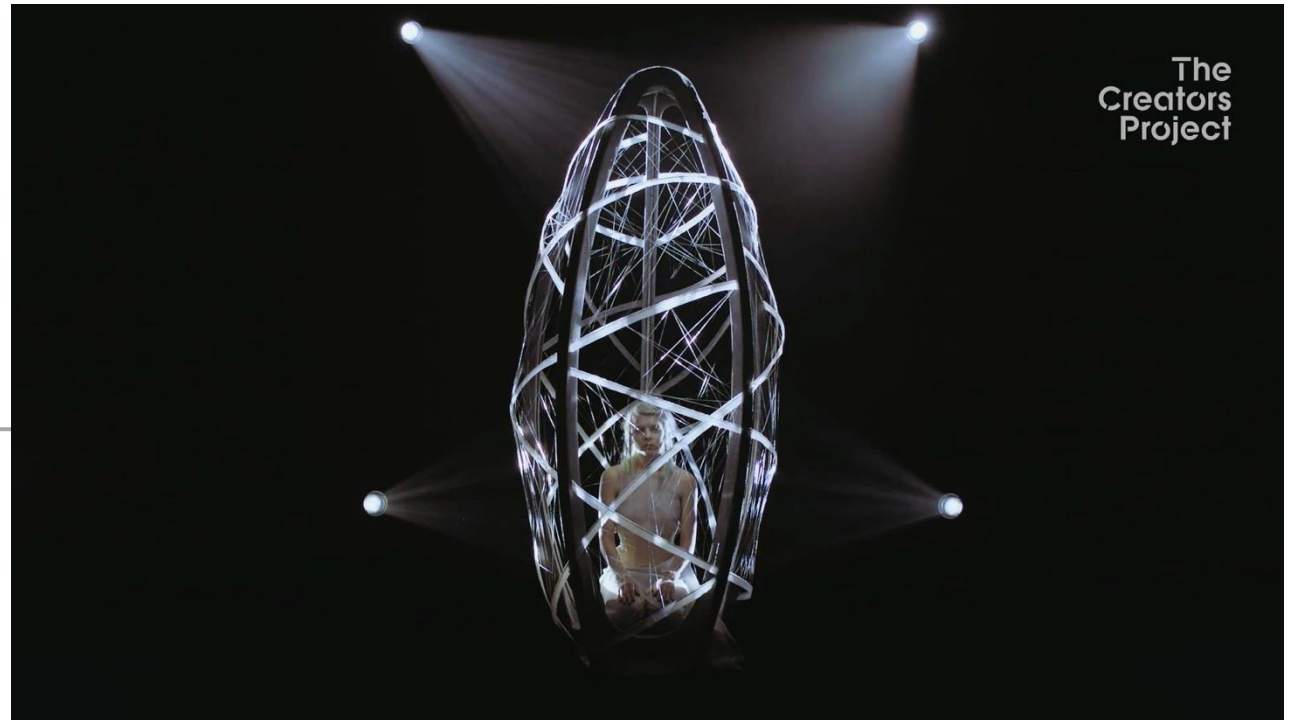
Background

Carnegie Mellon University

Undergrad

‘Externship’ at Interdisciplinary Media Arts Lab

Carnegie Mellon University School of Art



Background



Social AR

Undergrad



Disney Research

Research Associate



Bipedal Robots



Soft Robotics

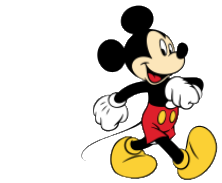
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Disney Research

Research Associate

PhD Student at UW CSE Working with Jon Froehlich

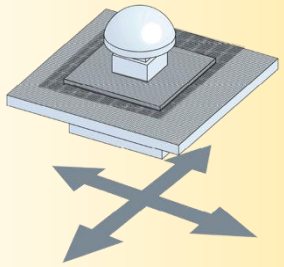
UNIVERSITY of WASHINGTON

Sensing

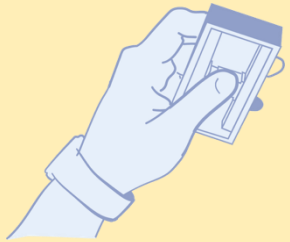
Fabrication

Robotics

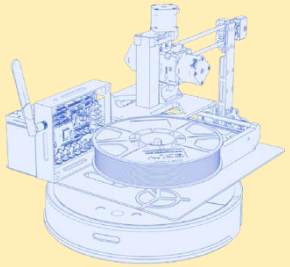
Augmenting Embodied Interactions at Different Scales



MoiréWidgets
CHI '24



HapticWidgets
In Submission



MobiPrint
UIST '24



NightLight
CHI '25

mm cm m km

Sustainability

Accessibility

Public Health

Passive Tangible Interfaces

Adaptive Environments

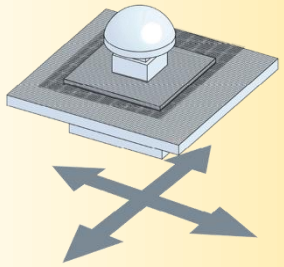
Improved Navigation Tools

Sensing

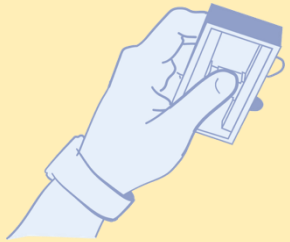
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Robotics

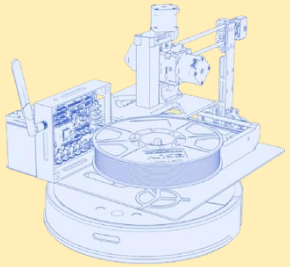
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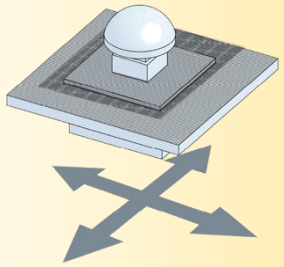
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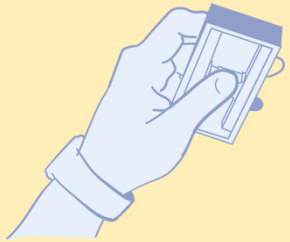
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Robotics

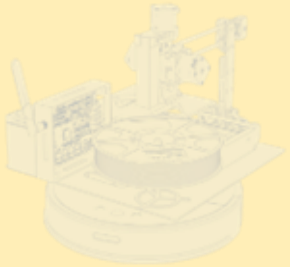
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MPC
MUSIC PRODUCTION CENTER
2500
Q-Link
PAD BANK
A
B
C
D
FULL LEVEL
16 LEVELS
NEXT SEQ
TRACK MUTE
DATA
TAP TEMPO
CURSOR
MAIN
WINDOW
SHIFT
UNDO
LOCATE
STEP
GO TO
BAR
PLAY/REC
STOP
PLAY
PLAY START
AKAI
ALC

Aulart

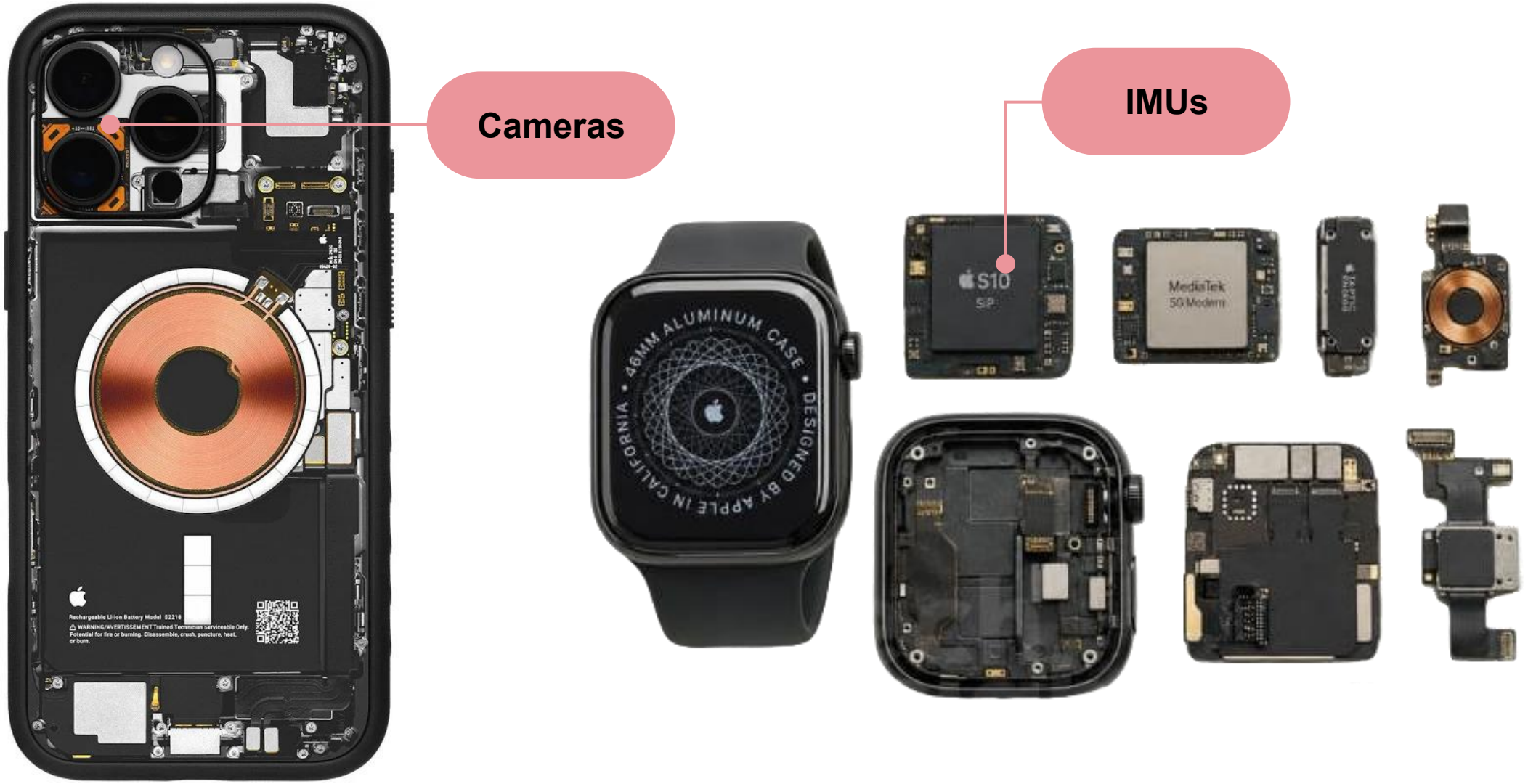
Tangible User Interfaces





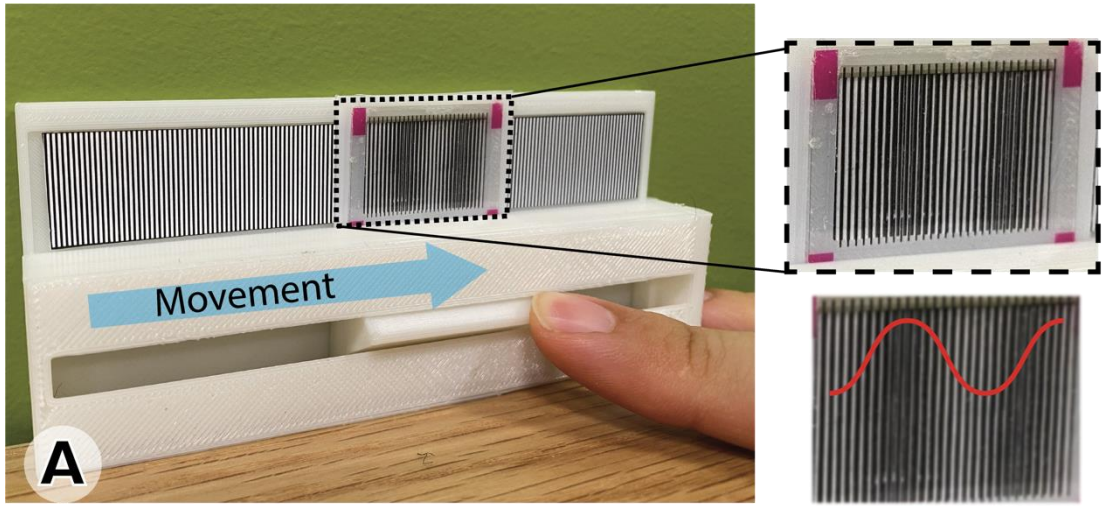
Extract the signal, not embedding electronics

Leverage Ubiquitous Sensors



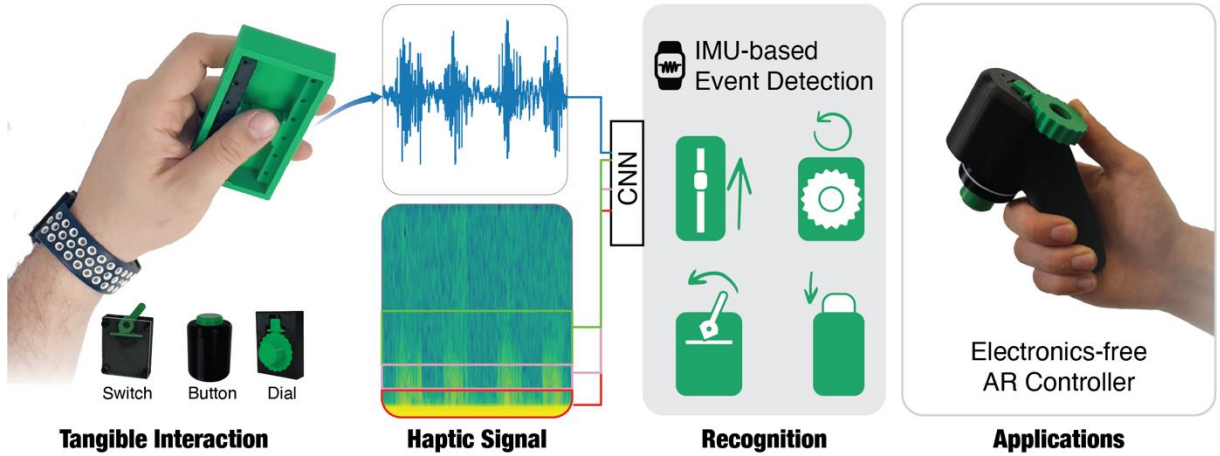
Battery-Free, Passive TUIs

Signal via Visual Appearance



Campos Zamora *et al.*, MoiréWidgets, *CHI 2024*

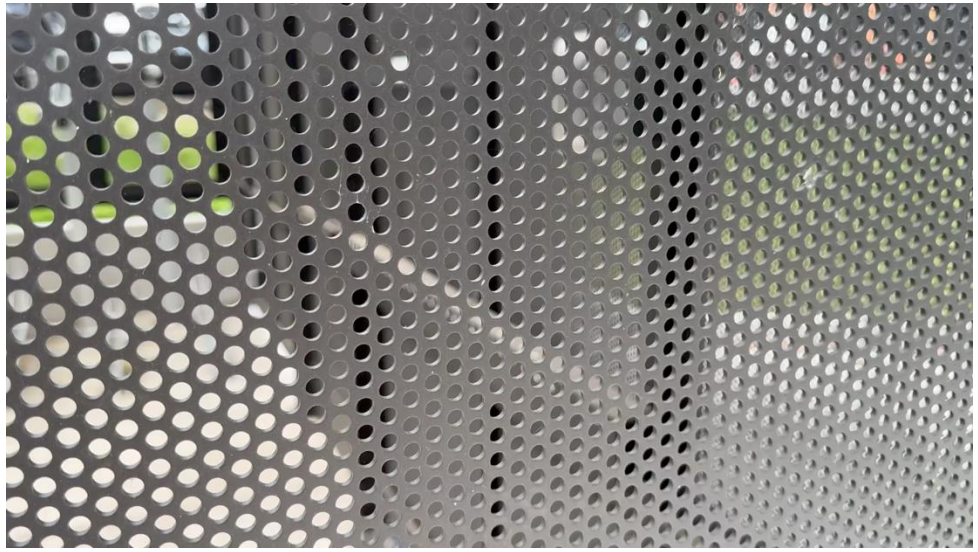
Signal via Mechanical Vibrations



Campos Zamora *et al.*, HapticWidgets, *In Submission*


3Dconnexion

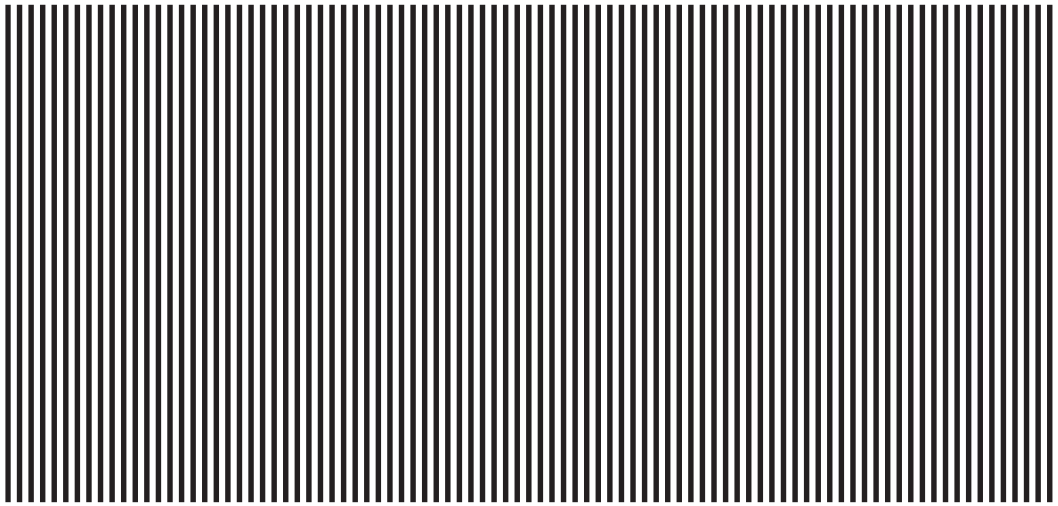
Our Method: Moiré Effect



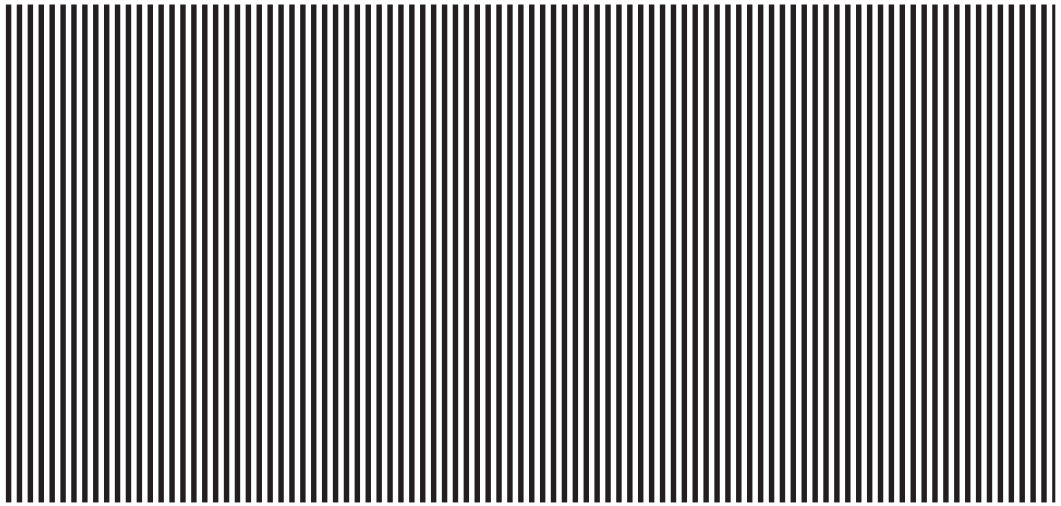




Moiré Effect



Layer 1

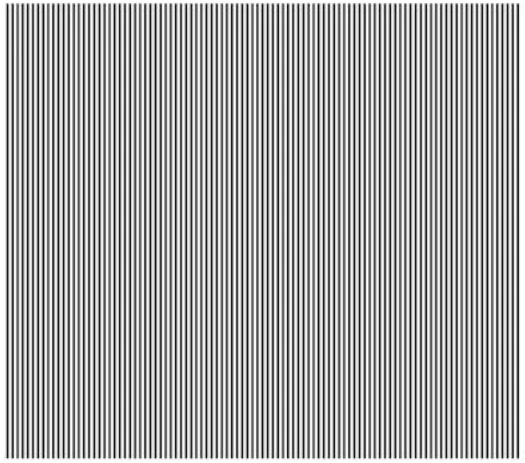


Layer 2

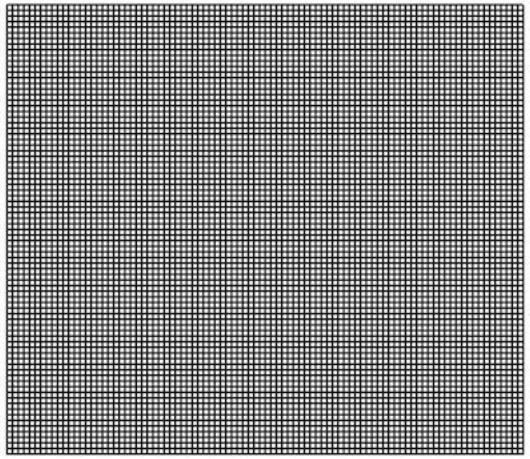
$$\Delta moire = \frac{T_{Layer1}\Delta_{Layer2}}{T_{Layer1} - T_{Layer2}}$$

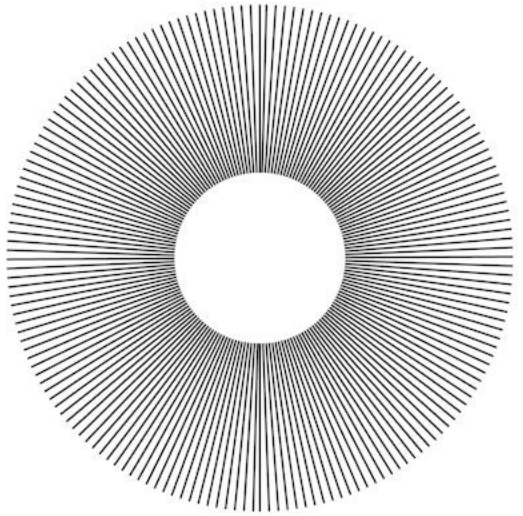
Can we use the Moiré effect to track inputs?

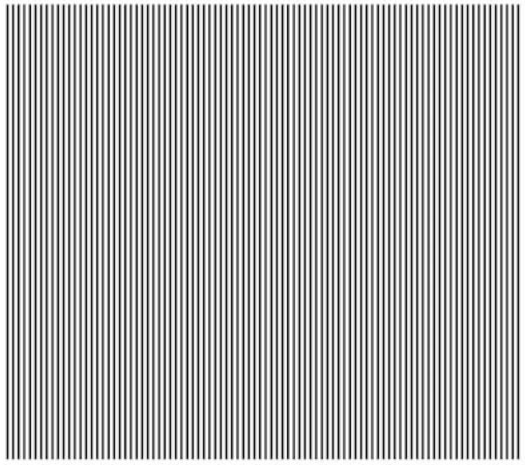
Movement Types

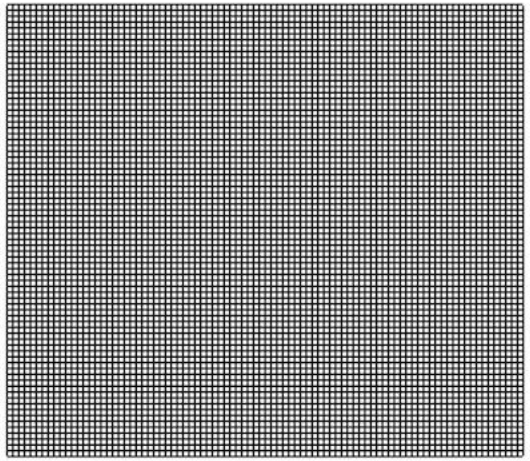


Top Layers

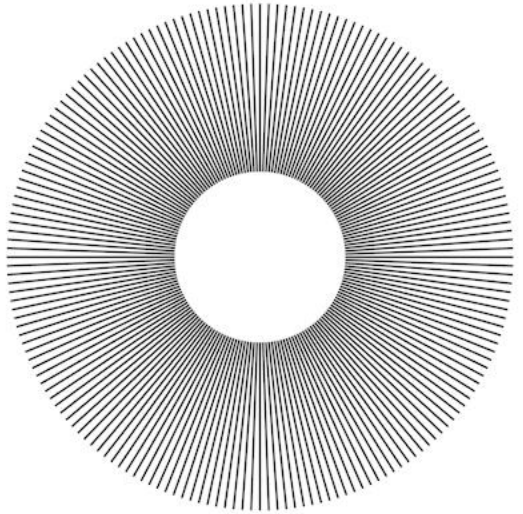




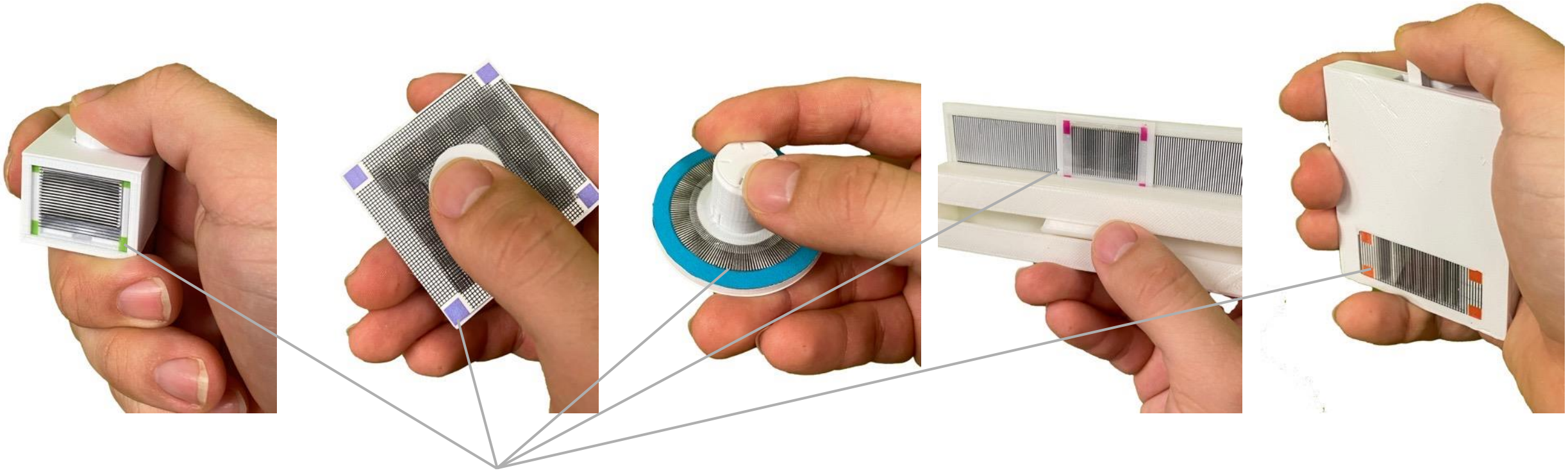




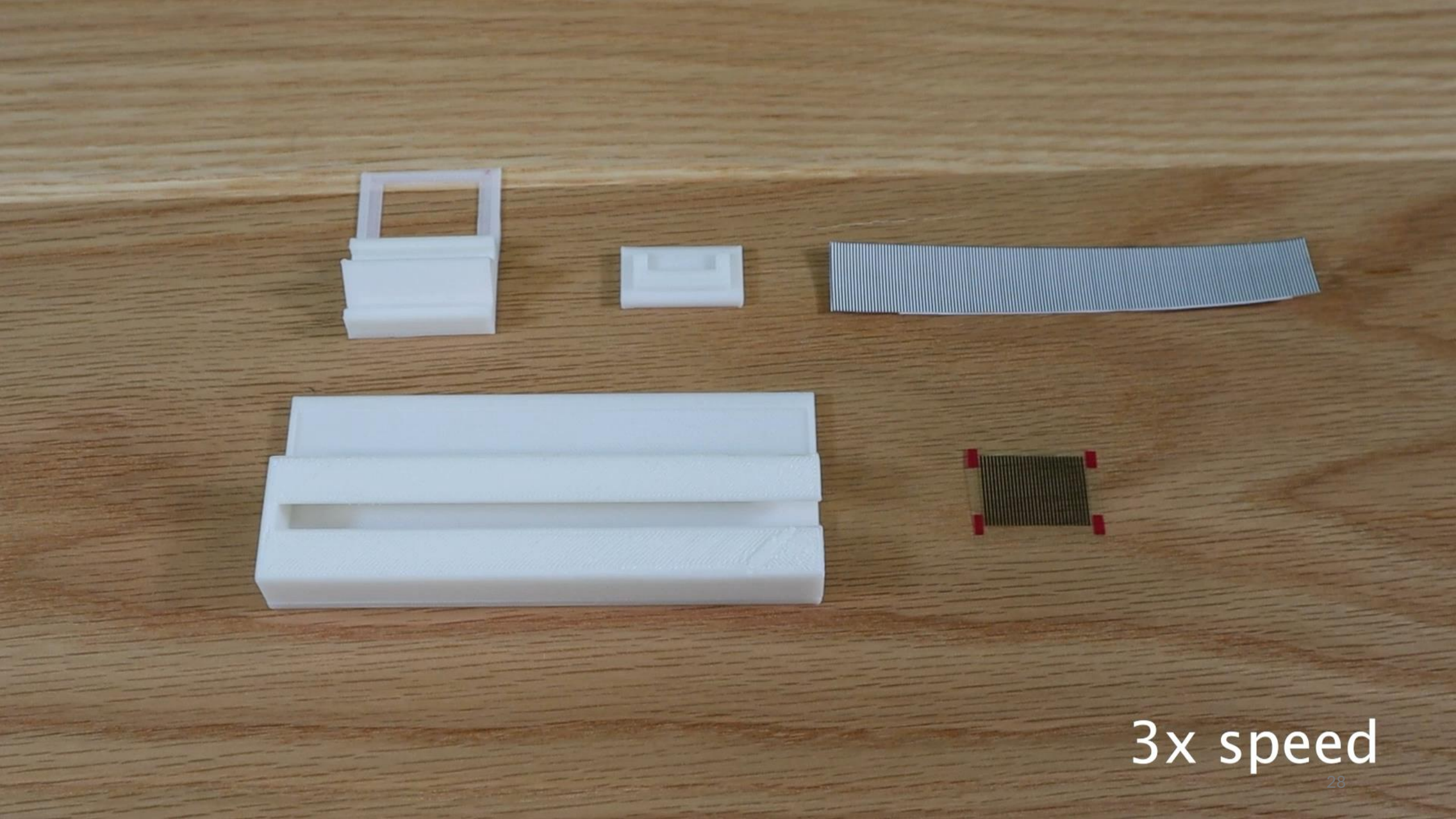
Bottom Layers



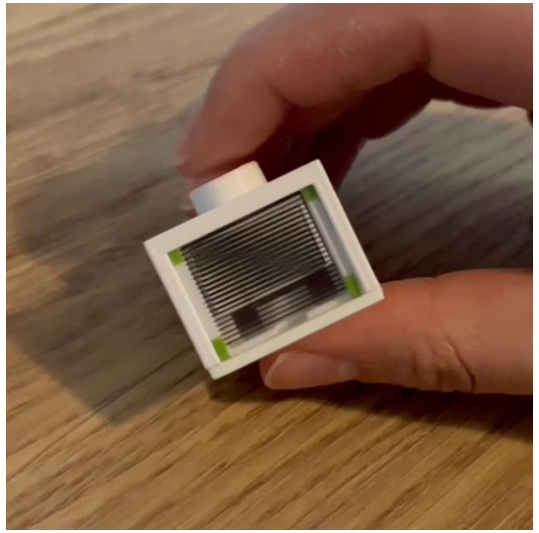
MoiréWidgets

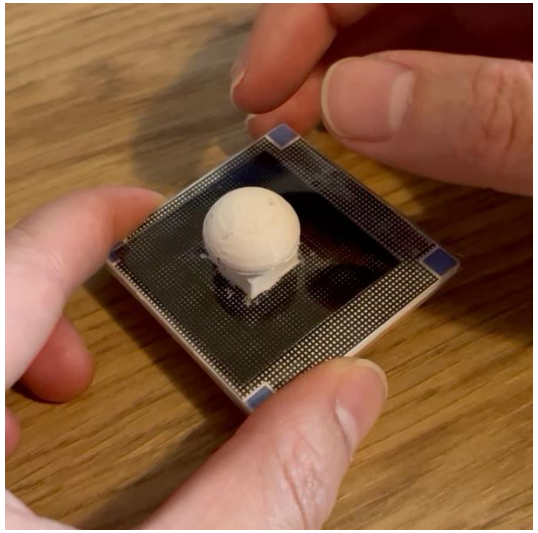


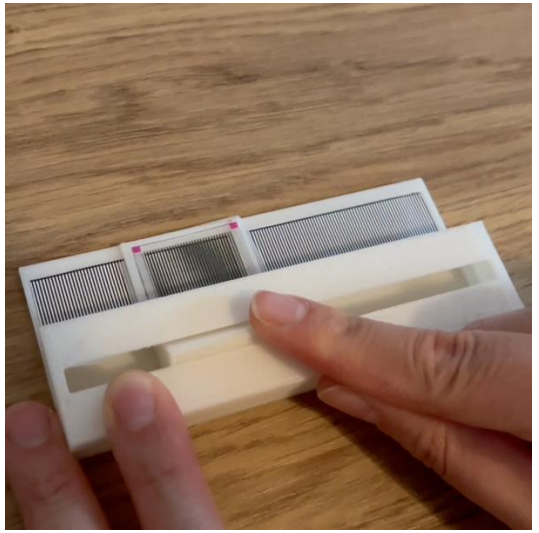
Colored Markers for Extracting Moiré Pattern


3x speed

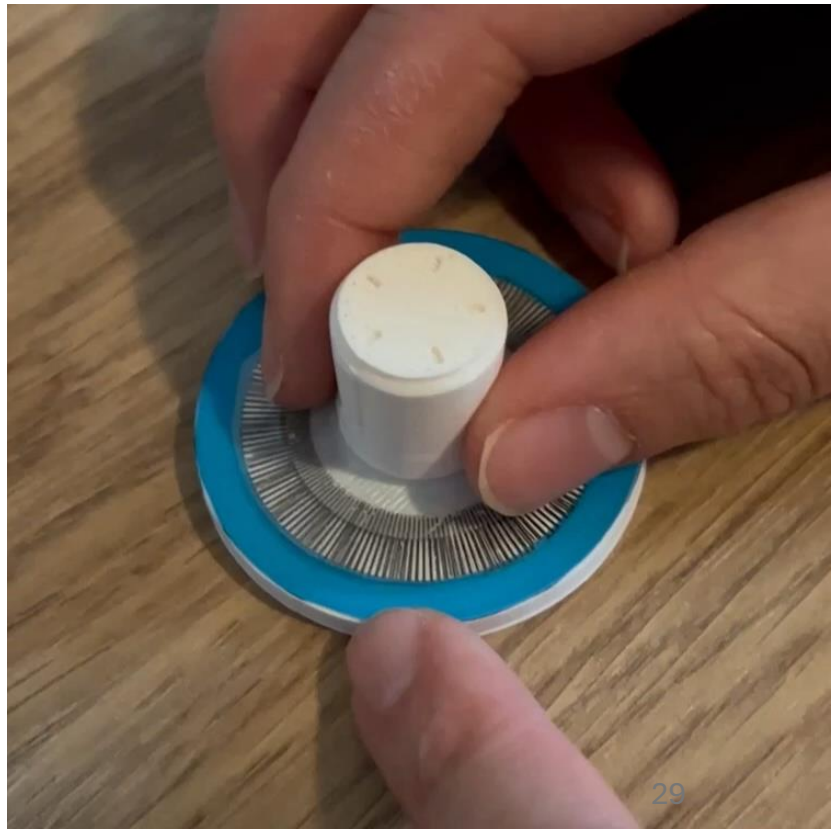
Widgets



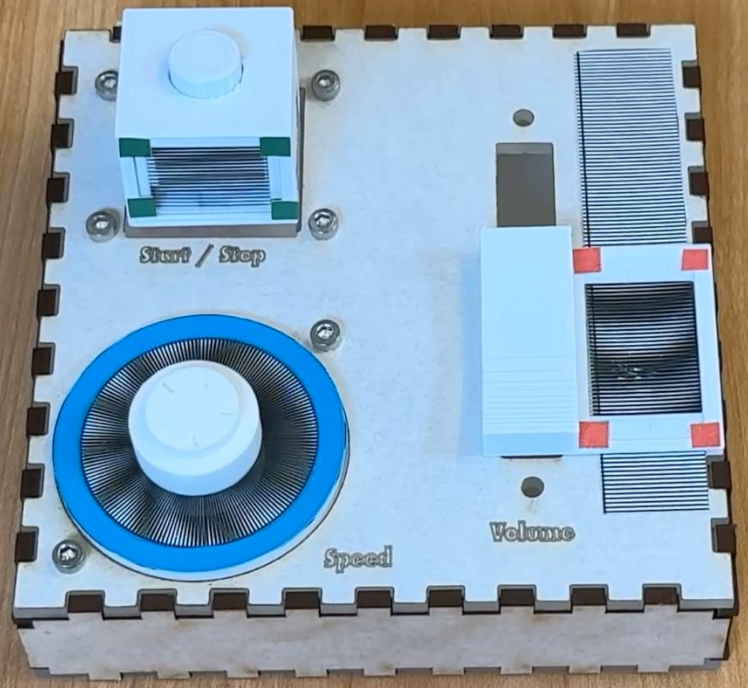


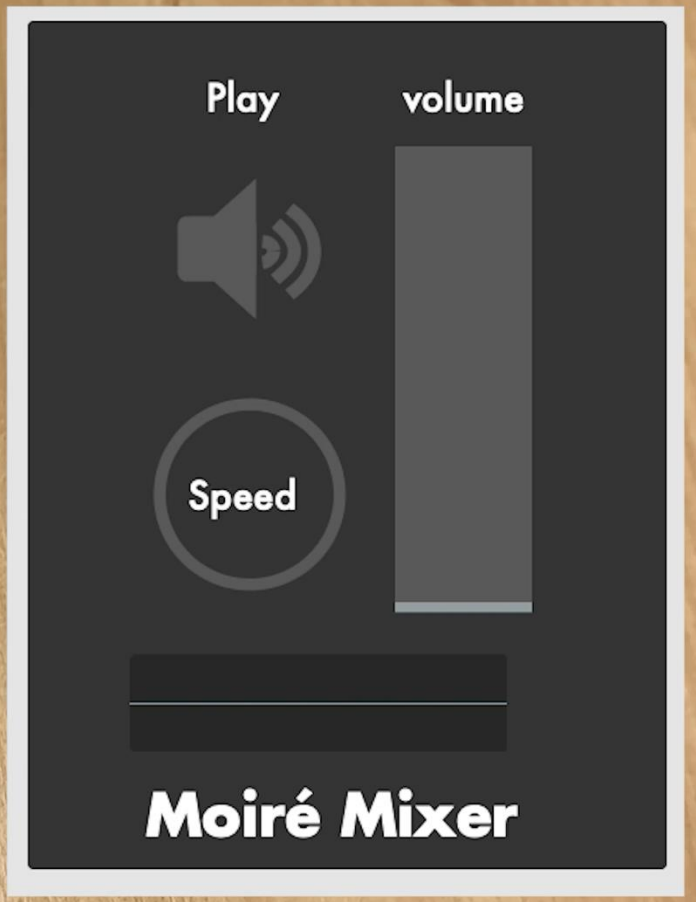






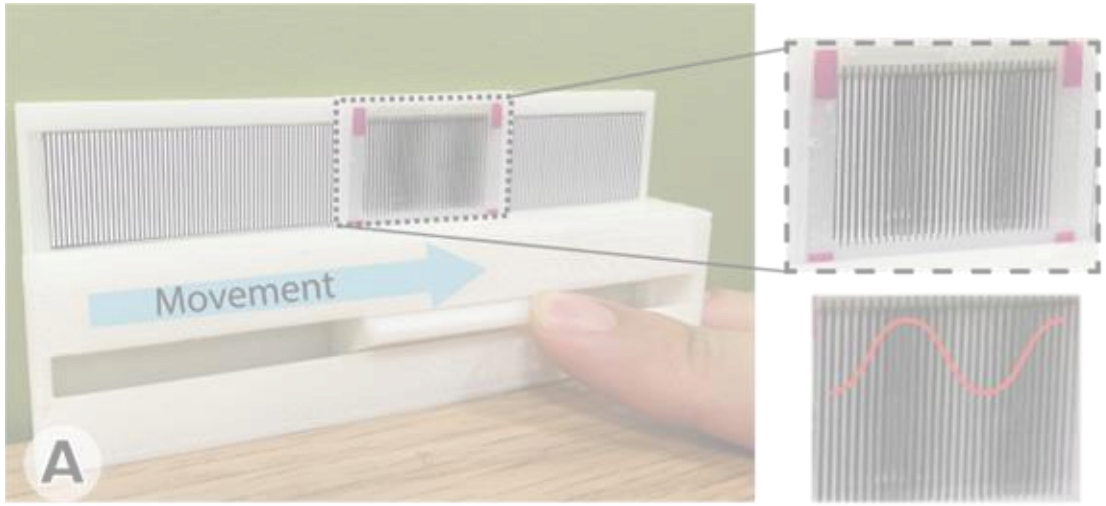
Demo





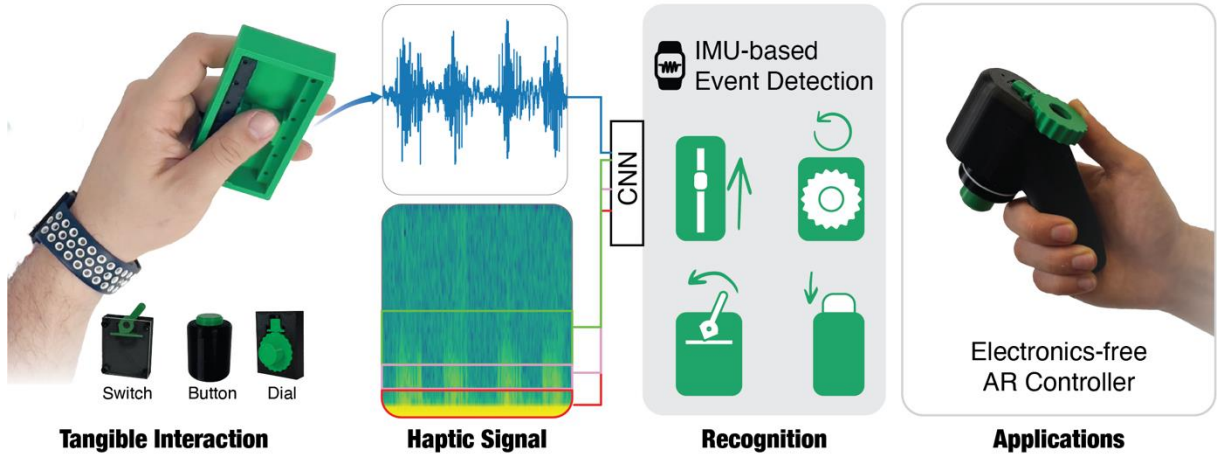
Battery-Free, Passive TUIs

Signal via Visual Appearance



Campos Zamora *et al.*, MoiréWidgets, *CHI 2024*

Signal via Mechanical Vibrations



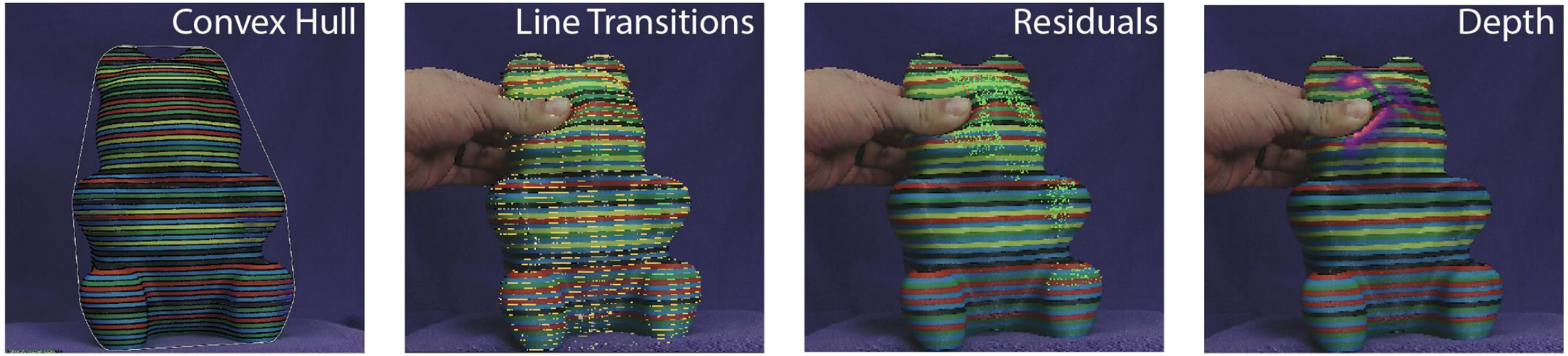
Campos Zamora *et al.*, HapticWidgets, *In Submission*

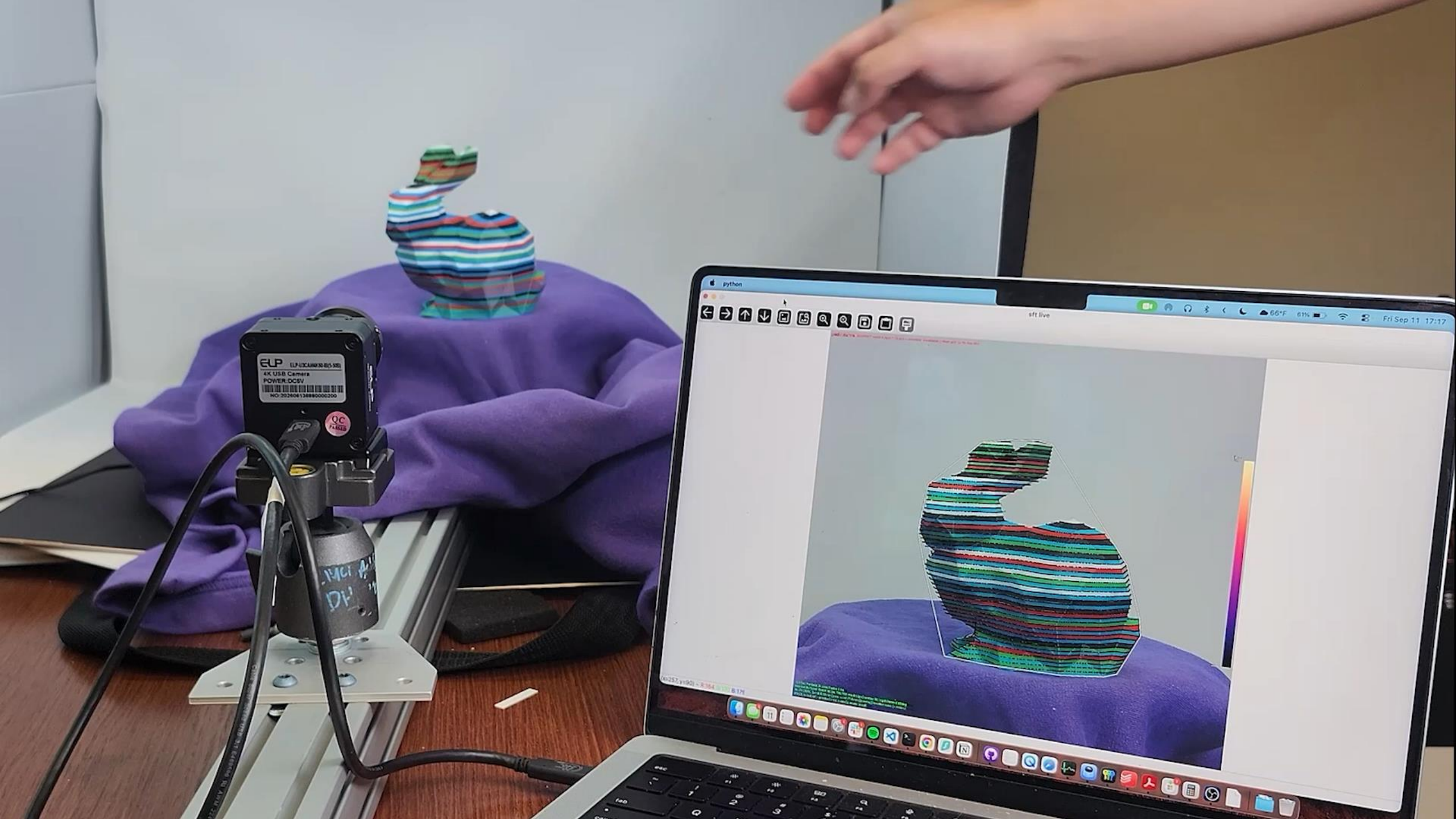
HapticWidgets

Battery-free tangible widgets



Future Work: Deformation Sensing




python
sft live
4K USB Camera
POWER:DC5V

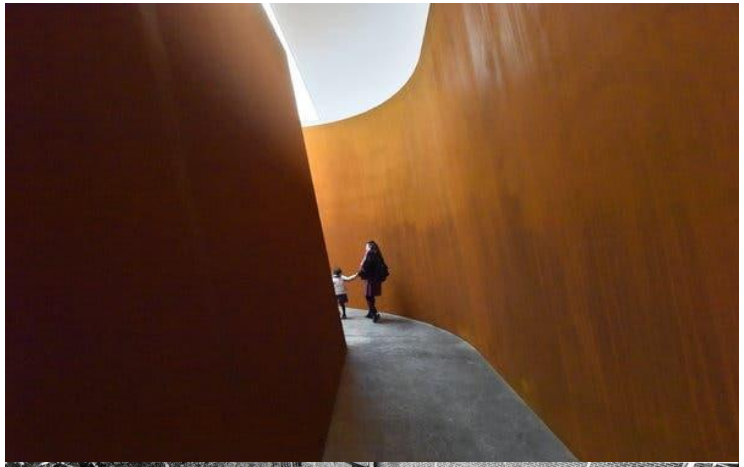
Richard Serra's *Verb List* (1967)

to roll
to crease
to fold
to store
to bend
to shorten
to twist
to dapple
to crumple
to shave
to tear
to chip
to split
to cut
to sever
to drop
to remove
to simplify
to differ
to disarrange
to open
to mix
to splash
to knot
to spill
to droop
to flow

to curve
to lift
to inlay
to impress
to fire
to flood
to smear
to rotate
to swirl
to support
to hook
to suspend
to spread
to hang
to collect
of tension
of gravity
of entropy
of nature
of grouping
of layering
of felting
to grasp
to tighten
to bundle
to heap
to gather

to scatter
to arrange
to repair
to discard
to pair
to distribute
to surfeit
to compliment
to enclose
to surround
to encircle
to hole
to cover
to wrap
to dig
to tie
to bind
to weave
to join
to match
to laminate
to bond
to hinge
to mark
to expand
to dilute
to light

to modulate
to distill
of waves
of electromagnetic
of inertia
of ionization
of polarization
of refraction
of tides
of reflection
of equilibrium
of symmetry
of friction
to stretch
to bounce
to erase
to spray
to systematize
to refer
to force
of mapping
of location
of context
of time
of cabonization
to continue



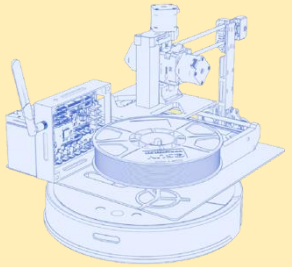


Sensing

Fabrication

Robotics

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UIST '24

NightLight
CHI '25

mm **cm** **m** **km**

Sustainability

Accessibility

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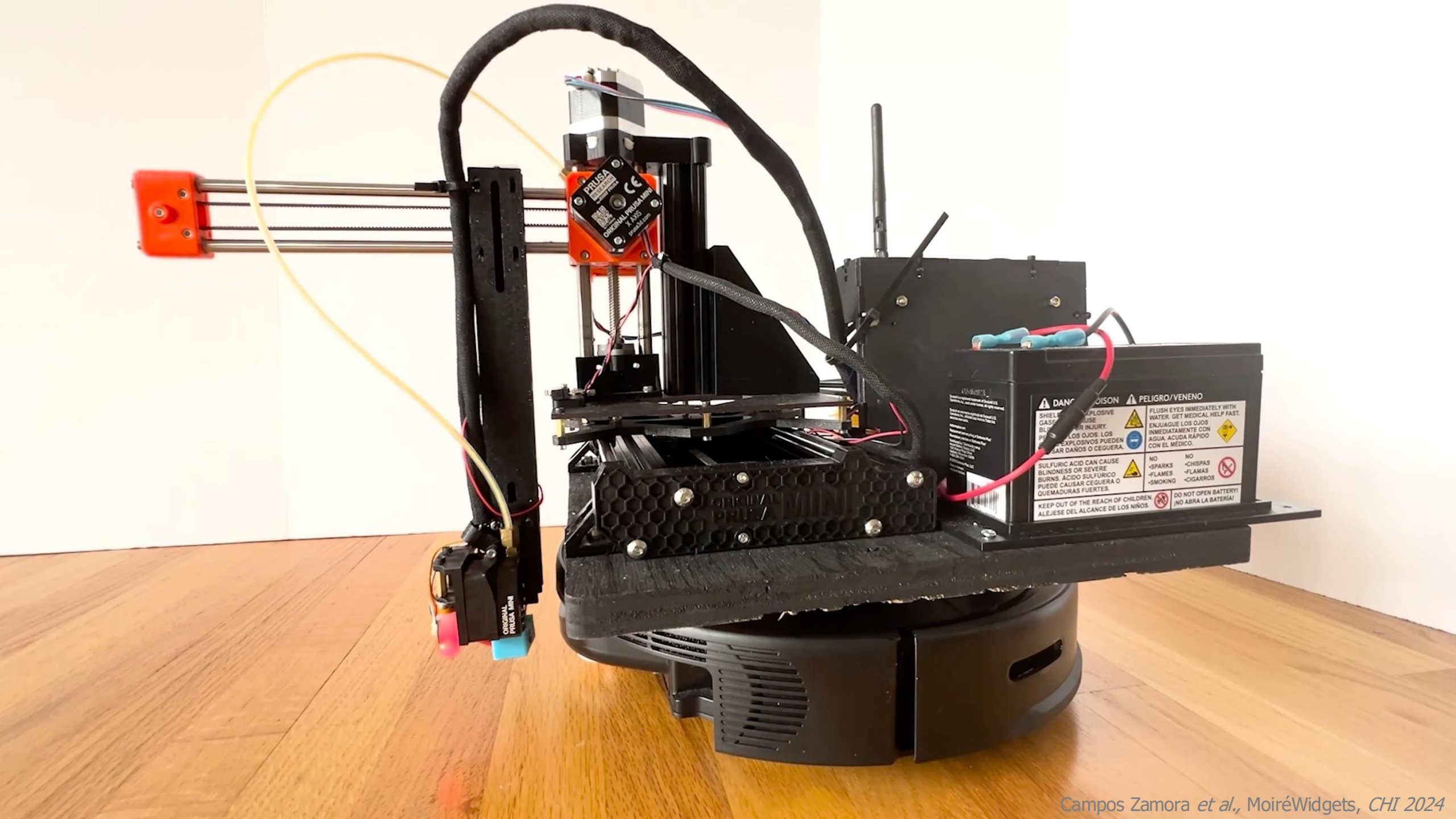
Passive Tangible Interfaces

Adaptive Environments

Improved Navigation Tools

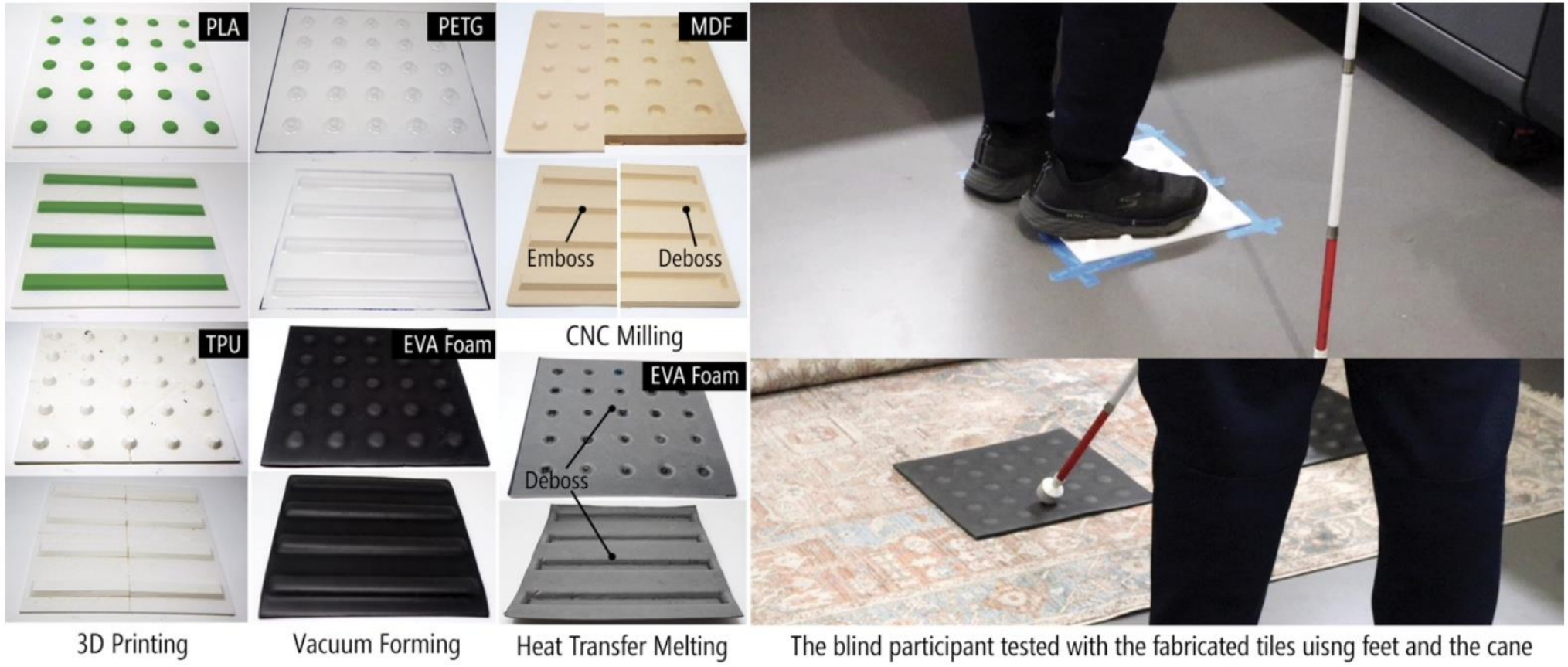

TICKET MACHINES
TRACKS 31 TO 42
THE SHOPS
GRAND CENTRAL MARKET
OPEN DAILY

How can we sense, perceive, and take action to alter and augment environments?



Campos Zamora *et al.,* MoiréWidgets, *CHI 2024*

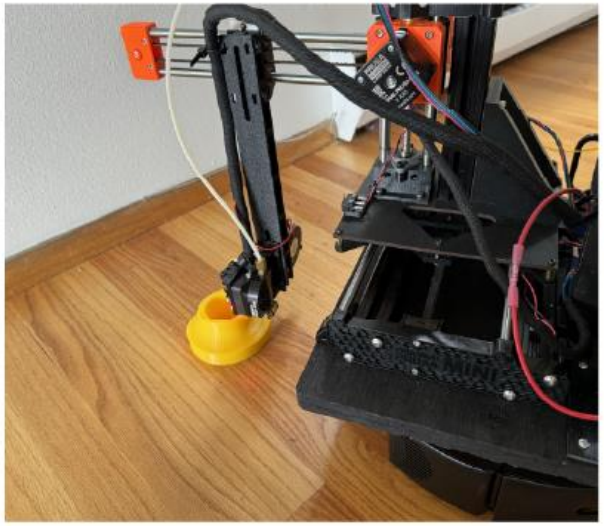
Formative Work



Campos Zamora *et al.*, Toward Fabrication of Tactile Surface Indicators, *ASSETS 2024*

Summary







- Mobiprint can navigate, map, and print in ad-hoc environments
- Convert a floorplan into a 3D printable canvas
- Enable large working area across real-world environments

Workflow

Map



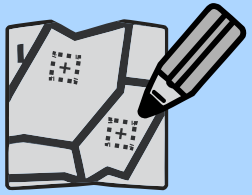
Robot completes initial scan and generates map

Select



Select from model library or upload a new design

Plan + Edit



Arrange and edit objects in the environment

Print

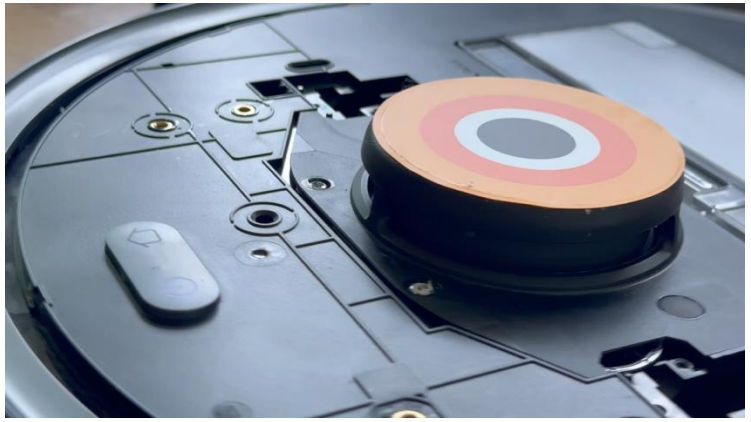


Robot navigates to target location and prints objects

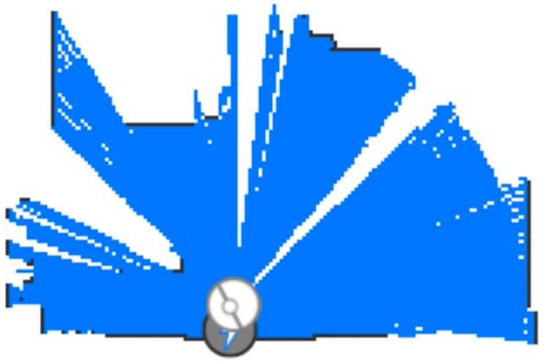
Mapping



Rooted Firmware



*Printer removed to show LiDAR





Workflow

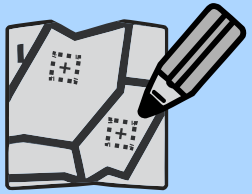
Map

Robot completes initial scan and generates map

Select

Select from model library or upload a new design

Plan + Edit



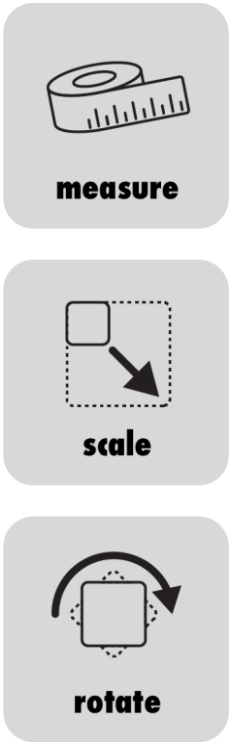
Arrange and edit objects in the environment

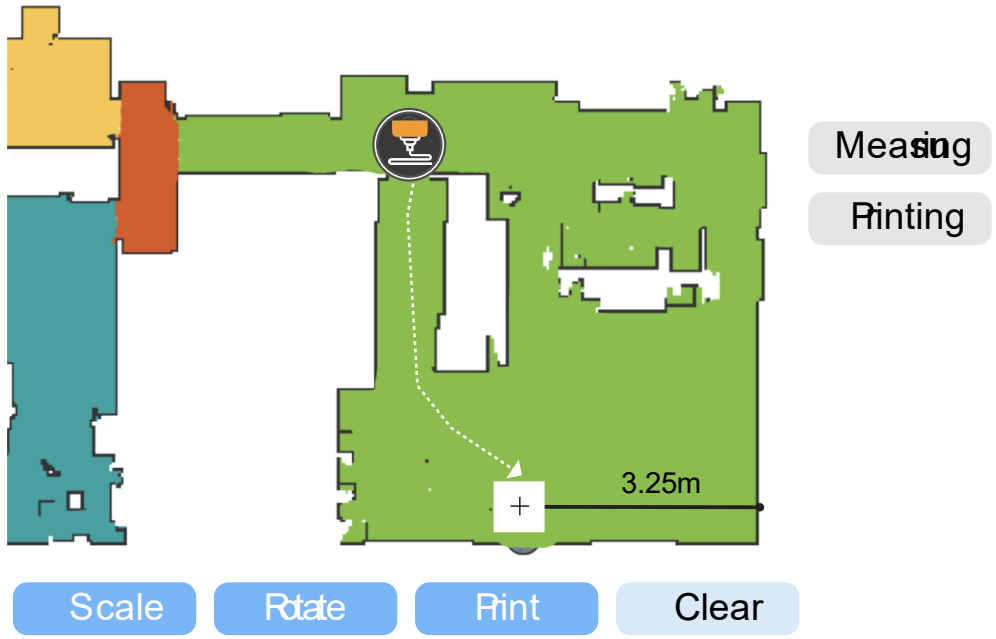
Print

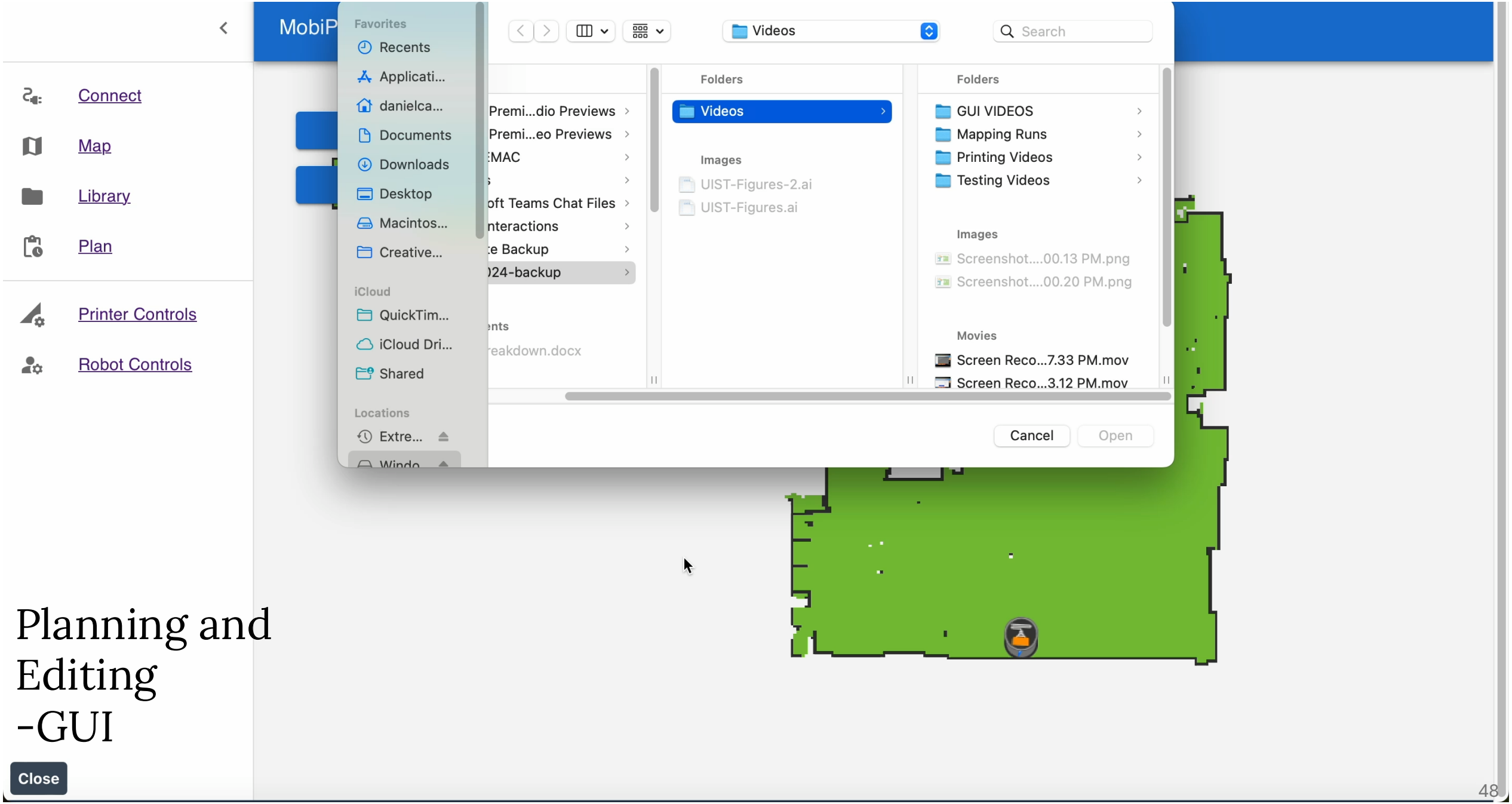
Robot navigates to target location and prints objects

Planning And Editing

Users can treat the map as a canvas to place and edit objects







Planning and Editing -GUI

Workflow

Map

Robot completes initial scan and generates map

Select

Select from model library or upload a new design

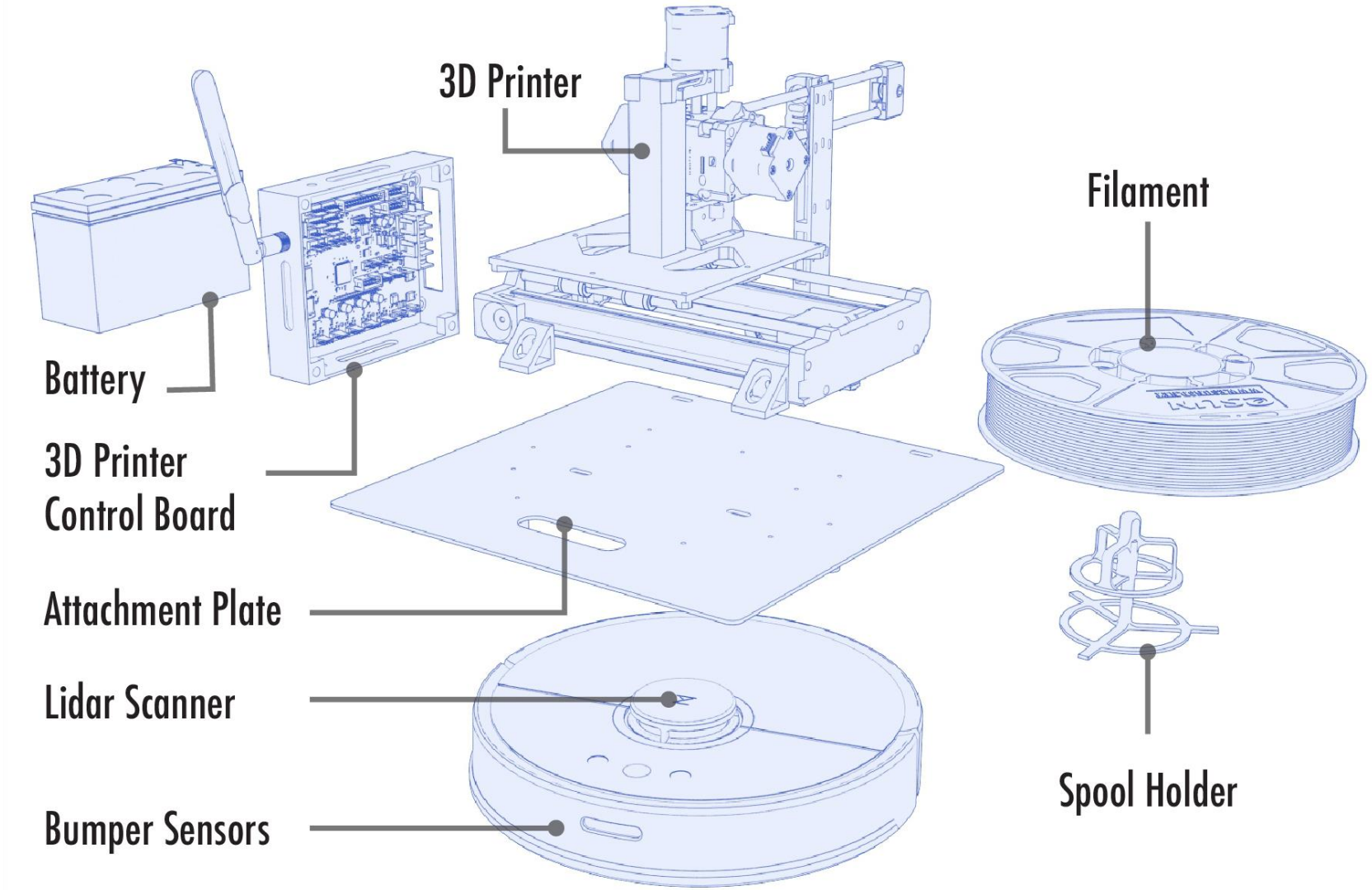
Plan + Edit

Arrange and edit objects in the environment

Print



Robot navigates to target location and prints objects



Exploded View



Assembled Views

Signage and Wayfinding



Conference Signage

Accessibility

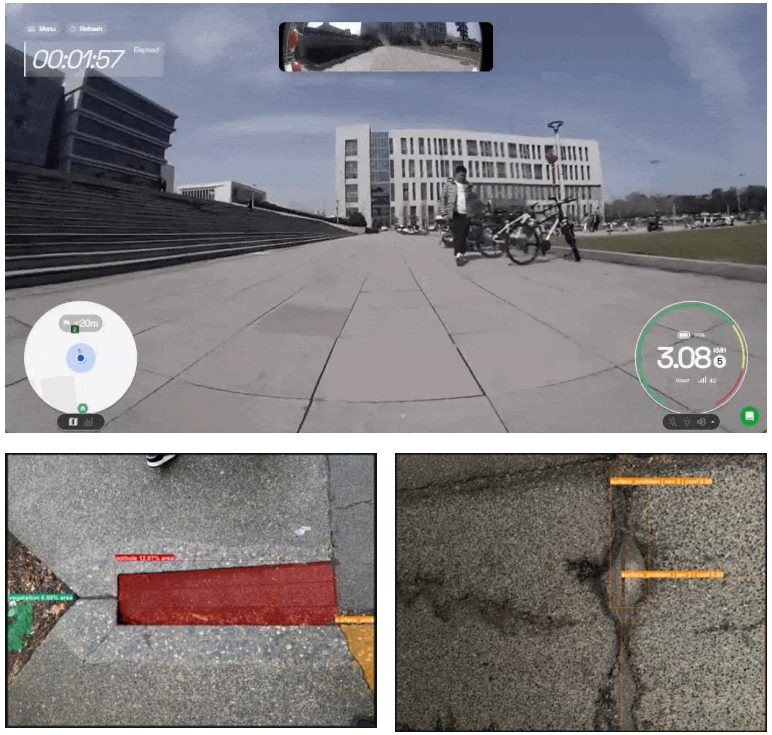


Tactile Surface Indicators

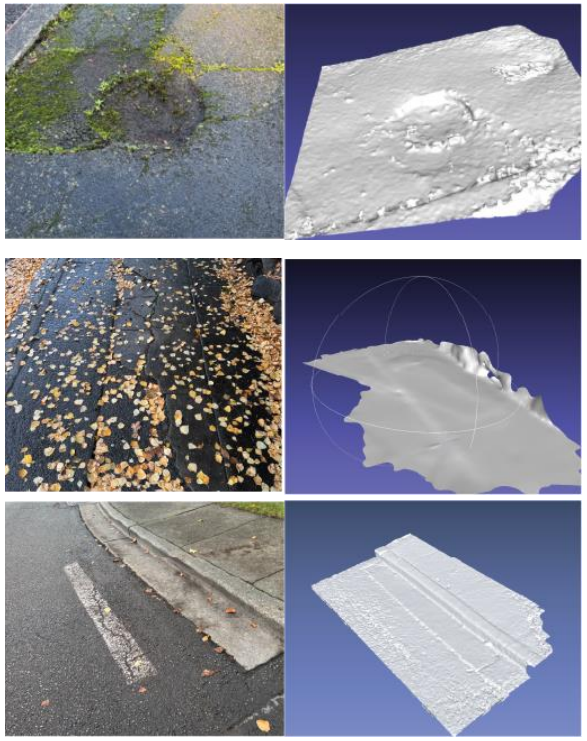


Cane Holder

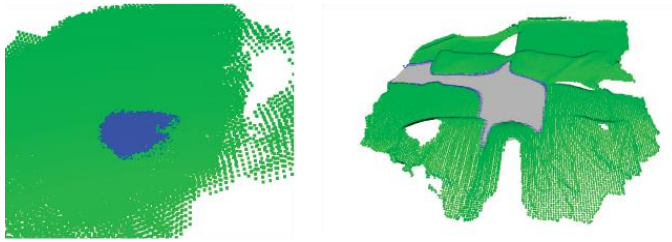
Future Work: Robotic Sidewalk Assessments



Robotics + VLMS



Defect Topology



Propose solutions





Accessibility Databases

Sensing

Fabrication

Robotics

Augmenting Embodied Interactions at Different Scales

MoiréWidgets
CHI '24

HapticWidgets
In Submission

MobiPrint
UIST '24



NightLight
CHI '25

mm cm m km

Sustainability

Accessibility

Public Health

Passive Tangible Interfaces

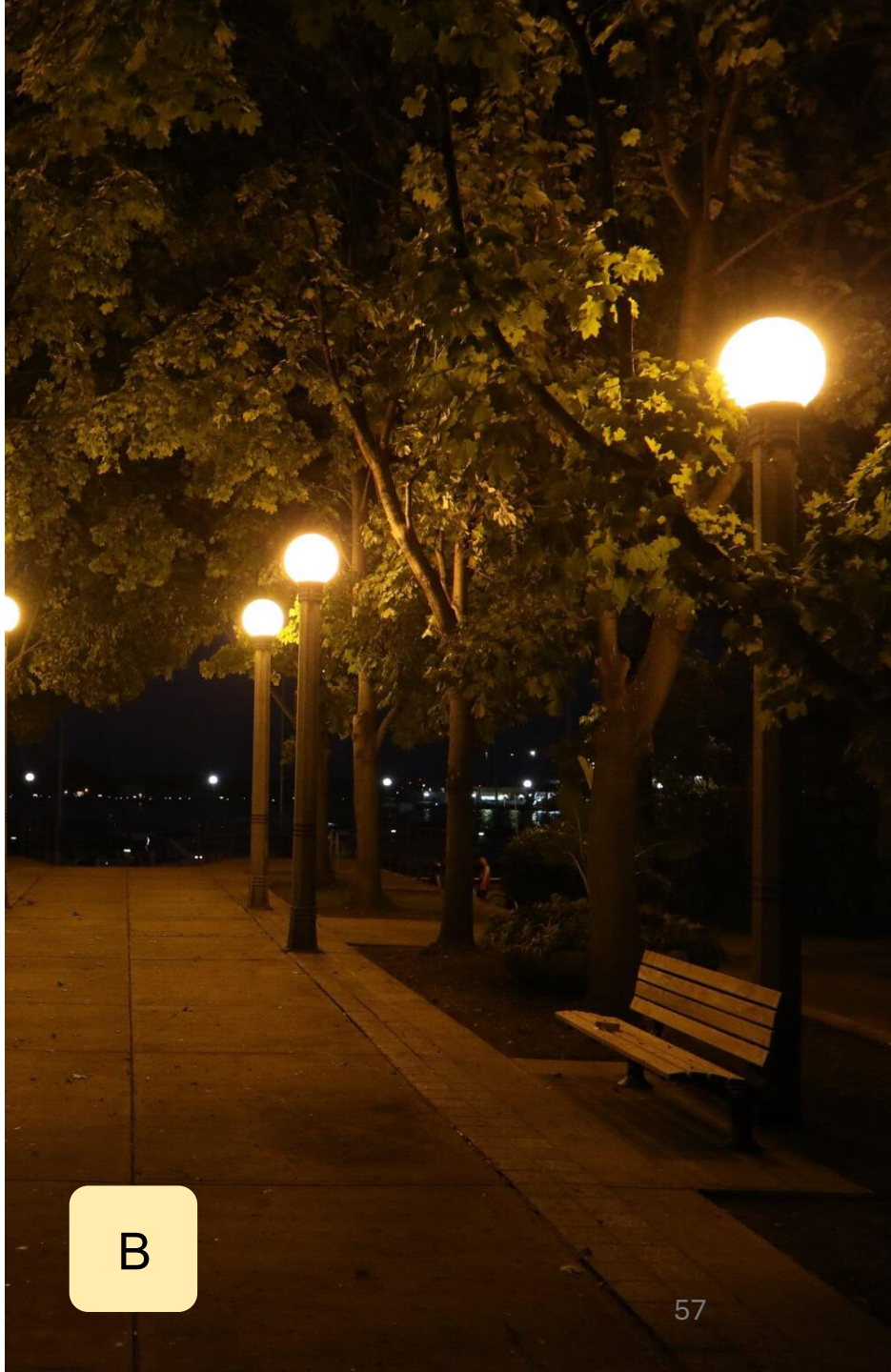
Adaptive Environments

Improved Navigation Tools

Where would you rather walk?



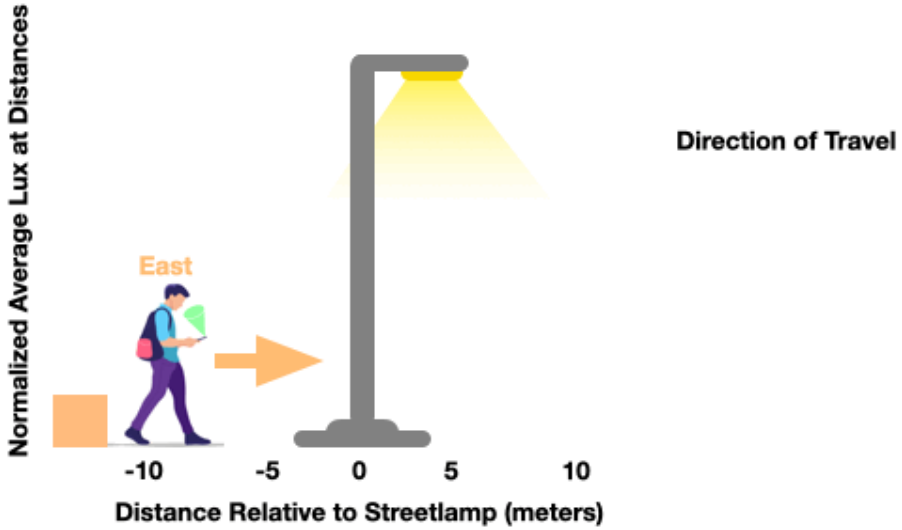
A



B



Mapping Pedestrian Lighting



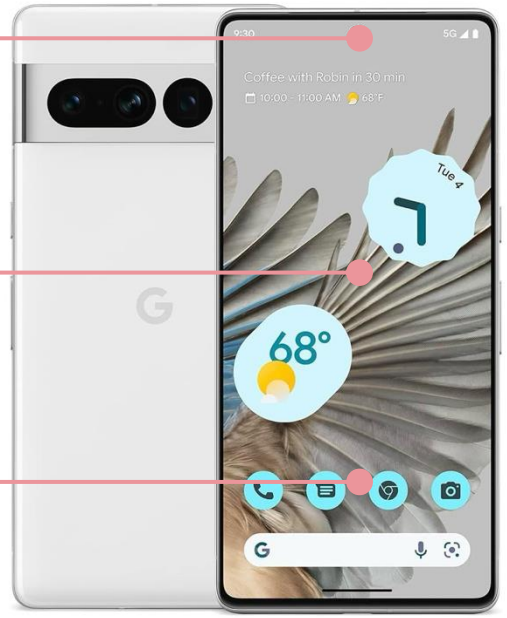
Direction of Travel



Ambient Light Sensor

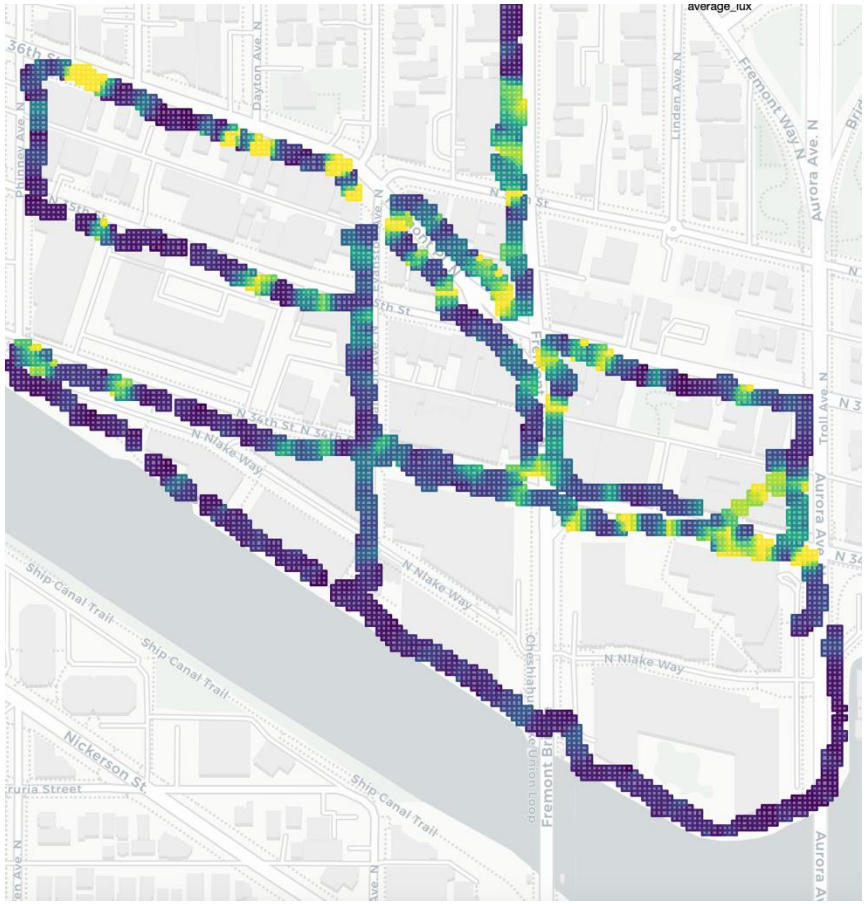
IMU

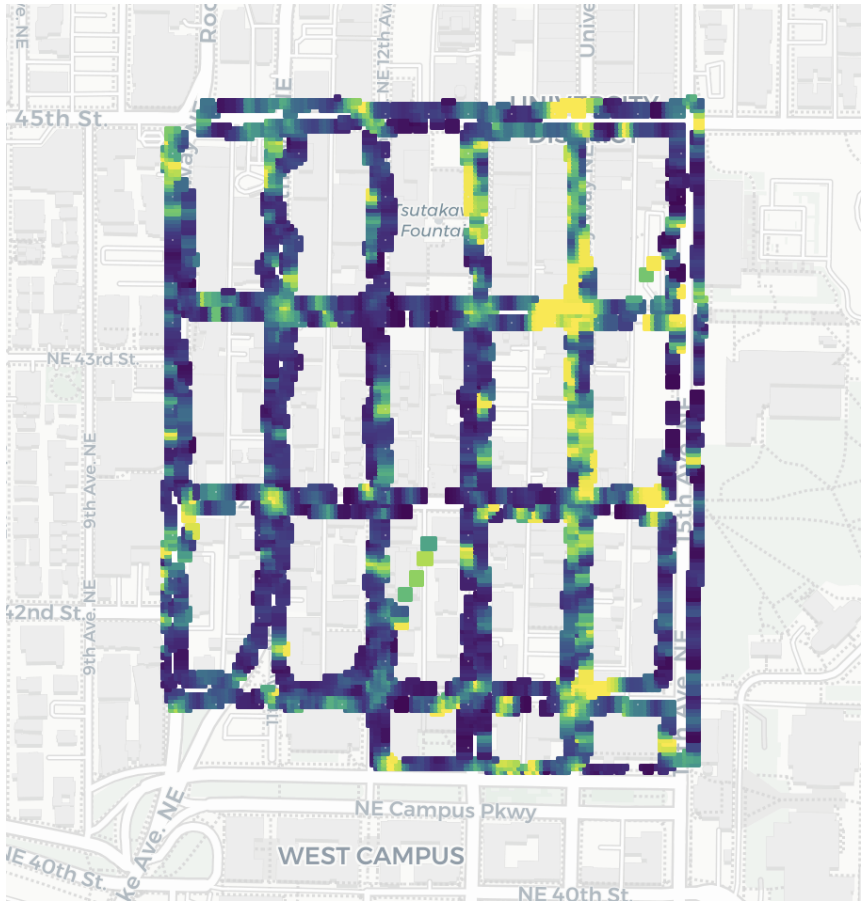
GPS

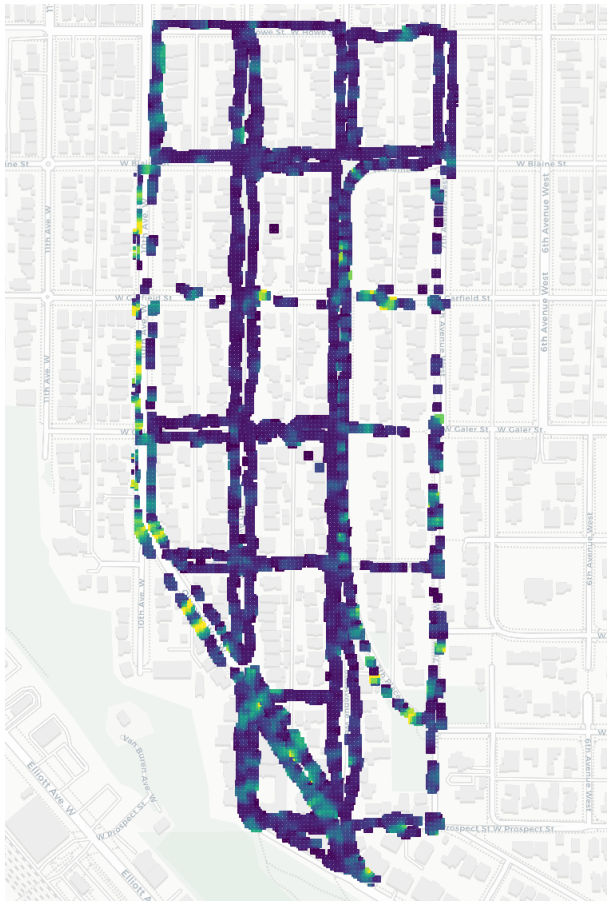


Breda* & Campos Zamora* *et al.*, NightLight, *CHI 2025*

Neighborhood Data Collection



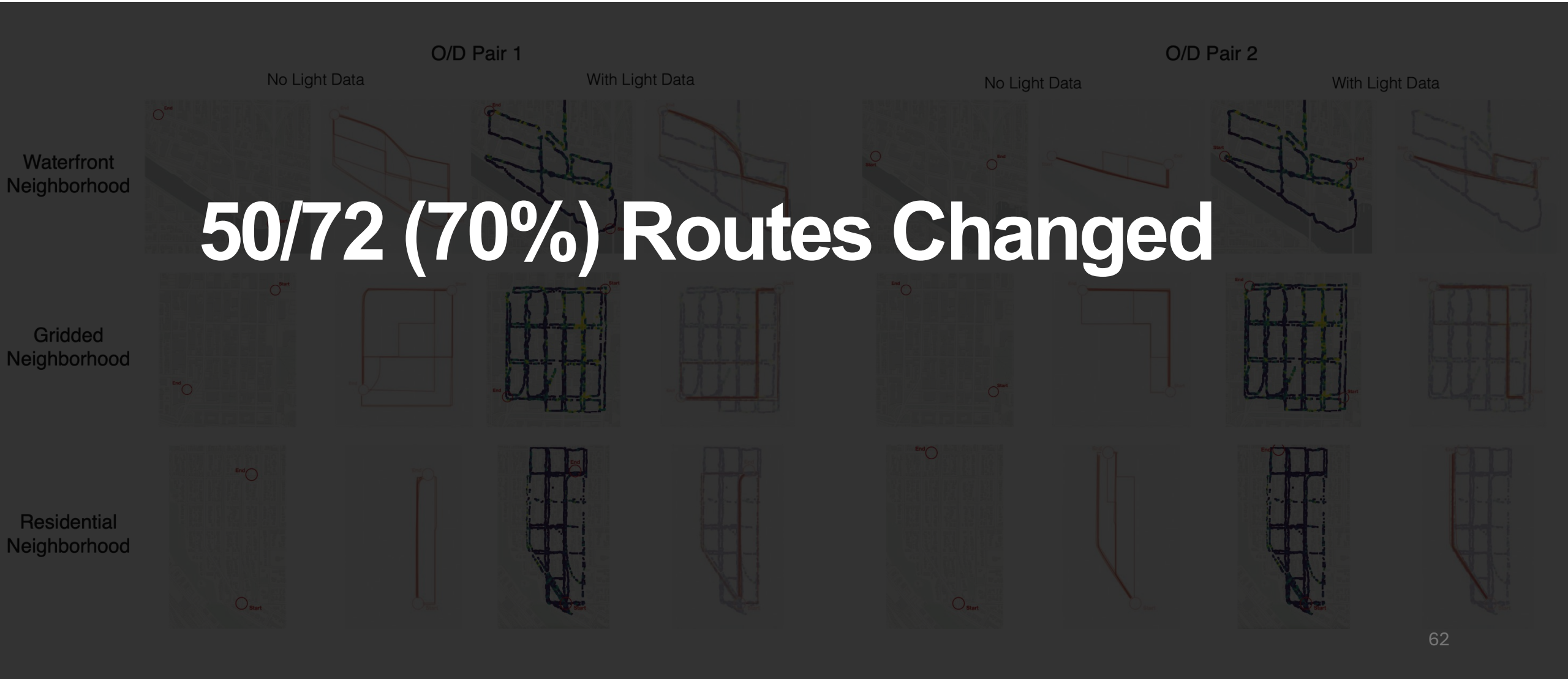




Low Light

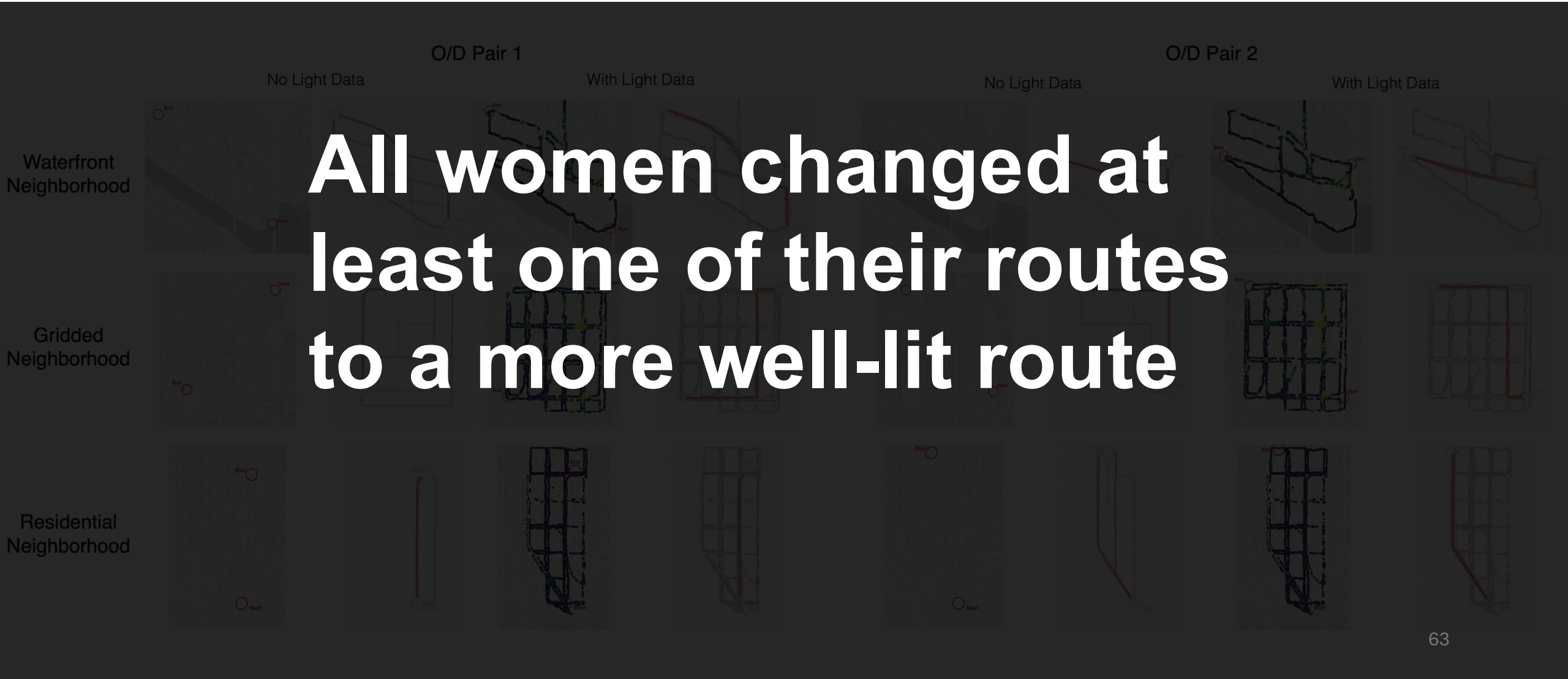
High Light

Impact of light maps on route choice



50/72 (70%) Routes Changed

Impact of light maps on route choice



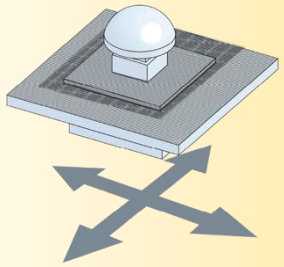
All women changed at least one of their routes to a more well-lit route

Sensing

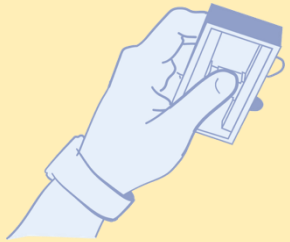
Fabrication

Robotics

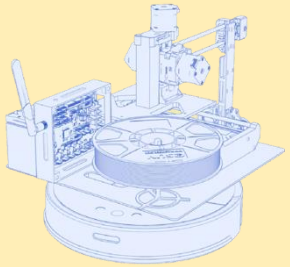
Augmenting Embodied Interactions at Different Scales



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HapticWidgets
In Submission



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NightLight
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mm cm m km

Sustainability

Accessibility

Public Health

Passive Tangible Interfaces

Adaptive Environments

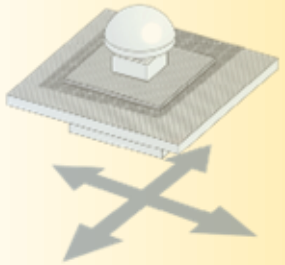
Improved Navigation Tools

Future Thrusts

Augmenting Embodied Interactions at Different Scales



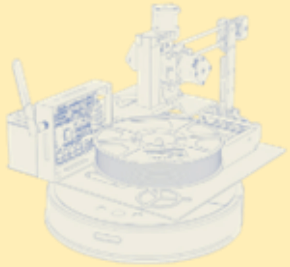
Bio-Materials



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HapticWidgets
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mm cm m km

Sustainability

Accessibility

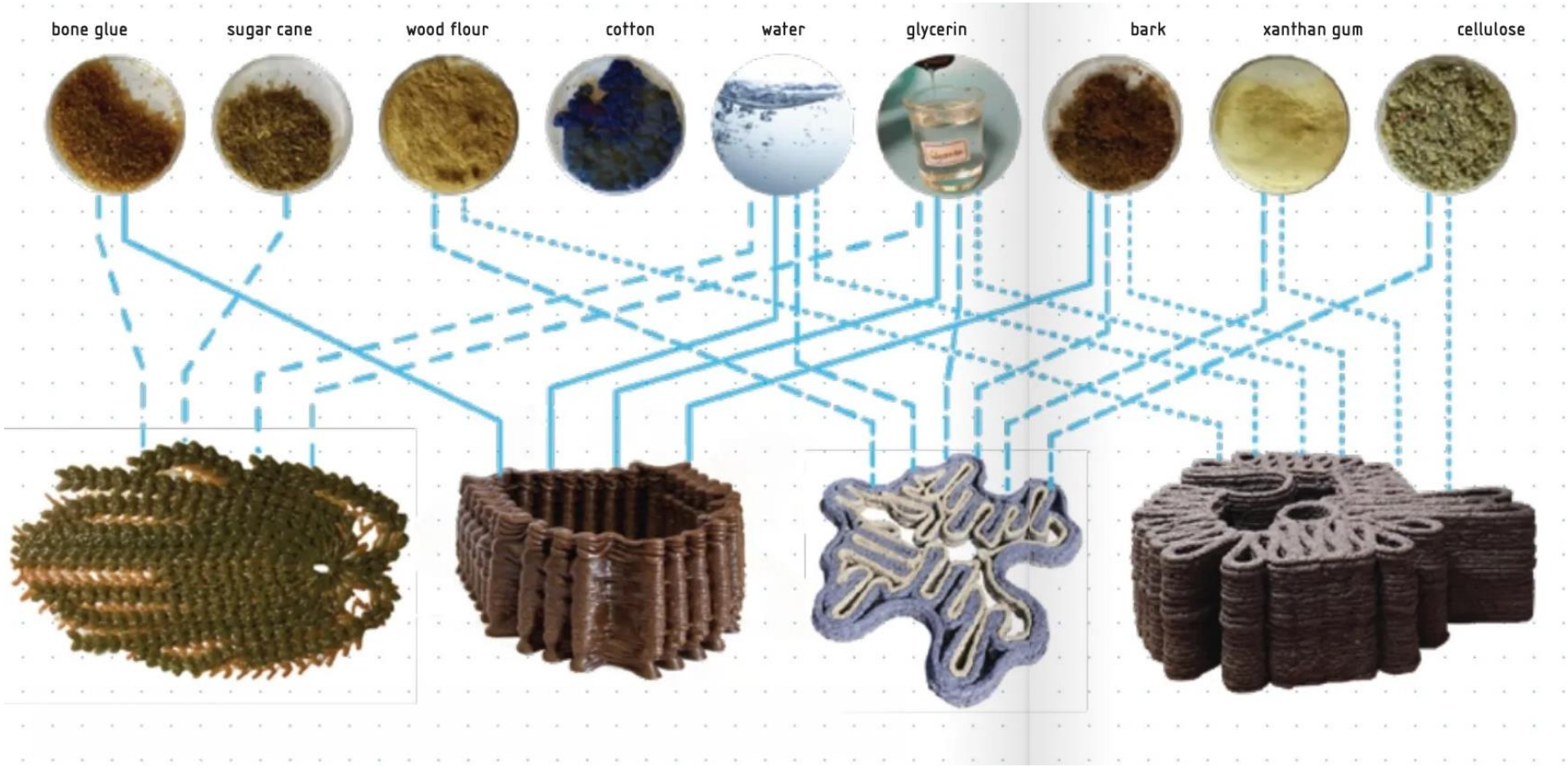
Public Health

Passive Tangible Interfaces

Adaptive Environments

Improved Navigation Tools

Future Thrusts: Biomaterials



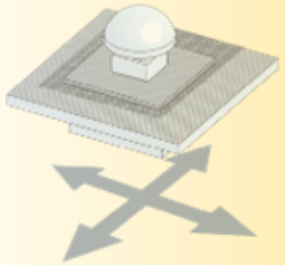
Credit: CITA Copenhagen

Future Thrusts

Augmenting Embodied Interactions at Different Scales



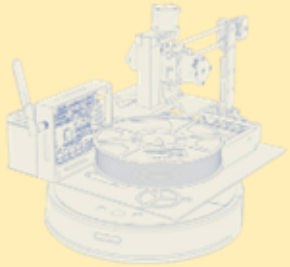
Bio-Materials



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CHI '24



HapticWidgets
In Submission



MobiPrint
UIST '24



NightLight
CHI '25

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Public Health

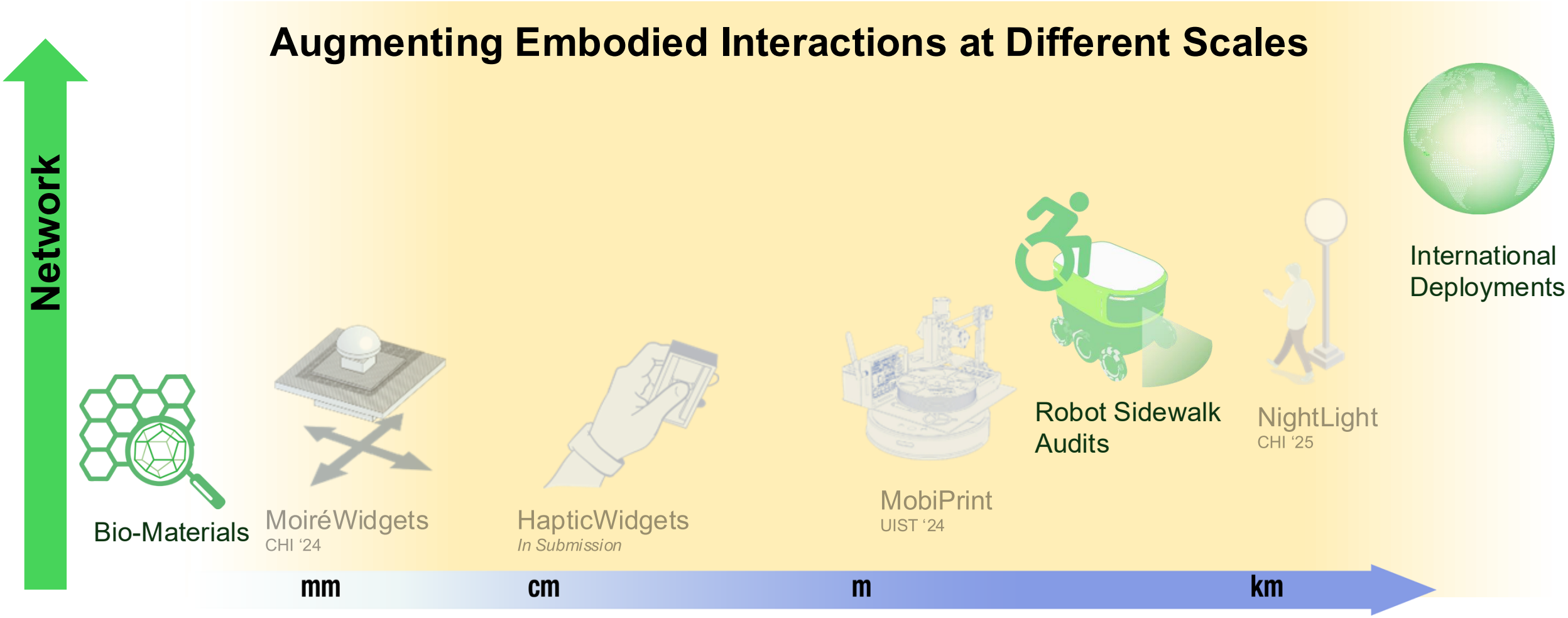
Passive Tangible Interfaces

Adaptive Environments

Improved Navigation Tools

Future Thrusts

Augmenting Embodied Interactions at Different Scales



Thank you!

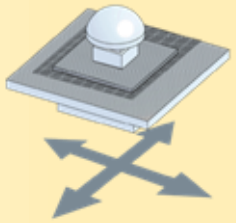
Daniel Campos Zamora
danielcz@cs.uw.edu
danielcz.xyz



Augmenting Embodied Interactions at Different Scales



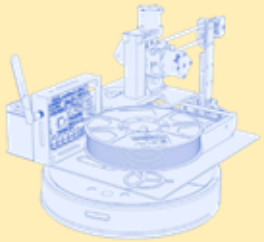
Bio-Materials



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HapticWidgets
In Submission



MobiPrint
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Robot-Sidewalk Assessments



NightLight
CHI '25



International Deployments

mm — cm — m — km

Sustainability — **Accessibility** — **Public Health**

Passive Tangible Interfaces | **Adaptive Environments** | **Improved Navigation Tools**