



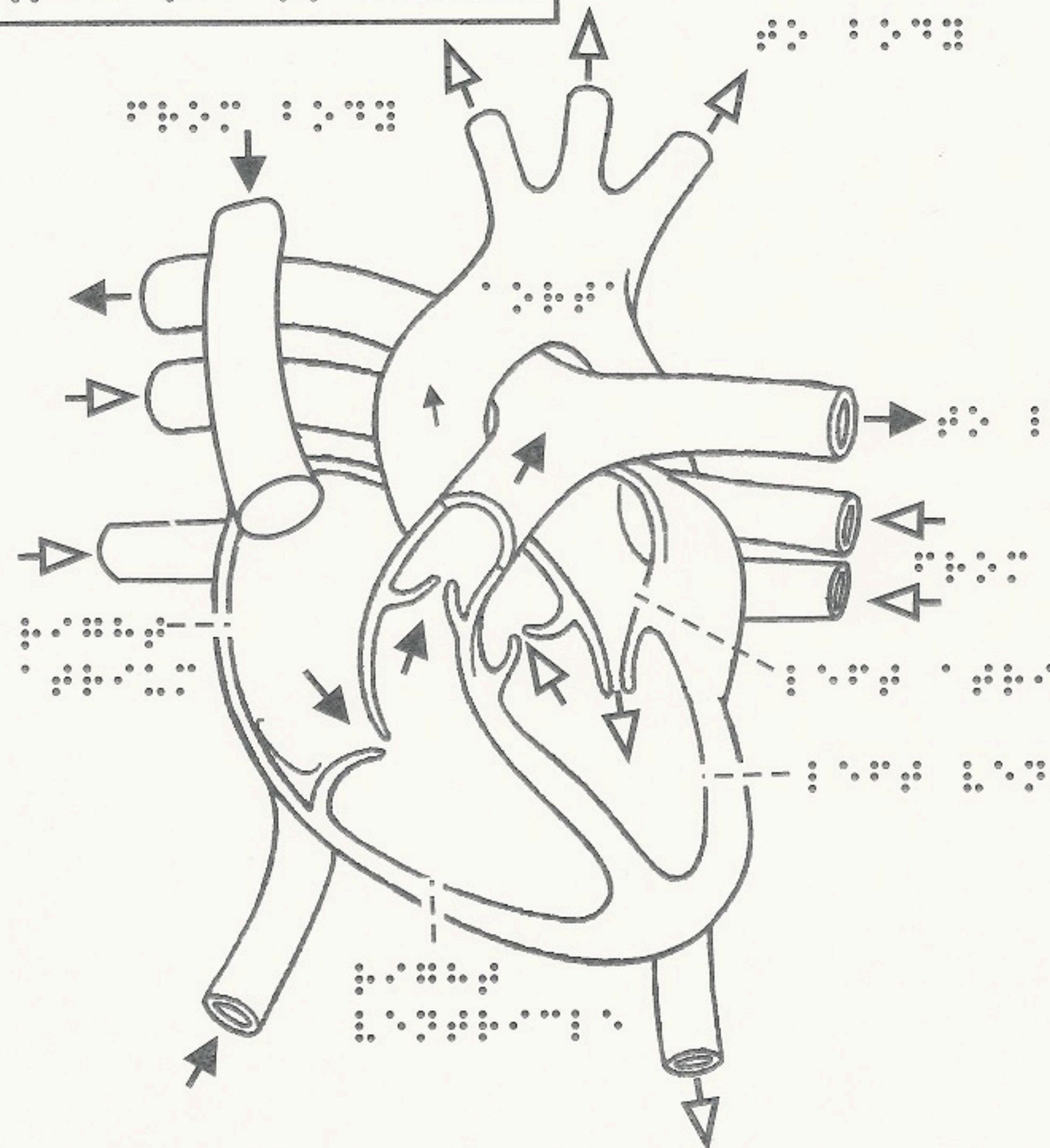
University of Colorado
Boulder



FluxMarker: Enhancing Tactile Graphics with Dynamic Tactile Markers

Ryo Suzuki, Abigale Stangl, Mark D. Gross, Tom Yeh

..::.. ..::.. :::: The Heart

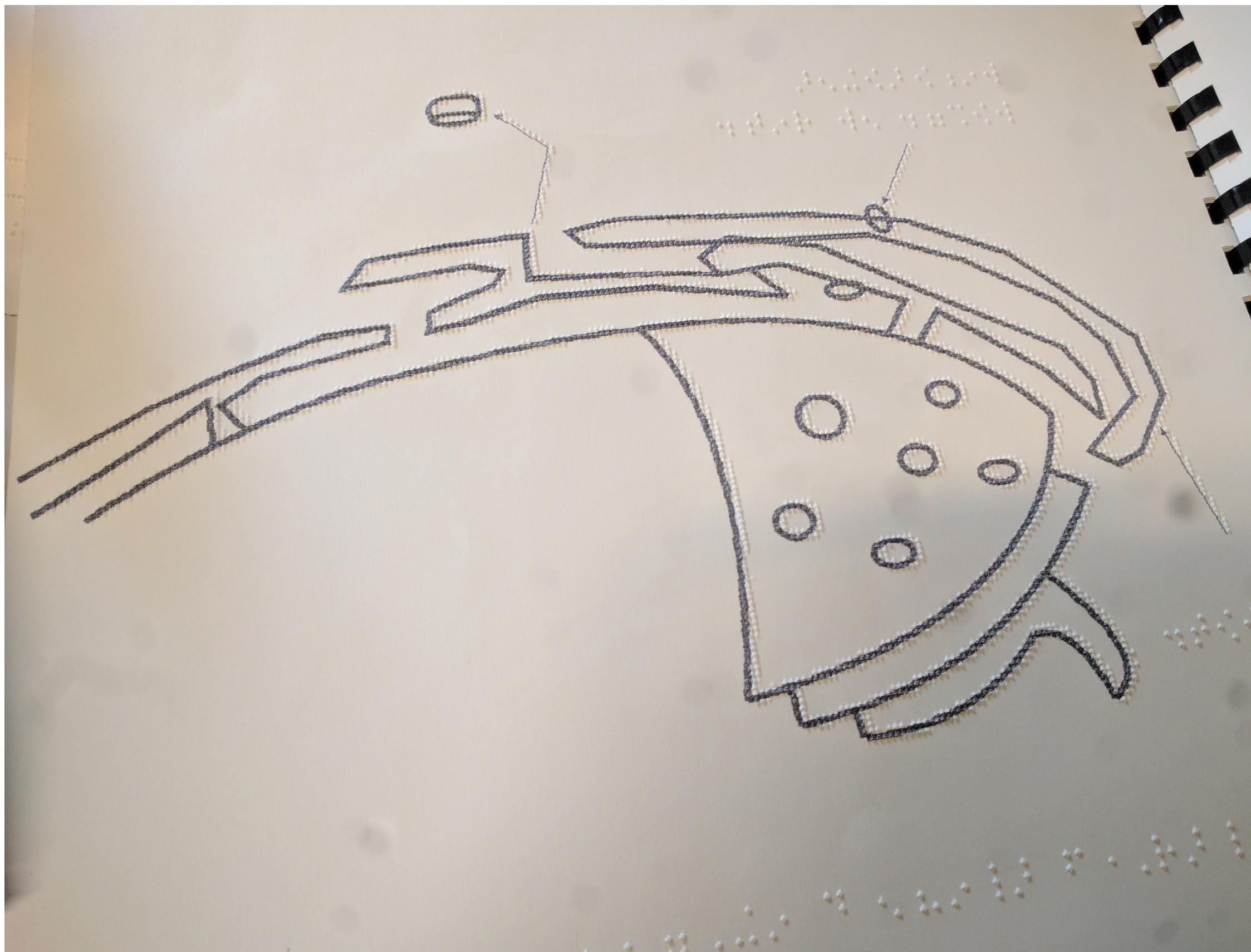


Classifying polygons

The image consists of a 4x4 grid of 16 squares. Each square contains a different geometric pattern or arrangement of dots. The patterns are as follows:

- Top-left square: A 4x4 grid of dots.
- Top-middle square: A 4x4 grid of dots with a central cross of four dots.
- Top-right square: A 4x4 grid of dots with a central cross of four dots.
- Middle-left square: A 4x4 grid of dots with a central cross of four dots.
- Middle-middle square: A 4x4 grid of dots with a central cross of four dots.
- Middle-right square: A 4x4 grid of dots with a central cross of four dots.
- Bottom-left square: A 4x4 grid of dots with a central cross of four dots.
- Bottom-middle square: A 4x4 grid of dots with a central cross of four dots.
- Bottom-right square: A 4x4 grid of dots with a central cross of four dots.
- Second column, top to bottom: Three separate groups of four dots each, forming a vertical column.
- Third column, top to bottom: Three separate groups of four dots each, forming a vertical column.
- Fourth column, top to bottom: Three separate groups of four dots each, forming a vertical column.

Traditional Tactile Graphics



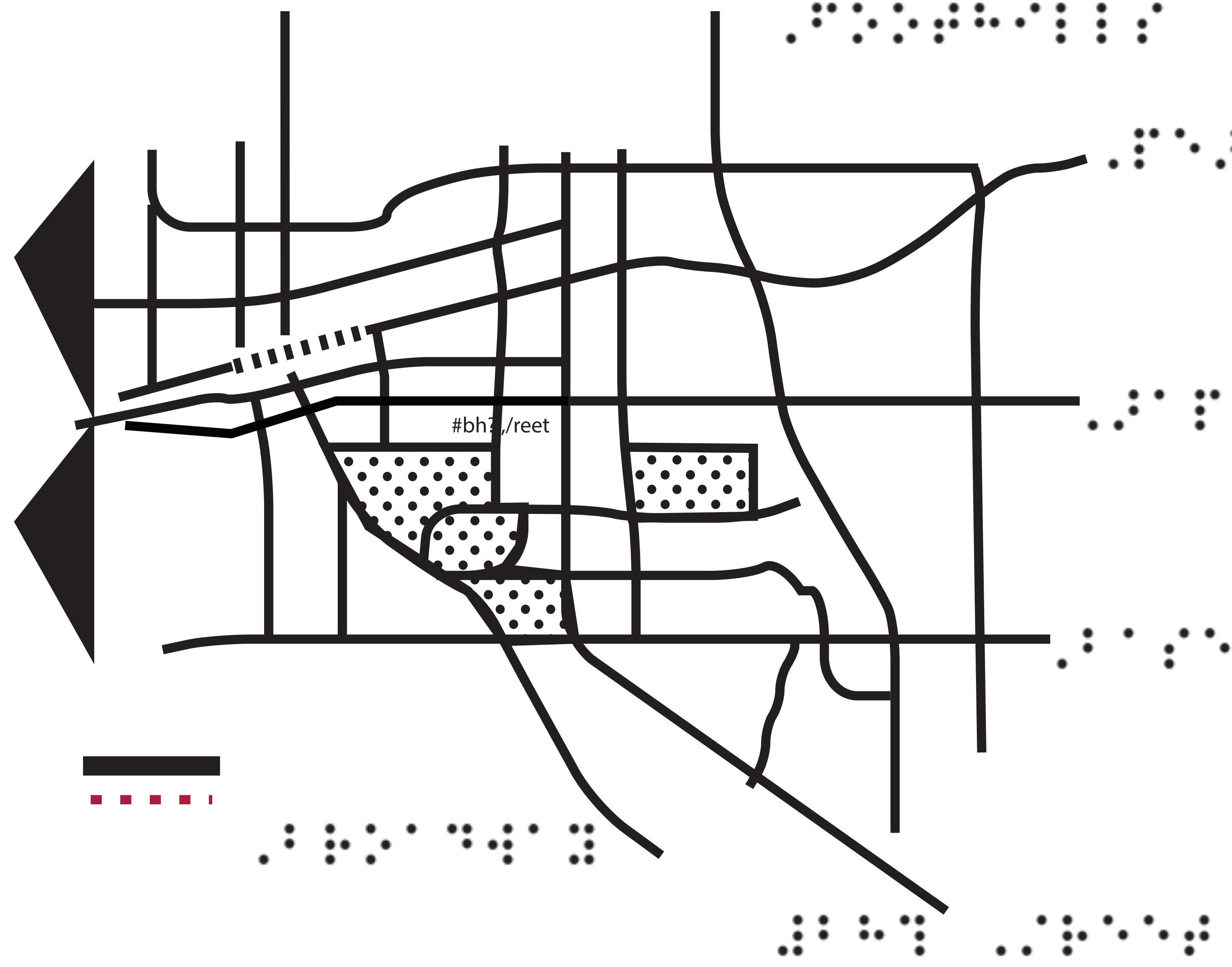
Refreshable Braille Display



static and **not interactive**

expensive and **small**

static and not interactive







Show me the nearest coffee shops?

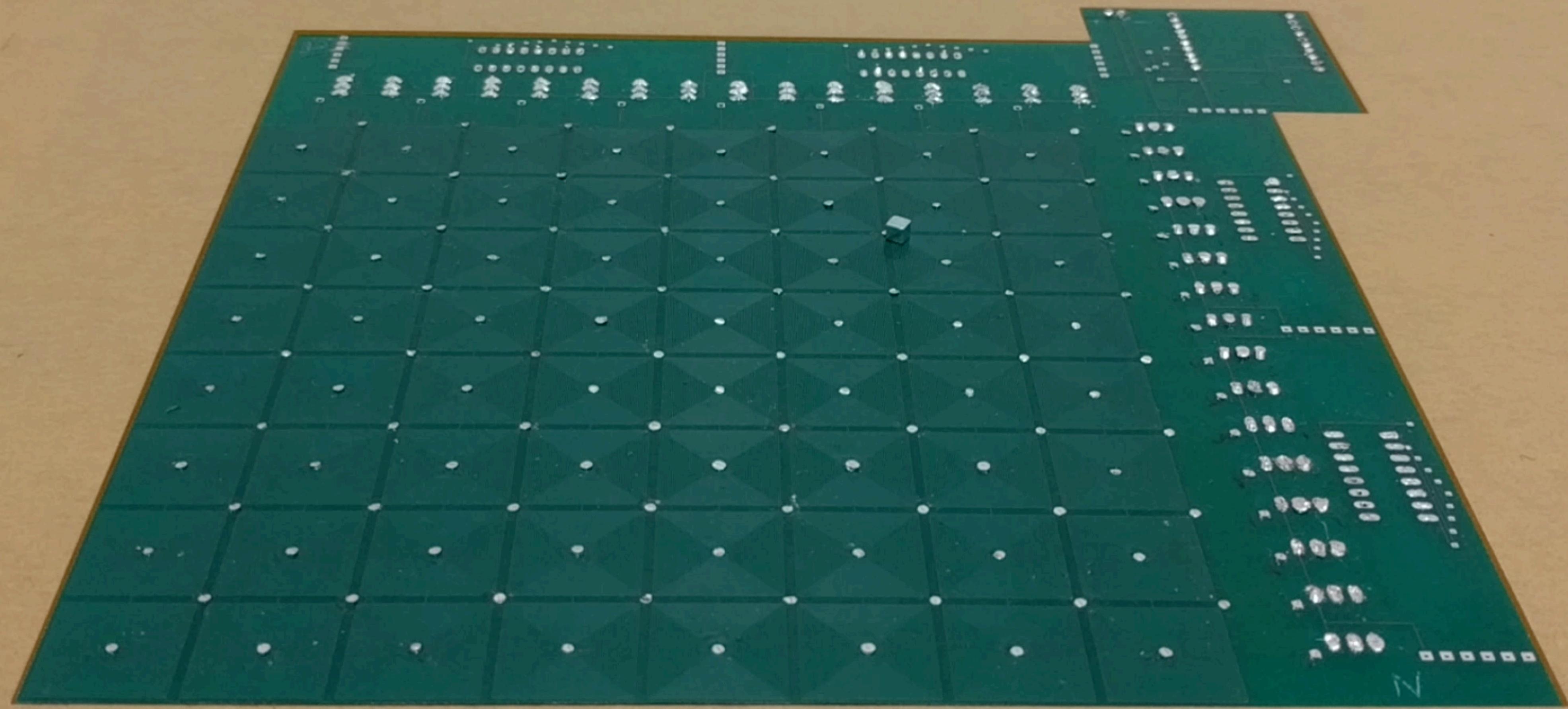
**Dynamic
Tactile Markers**

=

**Interactive
Tactile Output**

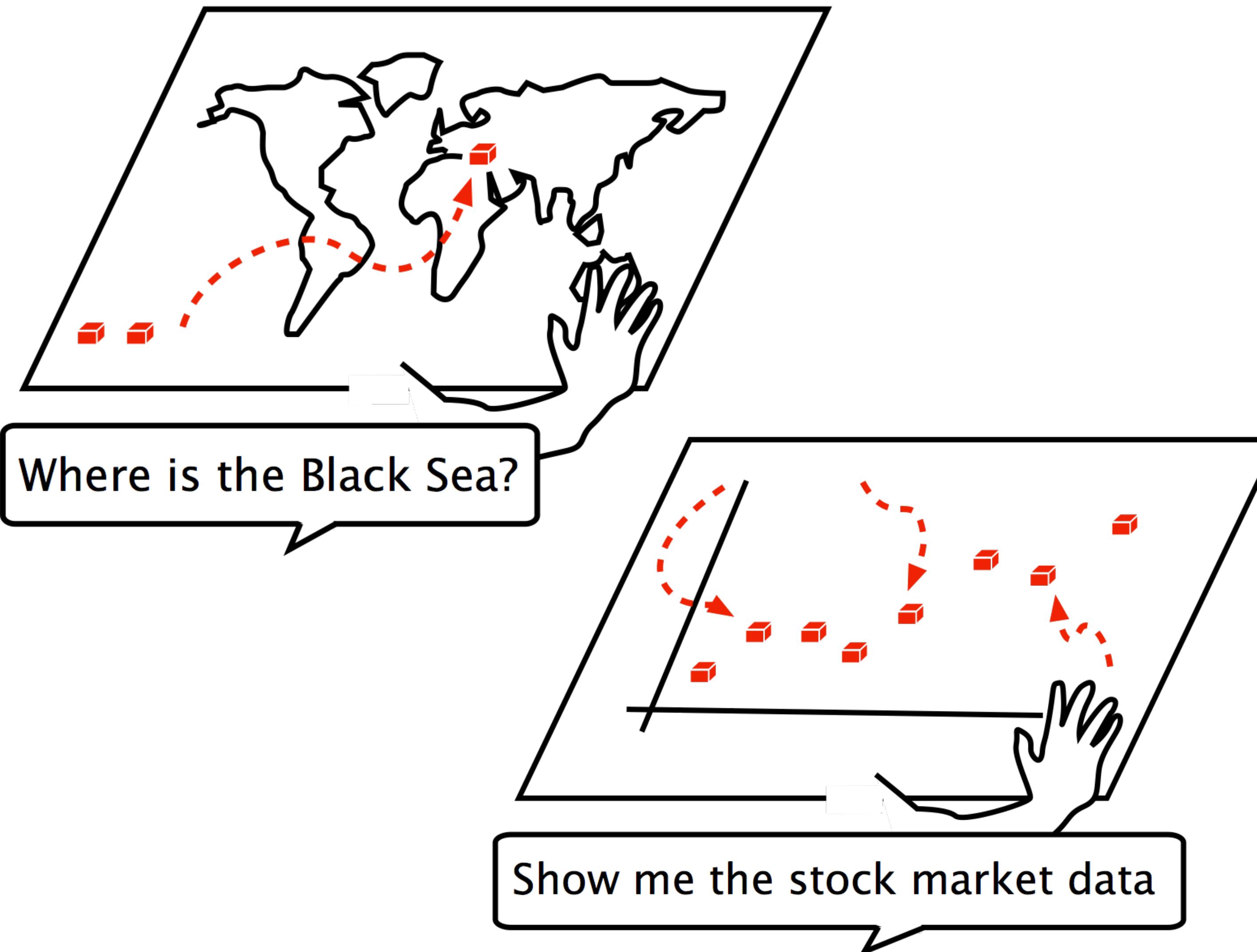


low-cost + scalable

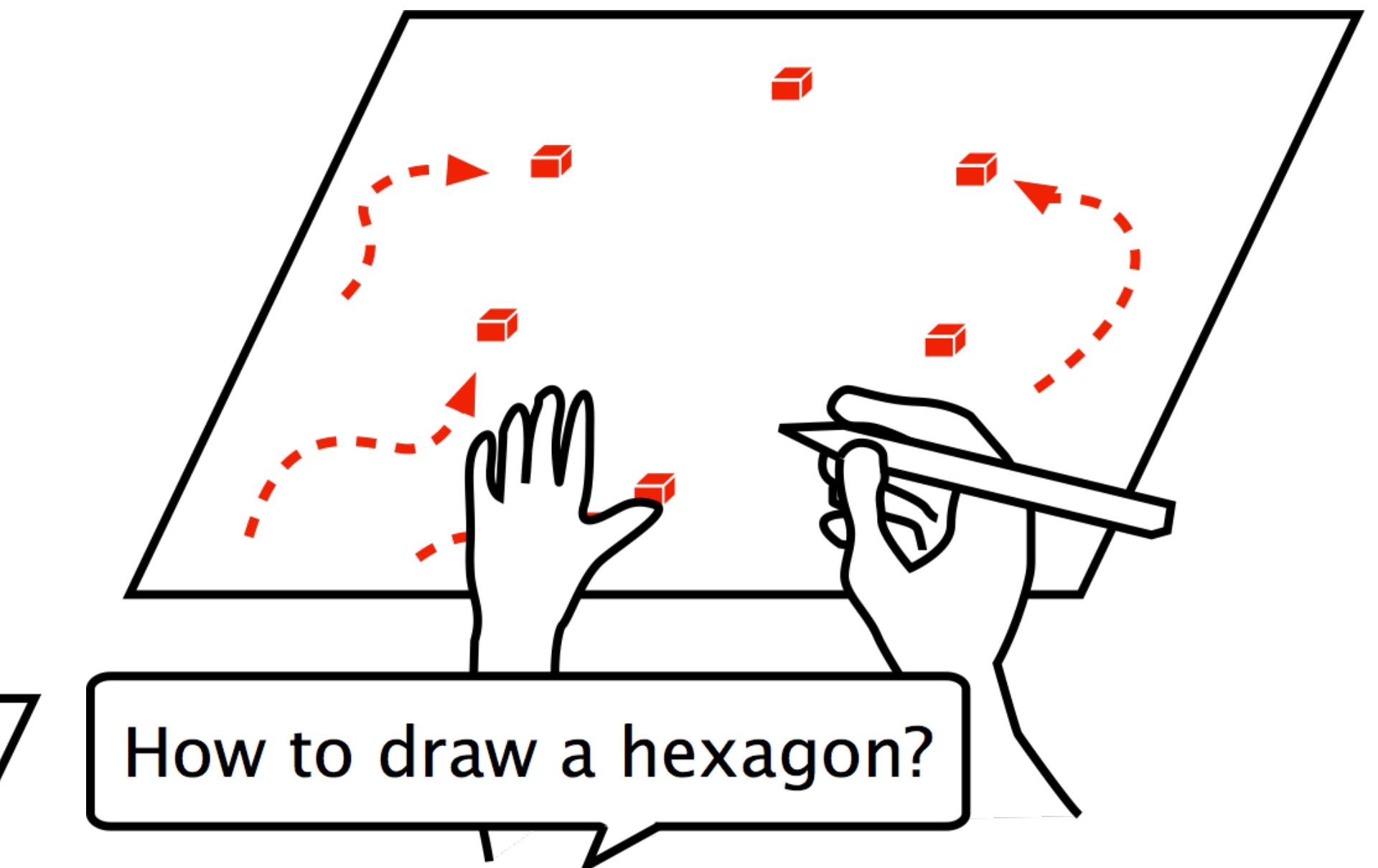


(15cm x 15cm: \$40, 100cm x 100cm: \$200)

1. Spatial Navigation



2. Data Analysis



3. Guided Drawing

1. Summary

2. Motivation

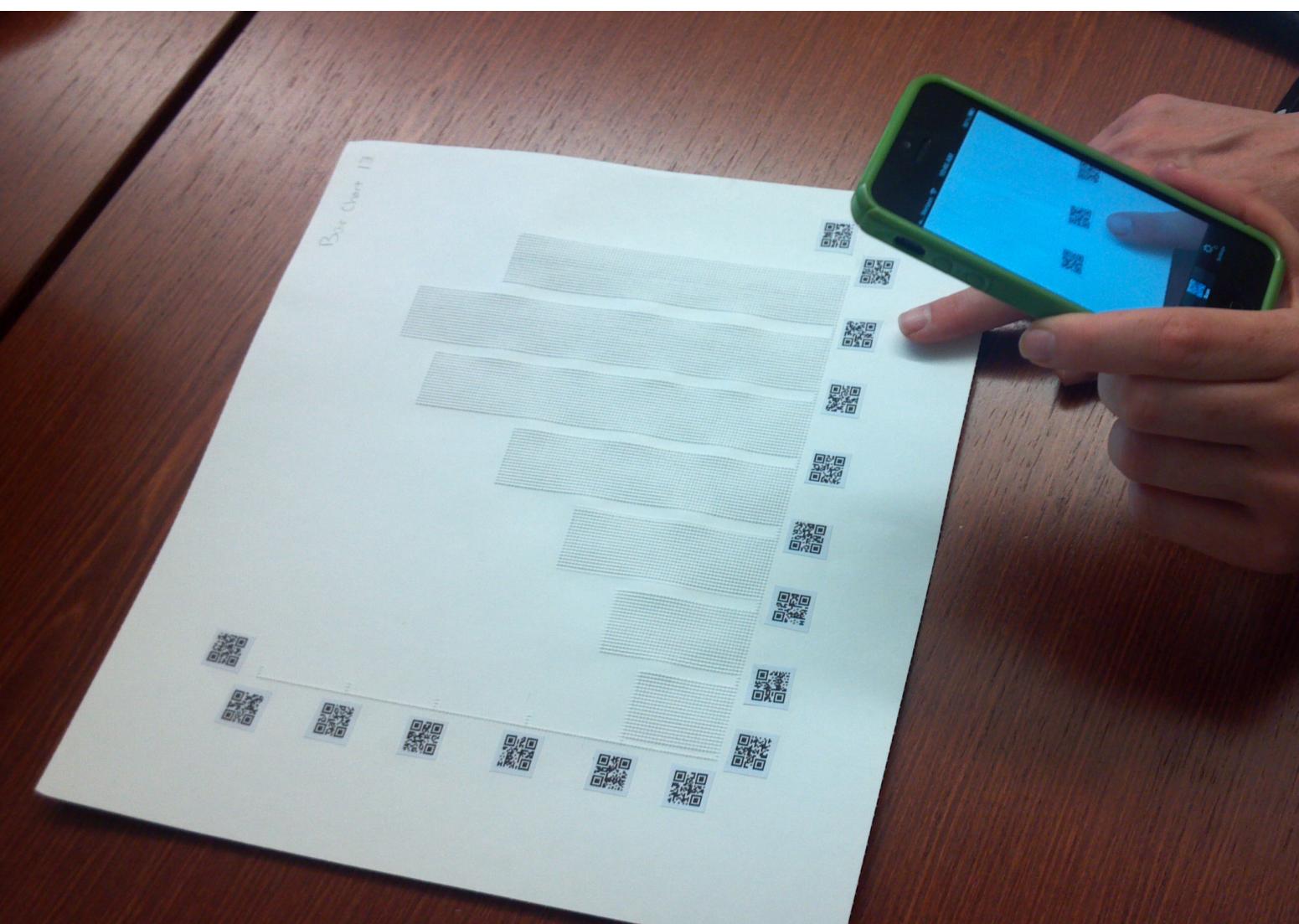
3. Design and Implementation

4. User Study

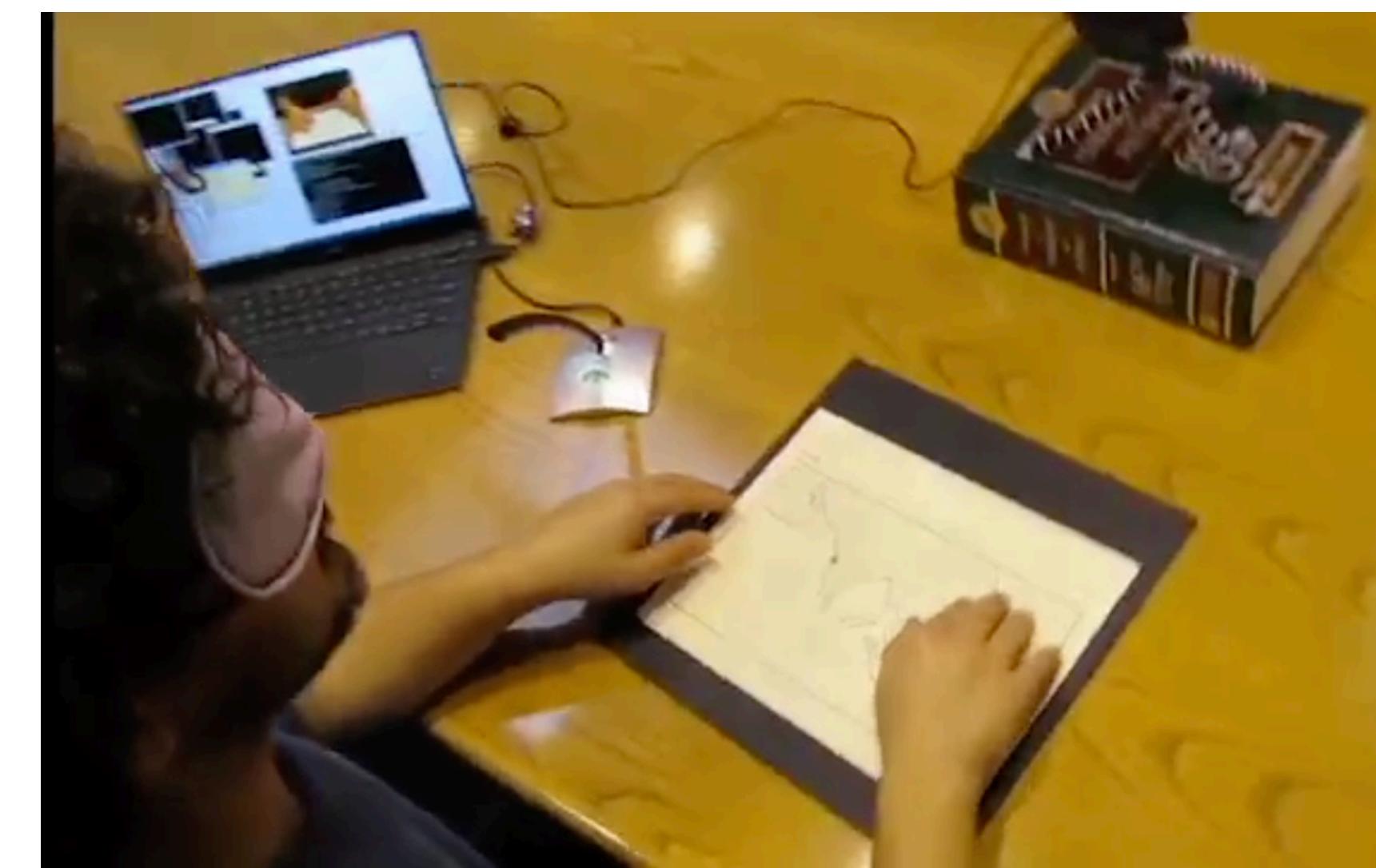
Interactive Tactile Graphics



Talking Tactile Tablet [2001]



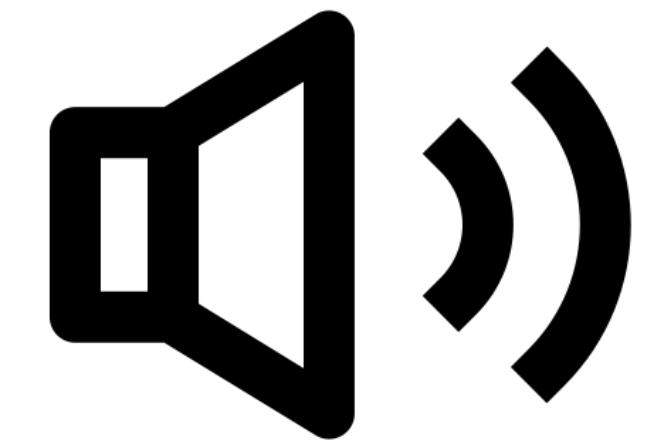
Baker et al. [ASSETS 2014]



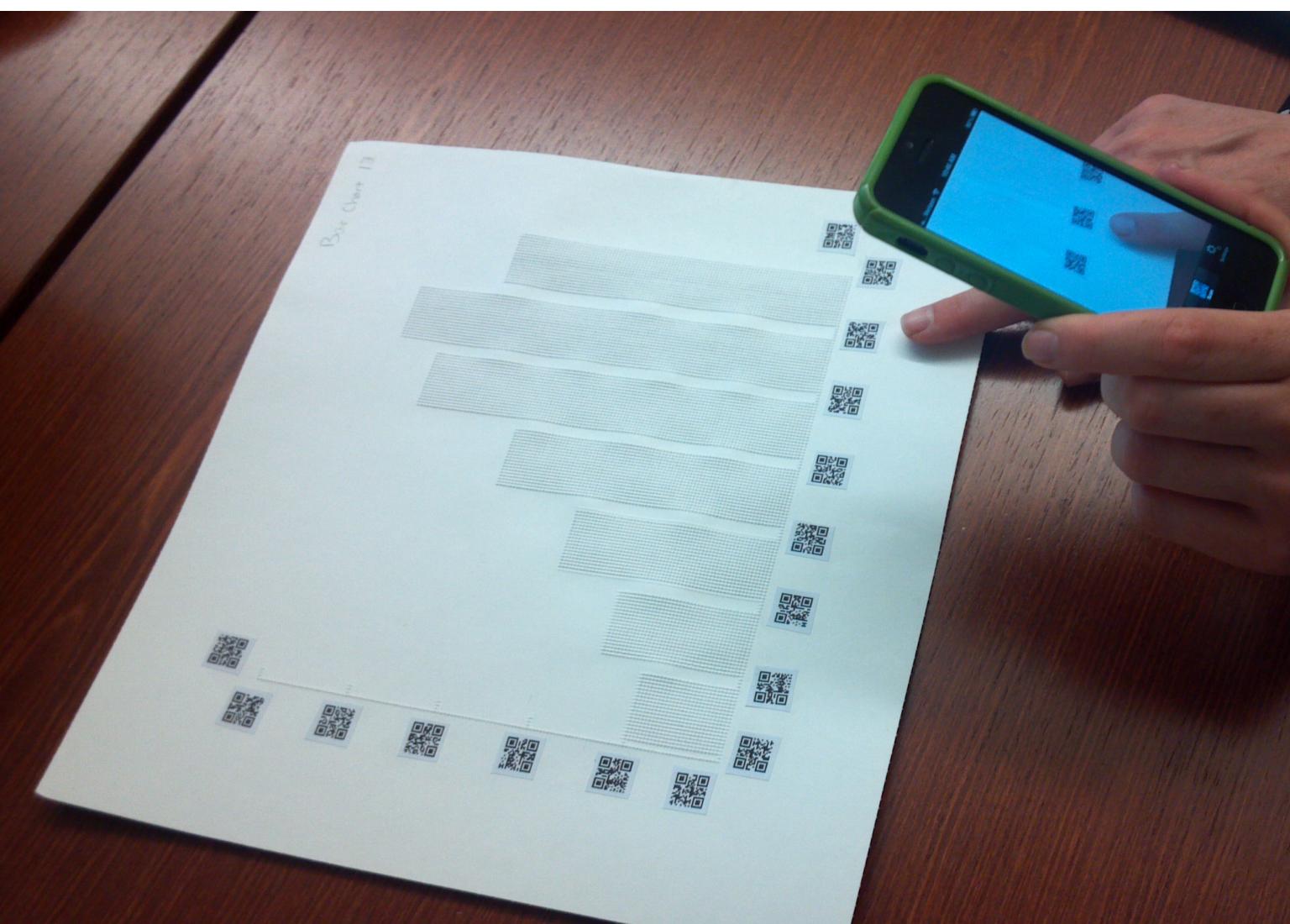
Fusco et al. [ASSETS 2015]

Audio Output

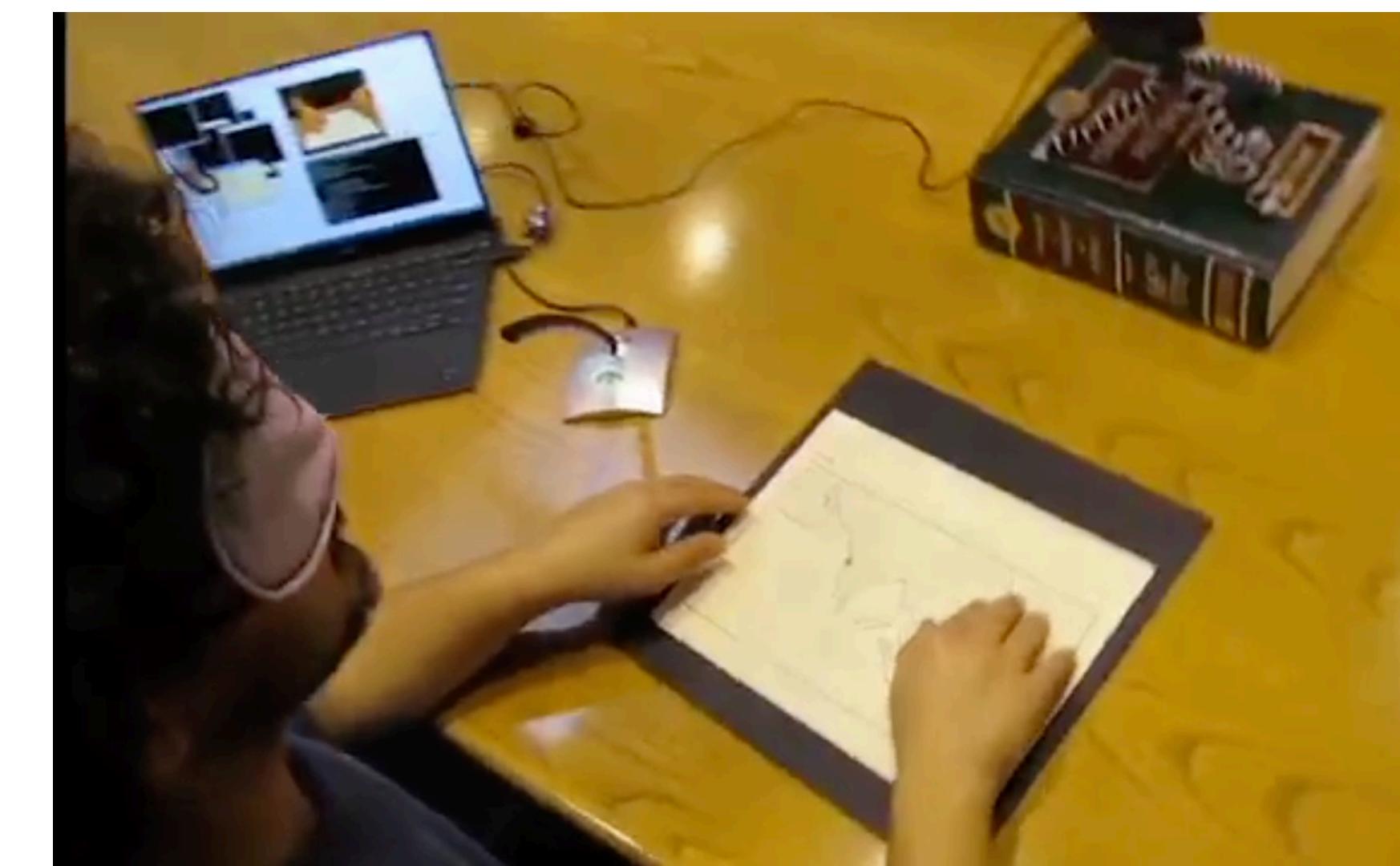
Interactive Tactile Graphics =



Talking Tactile Tablet [2001]



Baker et al. [ASSETS 2014]

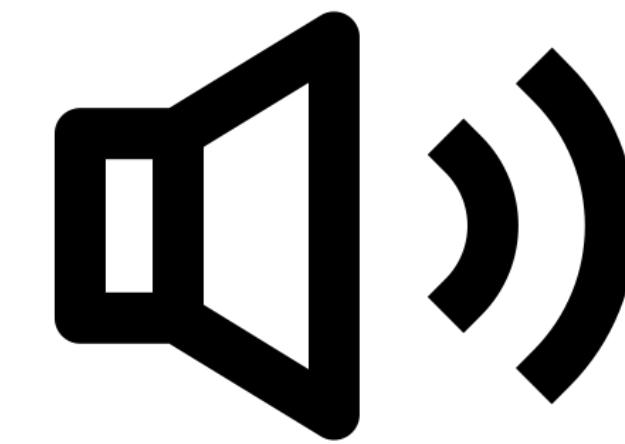


Fusco et al. [ASSETS 2015]

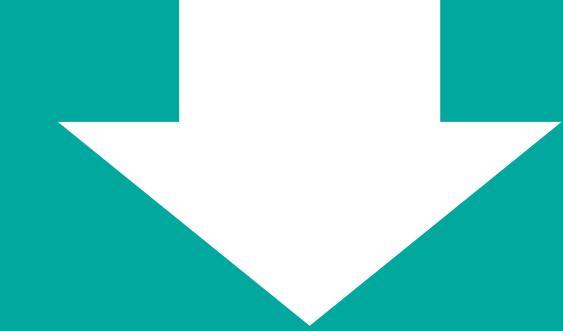


Spatial and Physical Guides

Audio Output



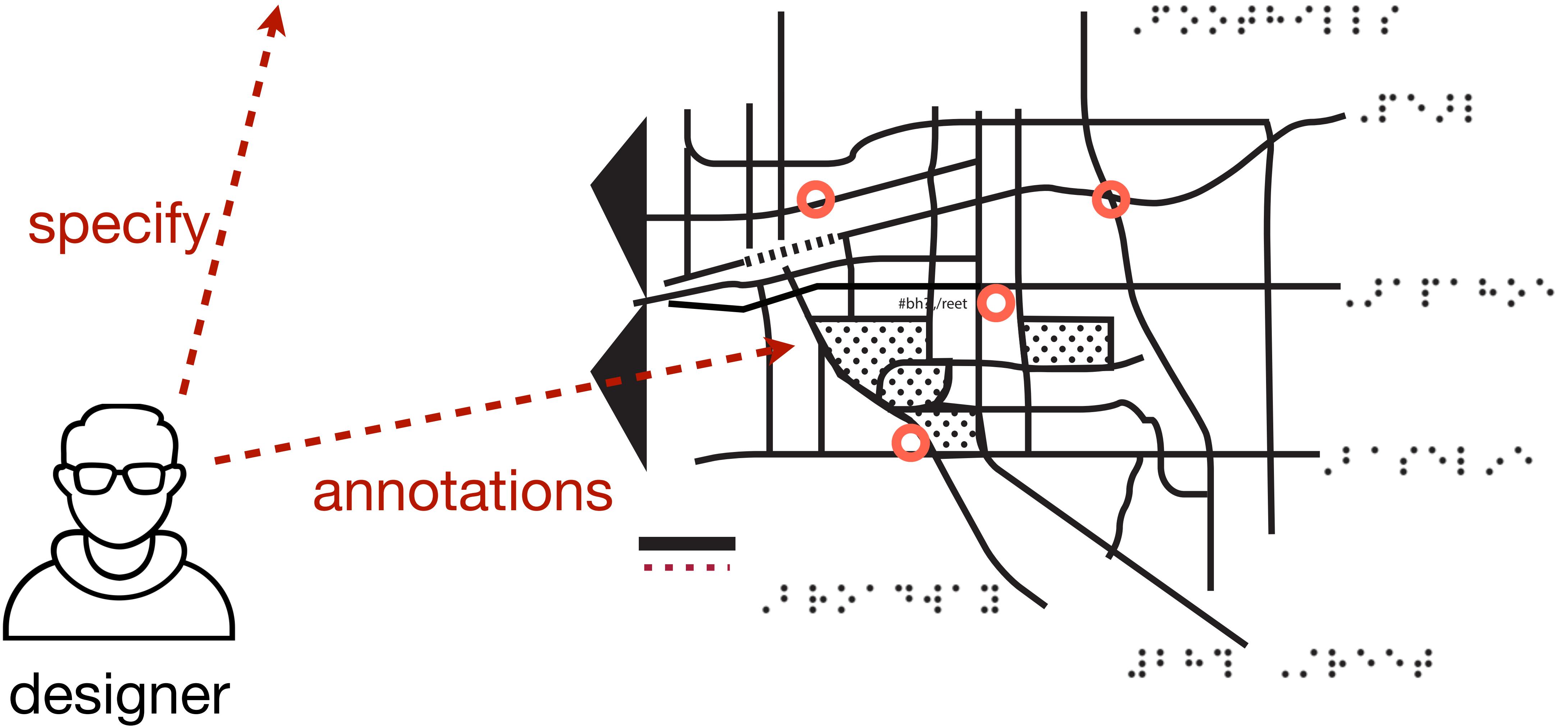
Tactile Output





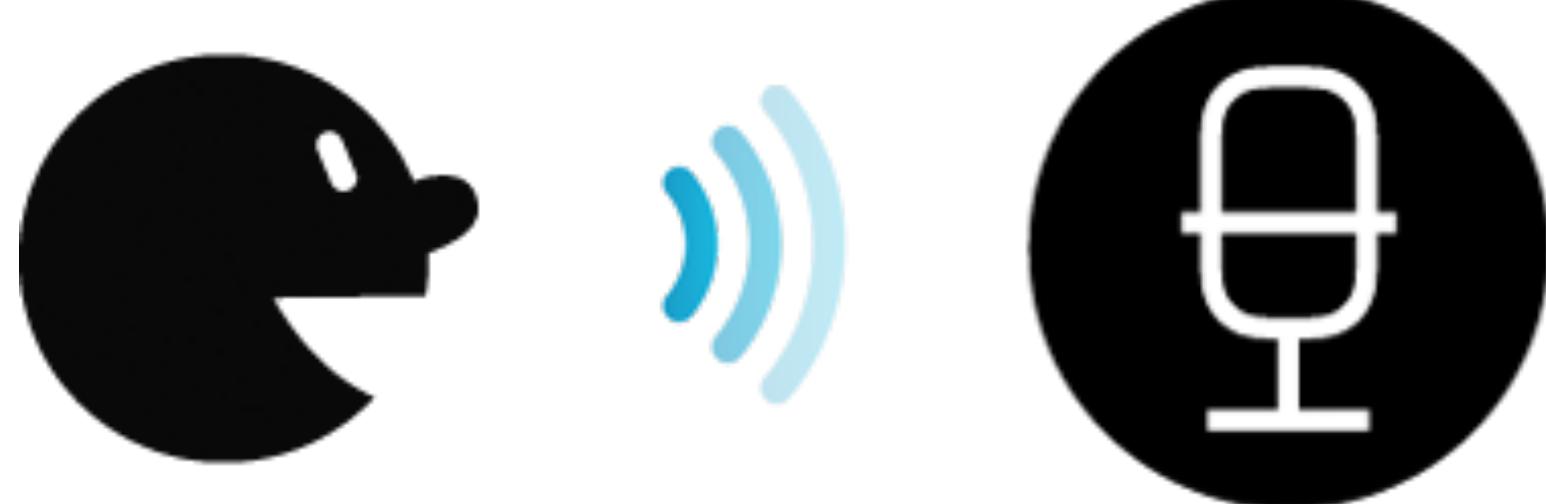
Where is the Black Sea?

keyword: **coffee shops**



keyword: **coffee shops**

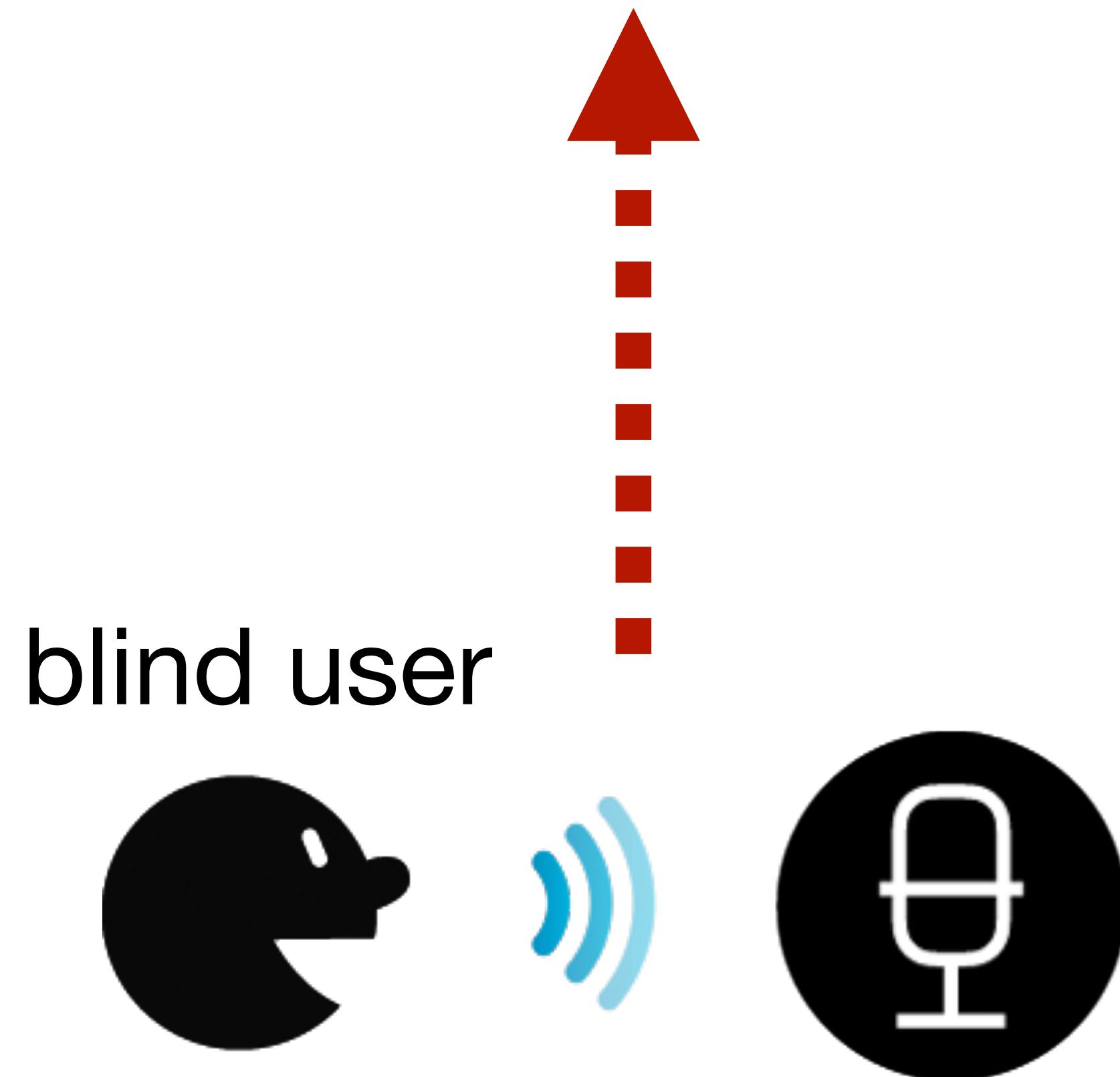
blind user



“Show me the nearest
coffee shops?”

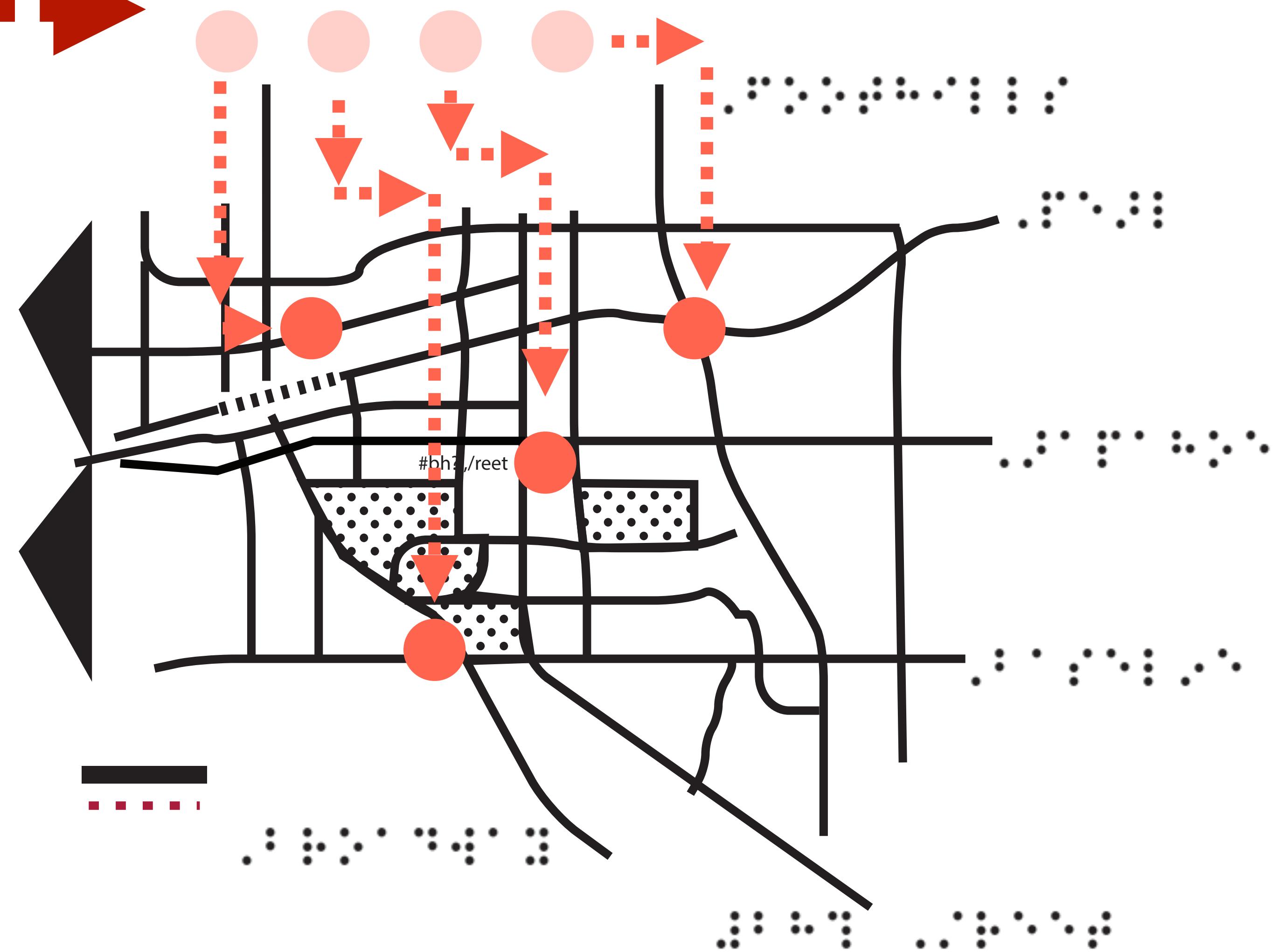


keyword: **coffee shops**



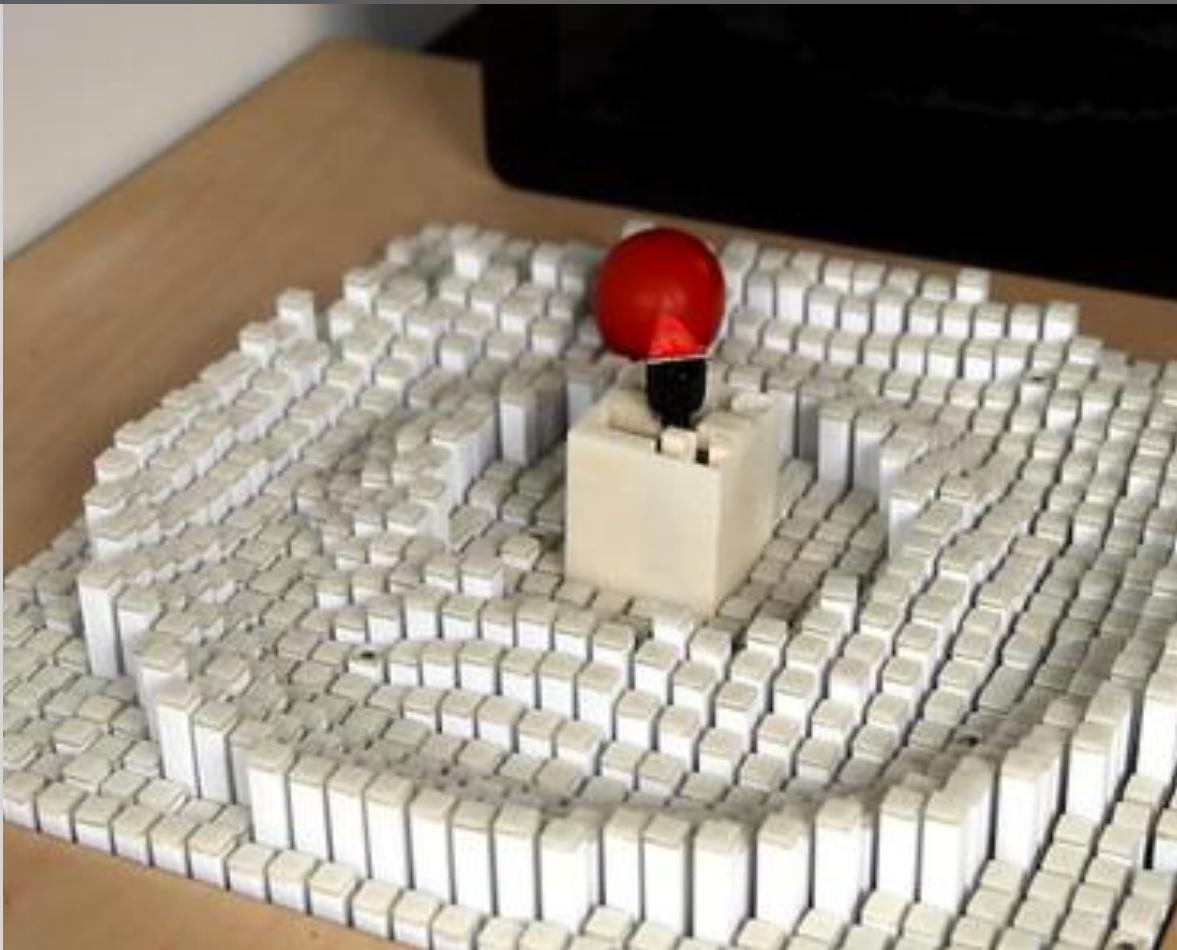
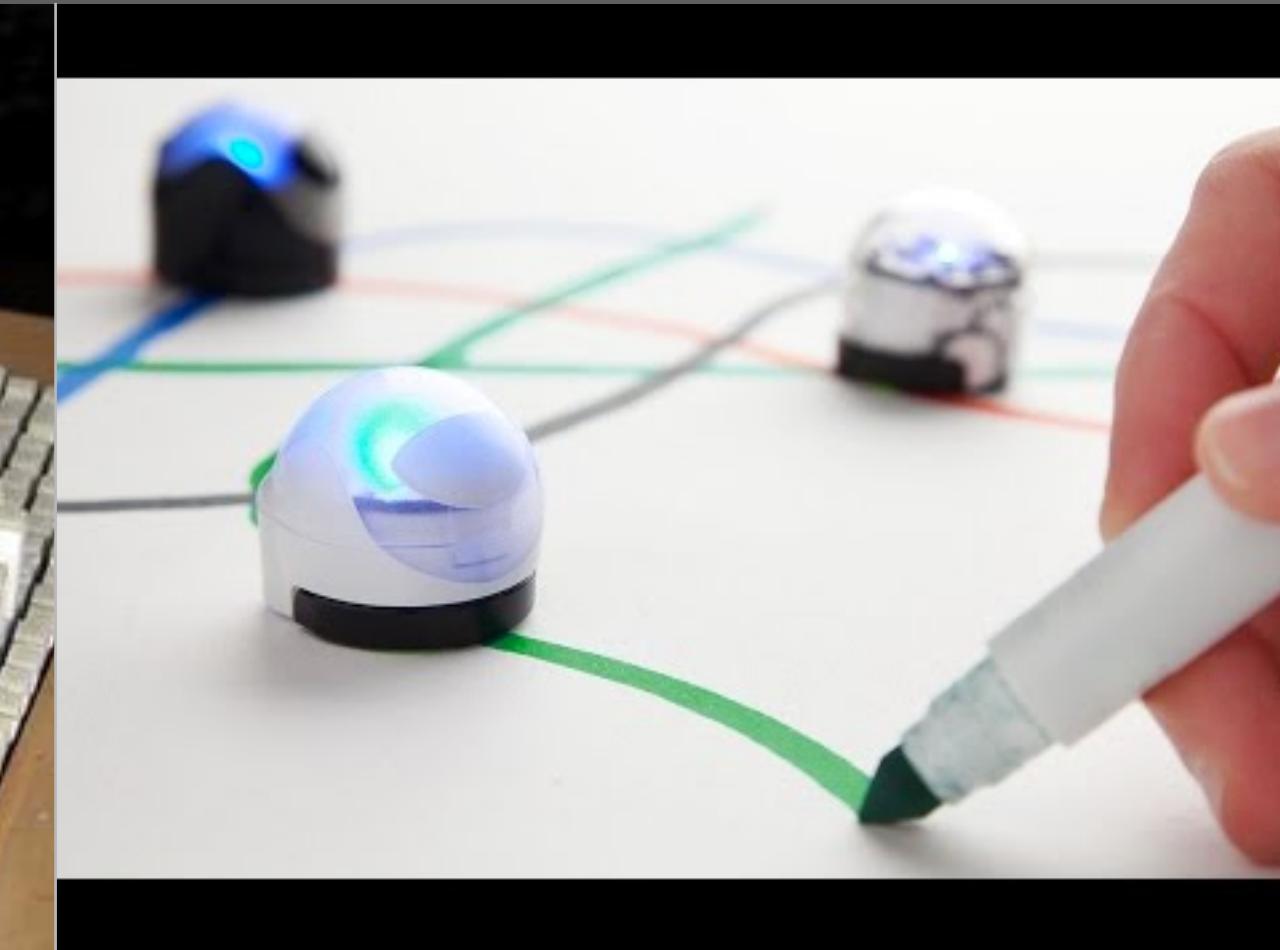
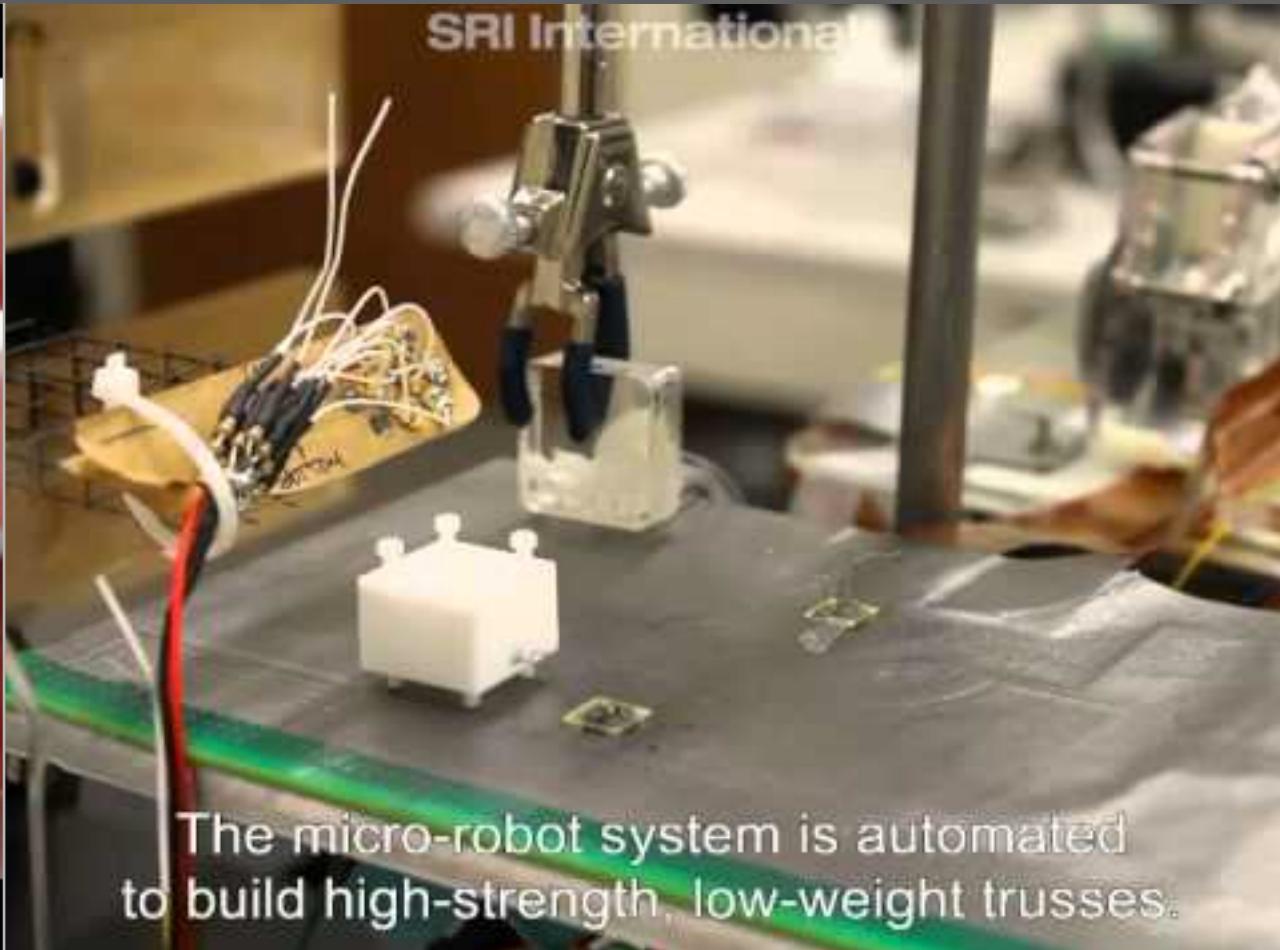
blind user

initial positions



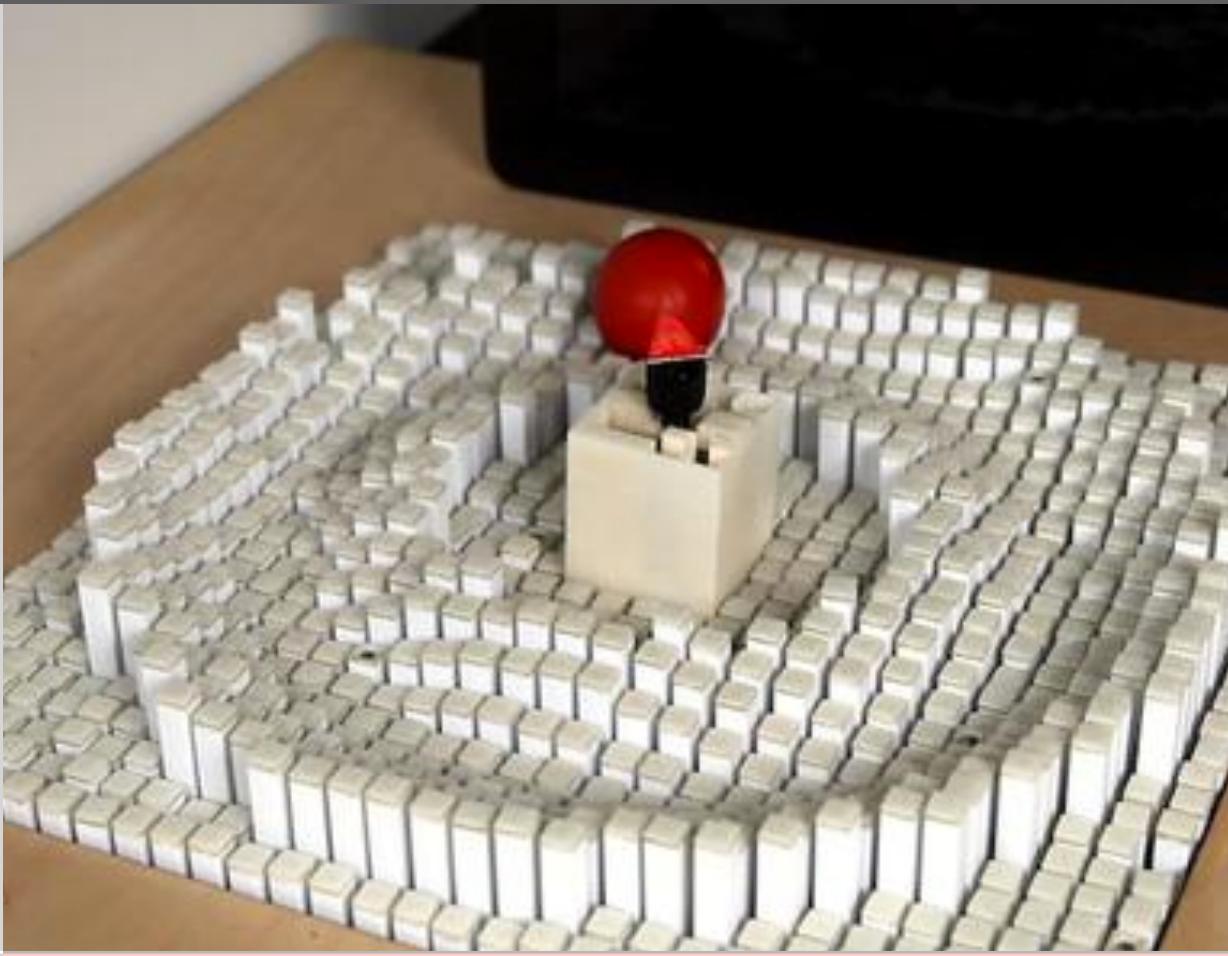
“Show me the nearest
coffee shops?”

1. Summary
2. Motivation
- 3. Design and Implementation**
4. User Study

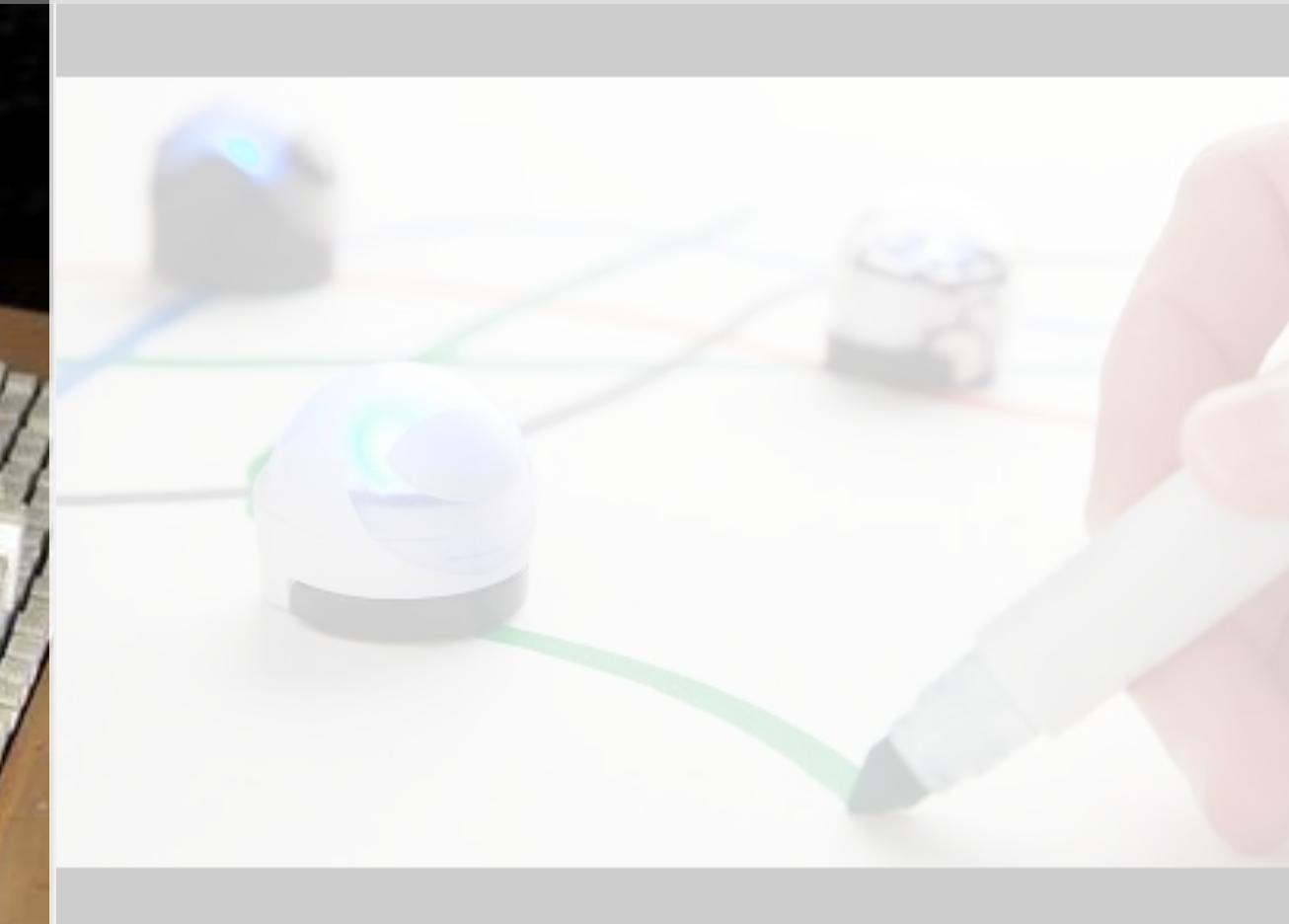
	Pin-based	Movable Robots	Electro-magnetic
Example			
Cost and Scalability	✗ ($10 \times 10 = \$500$)	✓ (each marker = \$50)	✓ (PCB = \$10-20)
Resolution / Size of Markers	△ (resolution: 1-3cm)	△ (size: 3-5 cm)	✓ (size: 0.5-1cm)
Fabrication Complexity	✓	✓	?

Example

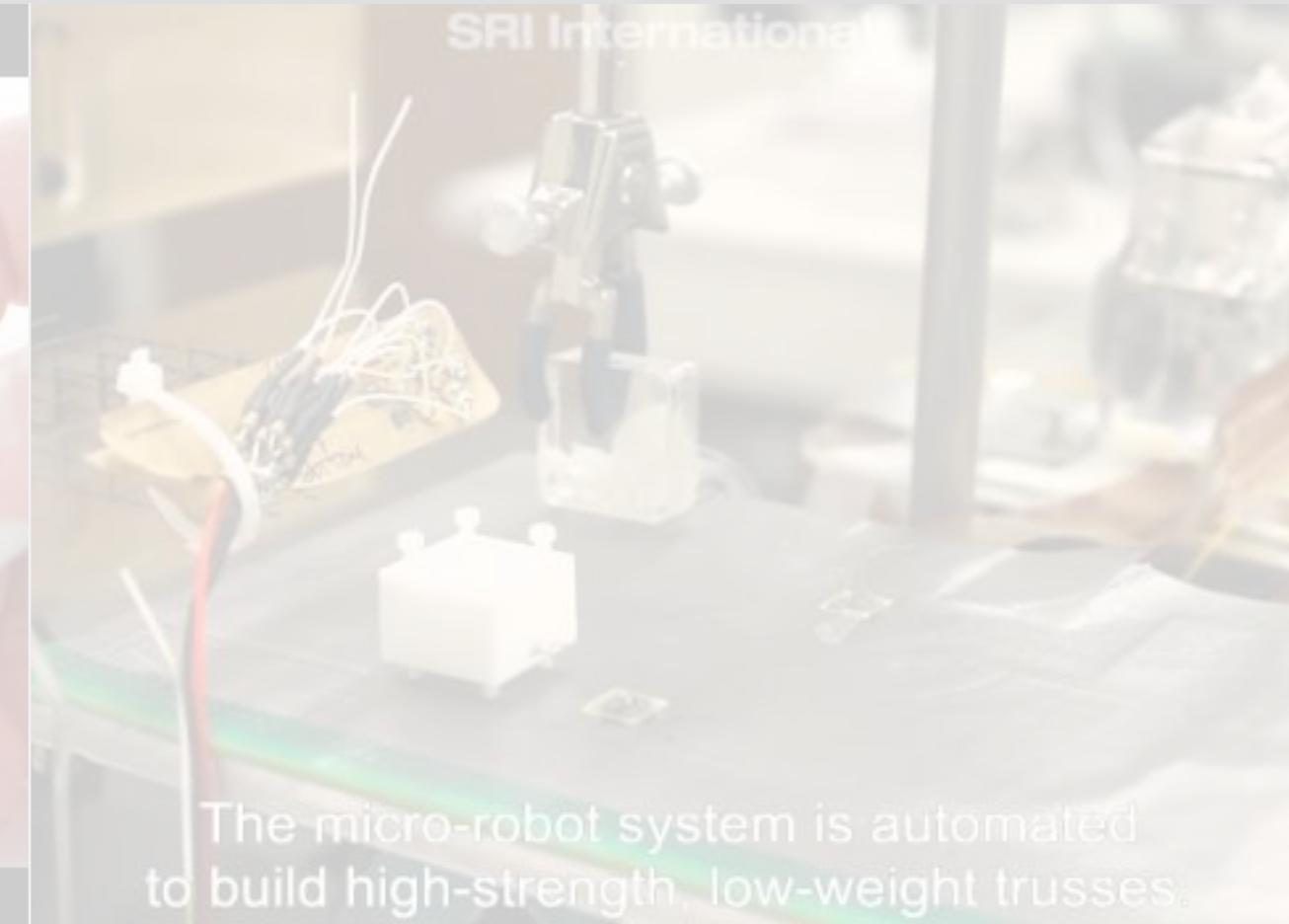
Pin-based



Movable Robots



Electro-magnetic



Cost and Scalability

✗

($10 \times 10 = \$500$)

✓

(each marker = \$50)

✓

(PCB = \$10-20)

Resolution / Size of Markers

△

(resolution: 1-3cm)

△

(size: 3-5 cm)

✓

(size: 0.5-1cm)

Fabrication Complexity

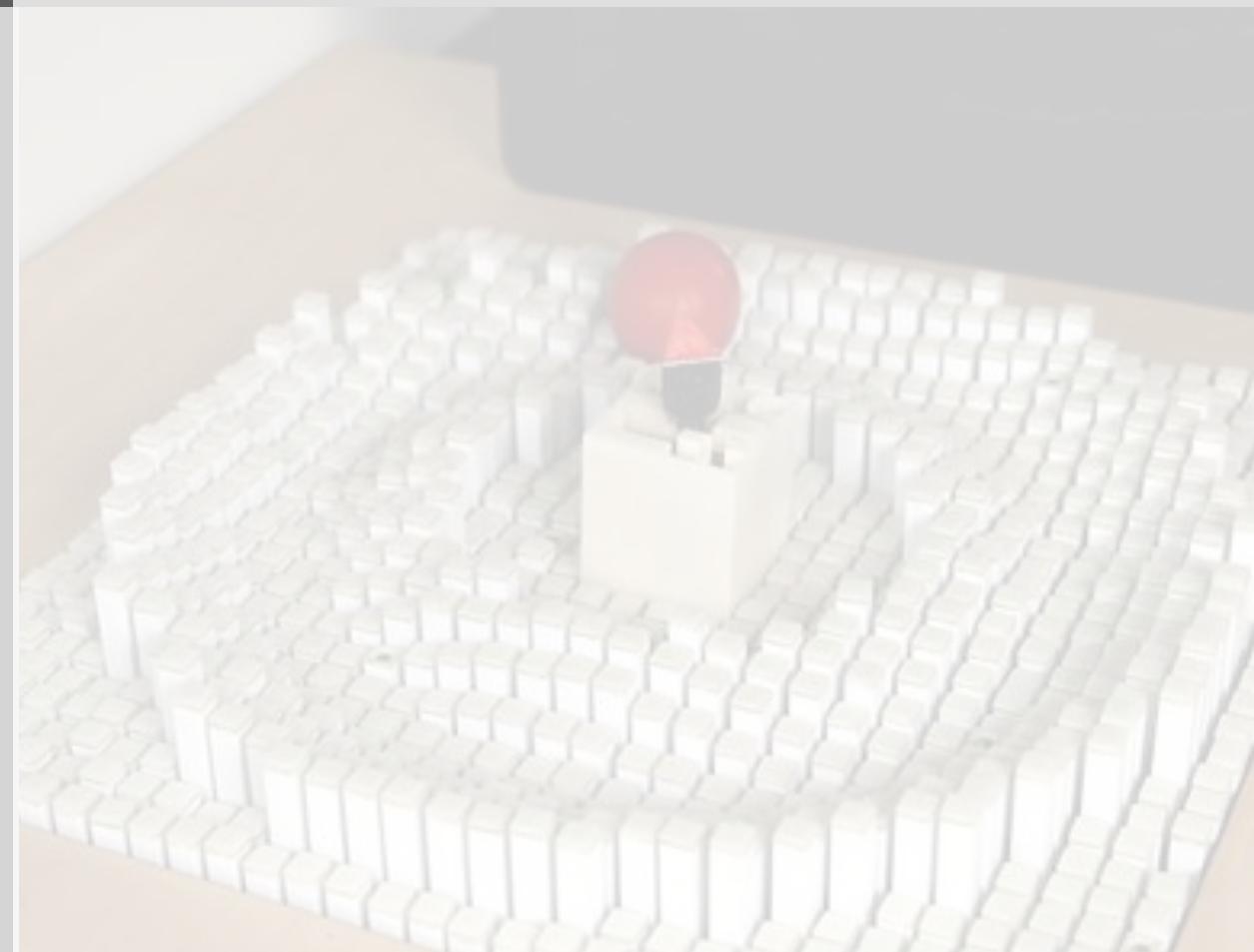
✓

✓

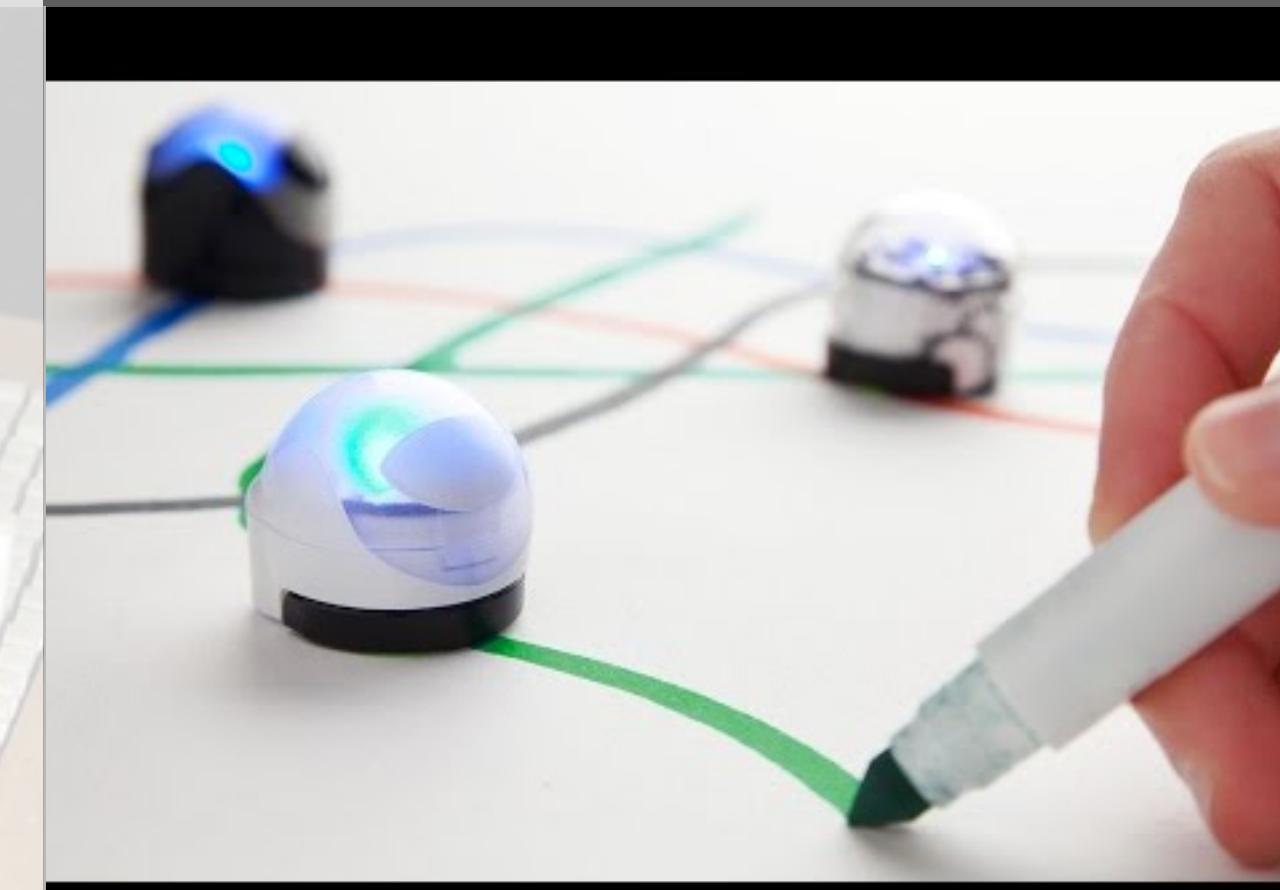
?

Example

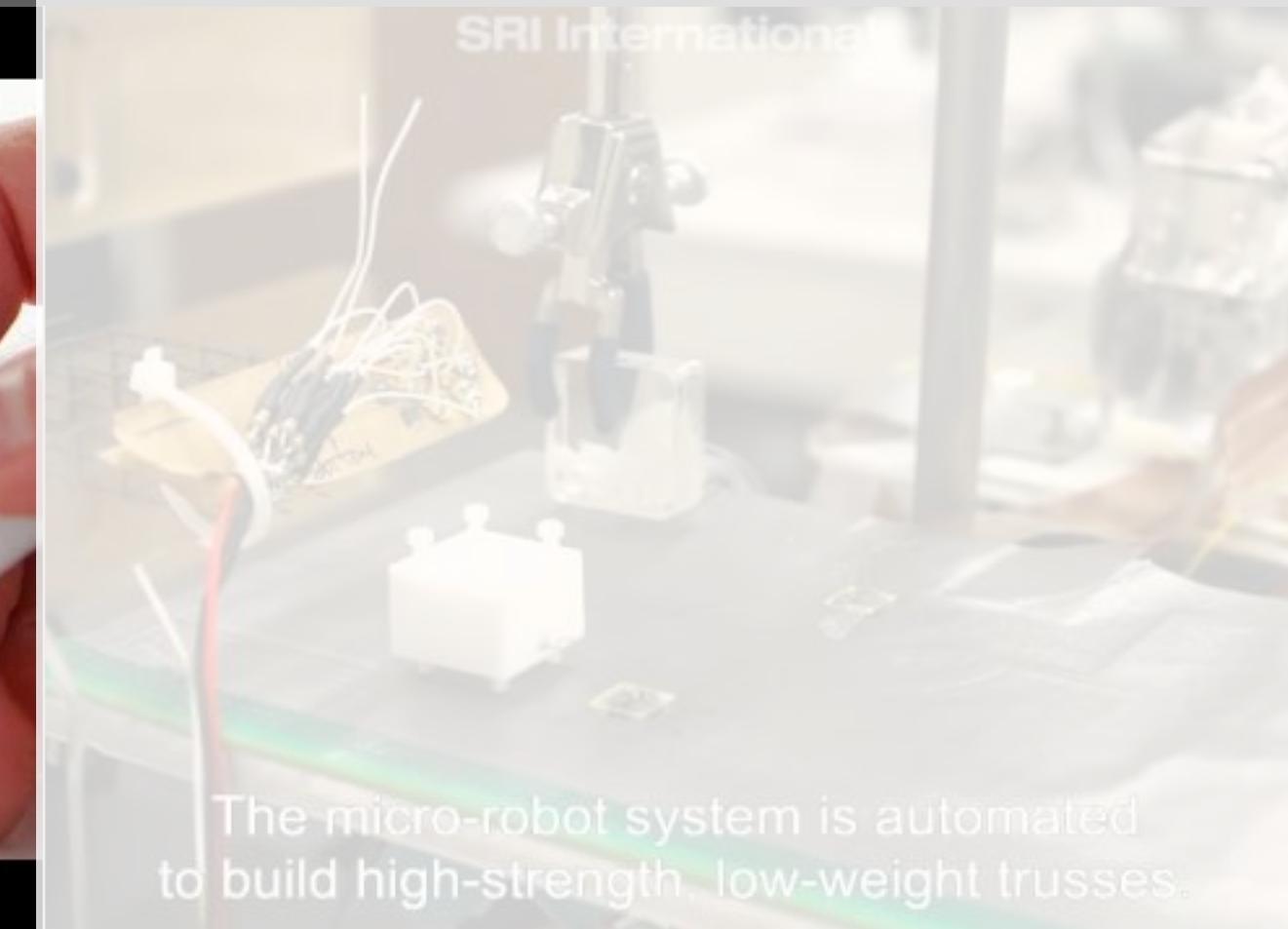
Pin-based



Movable Robots



Electro-magnetic



Cost and Scalability



($10 \times 10 = \$500$)



(each marker = \$50)



(PCB = \$10-20)

Resolution / Size of Markers



(resolution: 1-3cm)



(size: 3-5 cm)



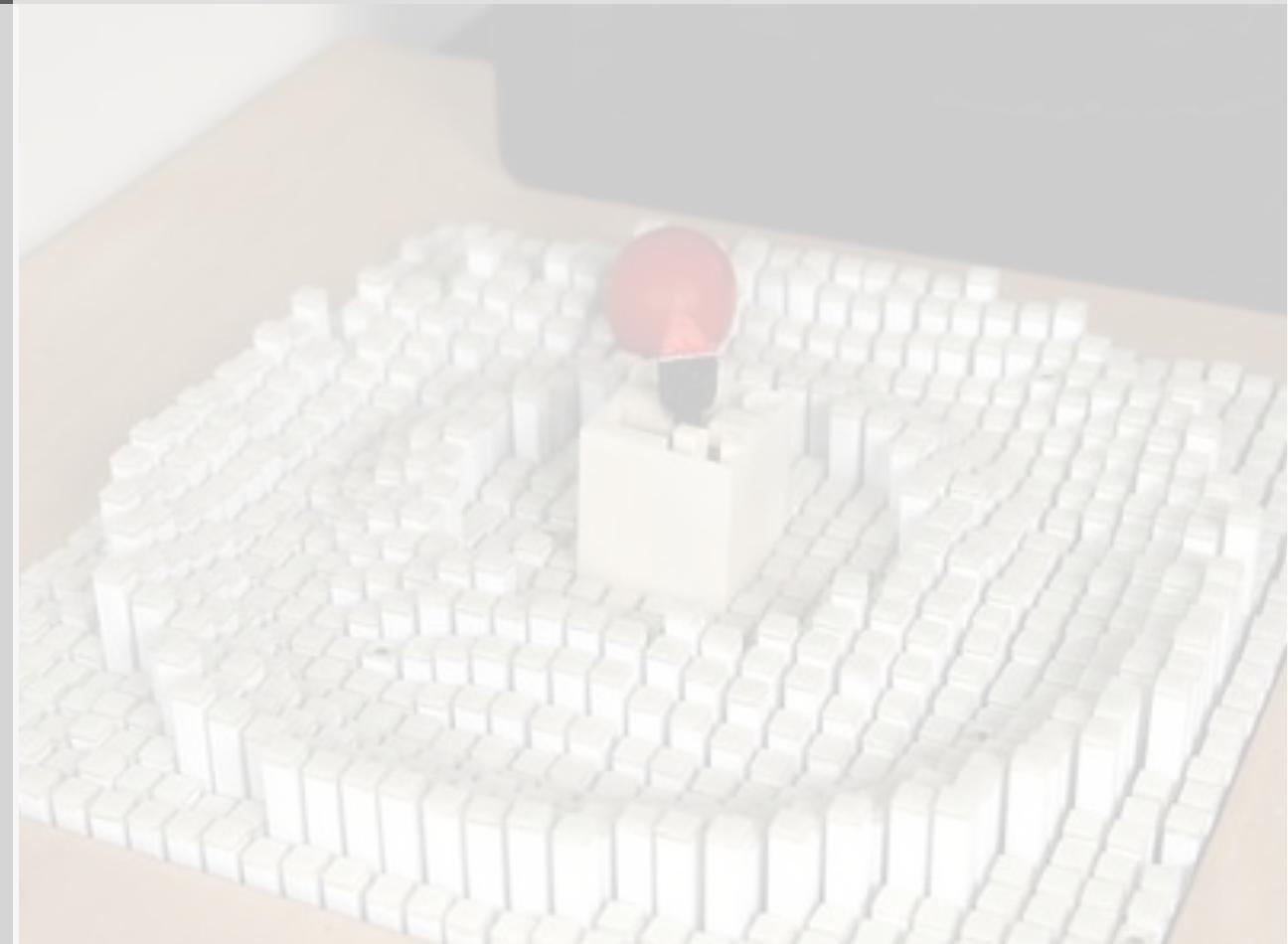
(size: 0.5-1cm)

Fabrication Complexity

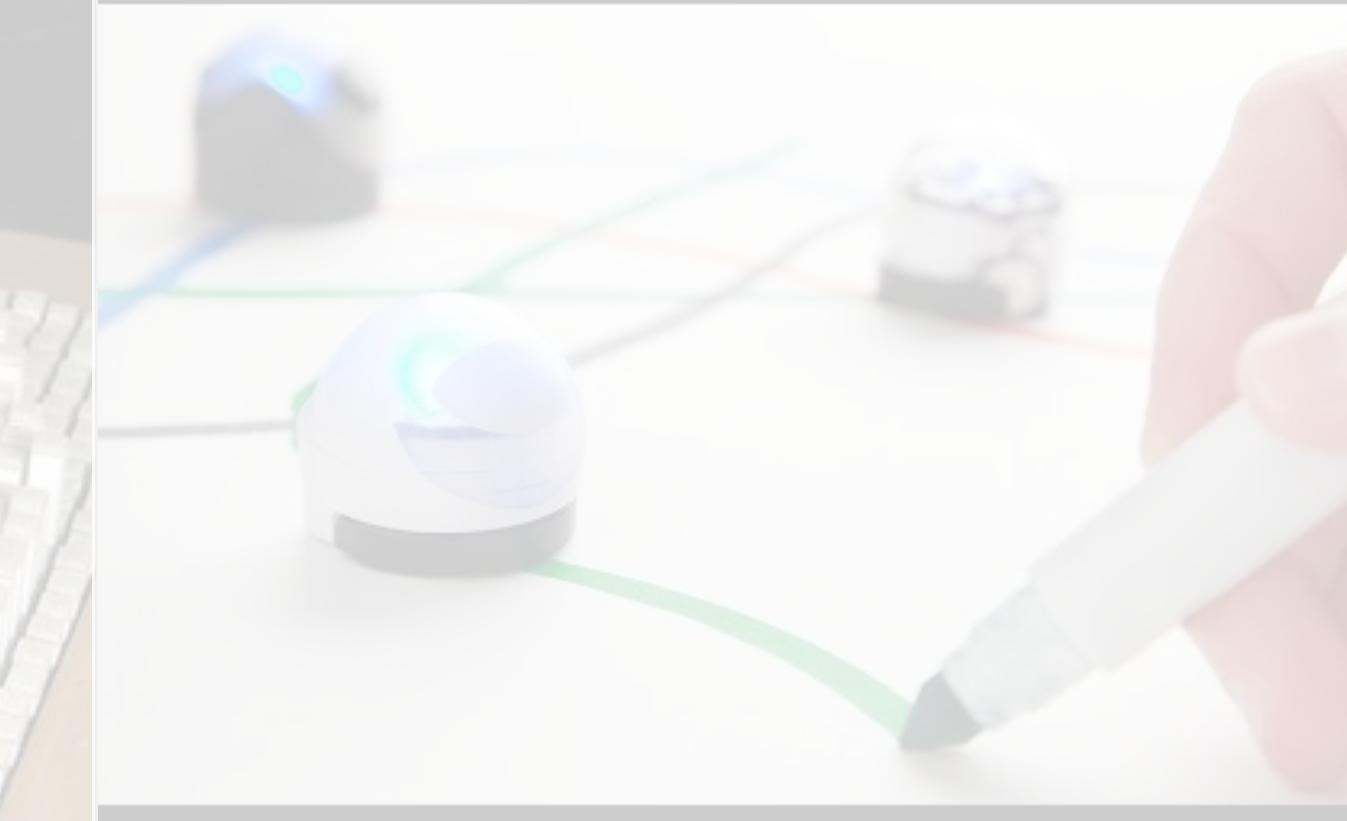


Example

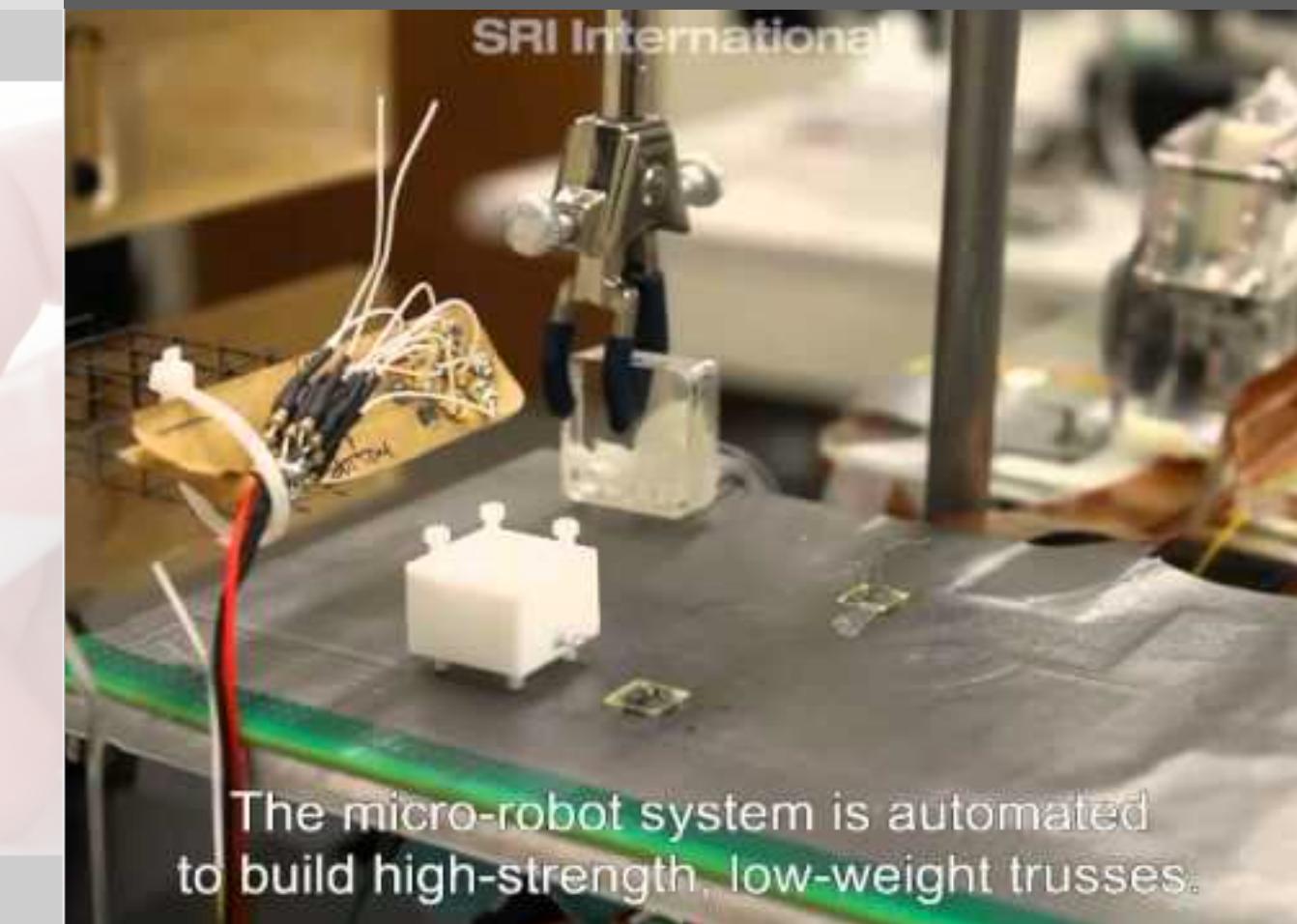
Pin-based



Movable Robots



Electro-magnetic



Cost and Scalability



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(each marker = \$50)



(PCB = \$10-20)

Resolution / Size of Markers



(resolution: 1-3cm)



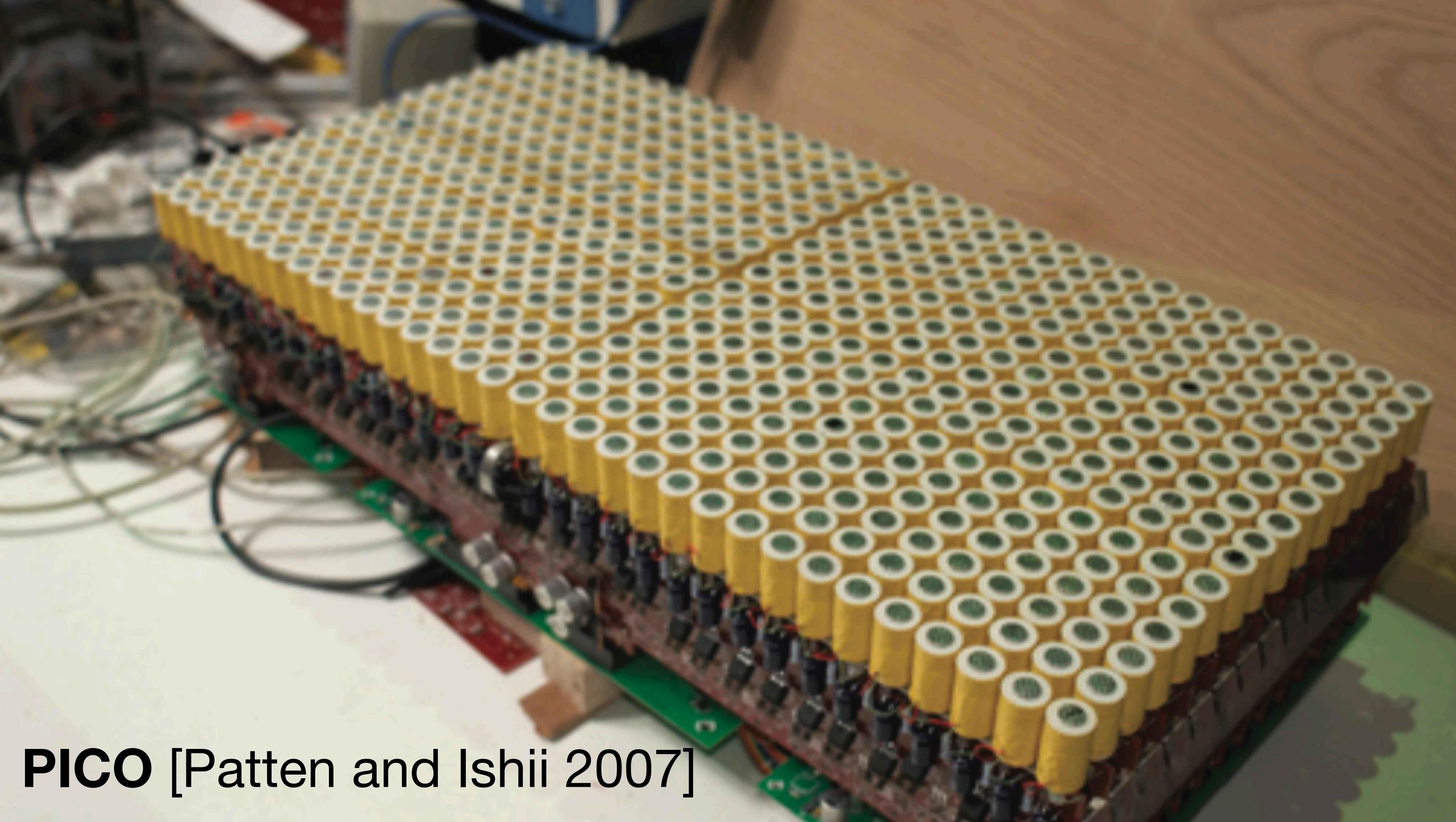
(size: 3-5 cm)



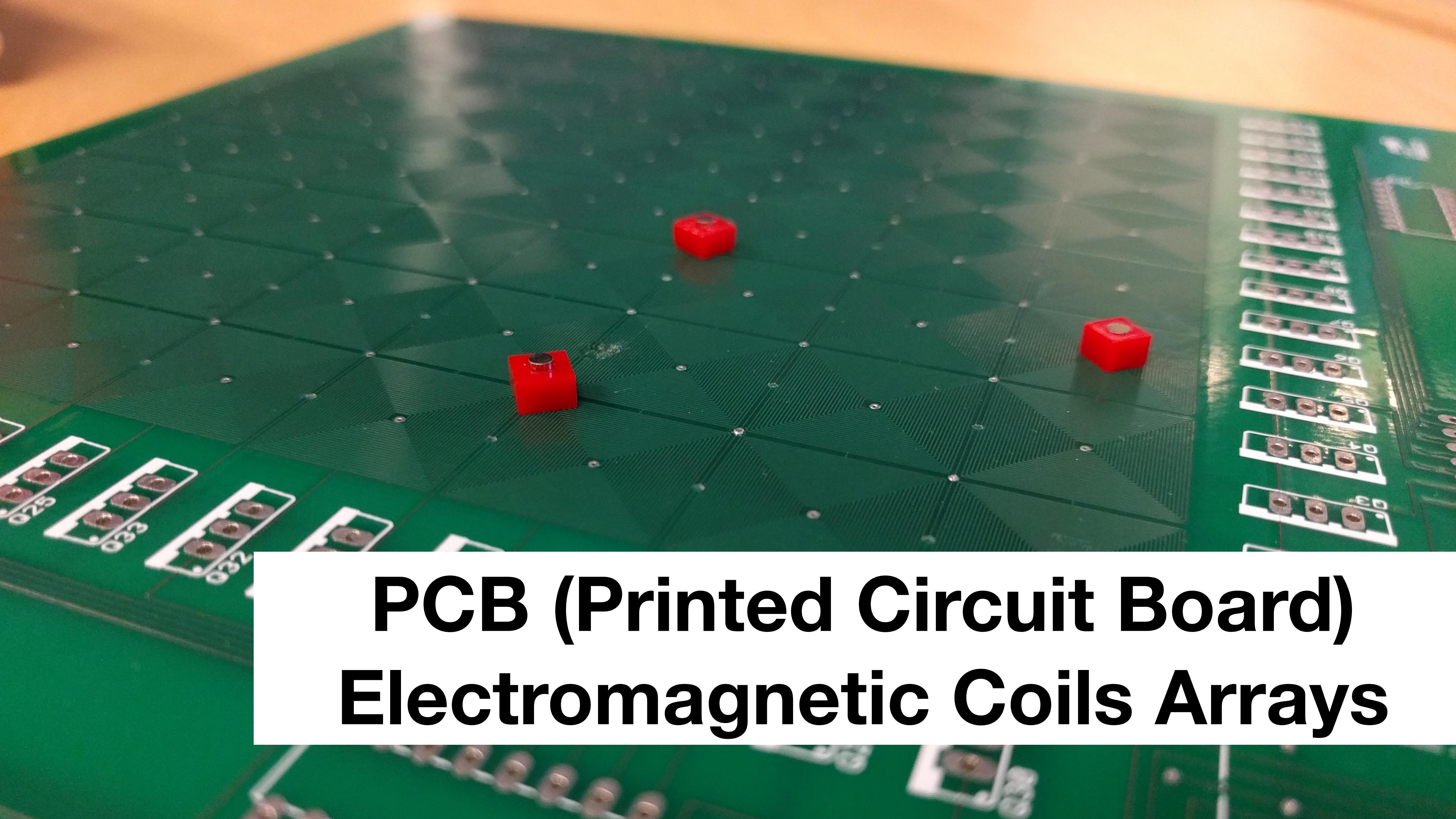
(size: 0.5-1cm)

Fabrication Complexity

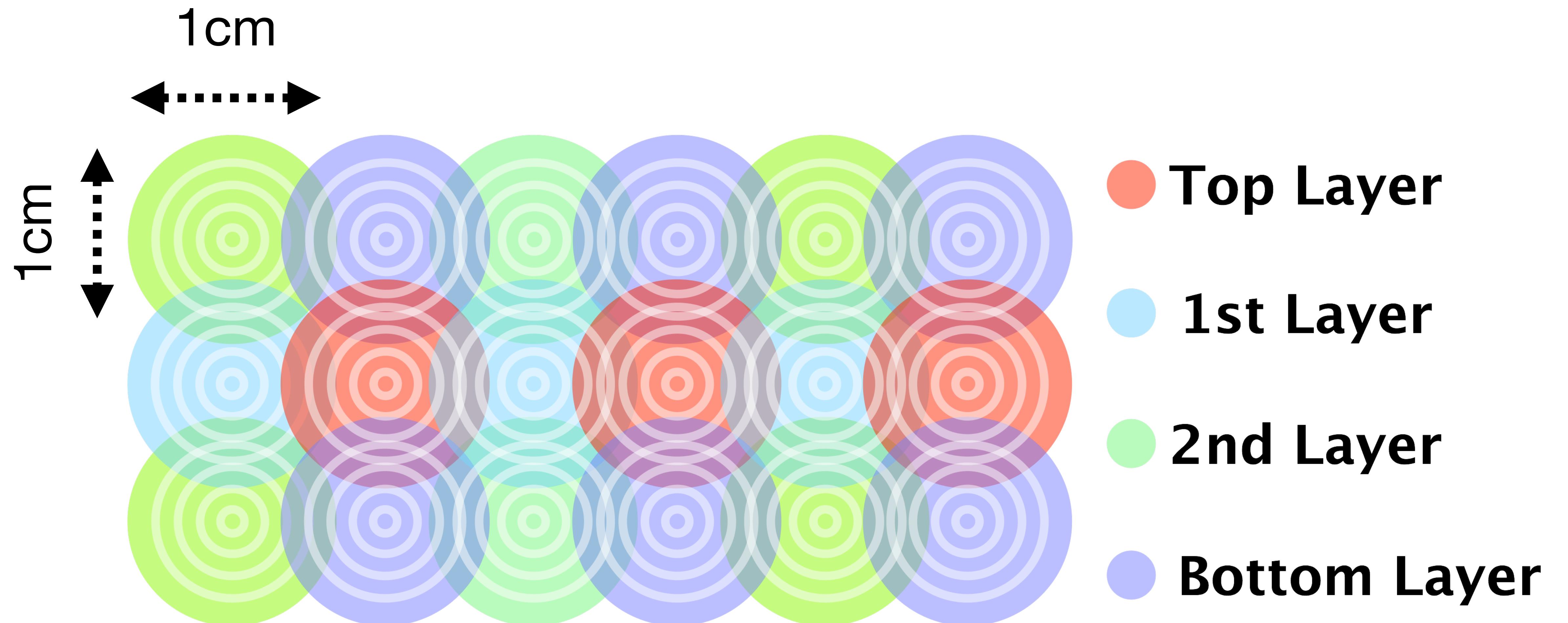




PICO [Patten and Ishii 2007]

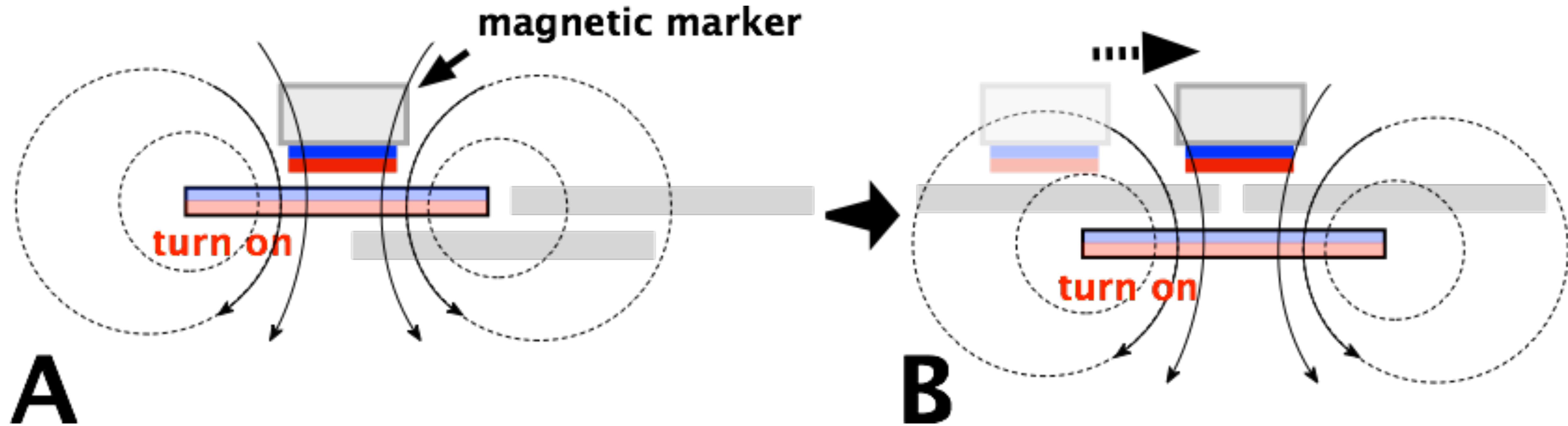
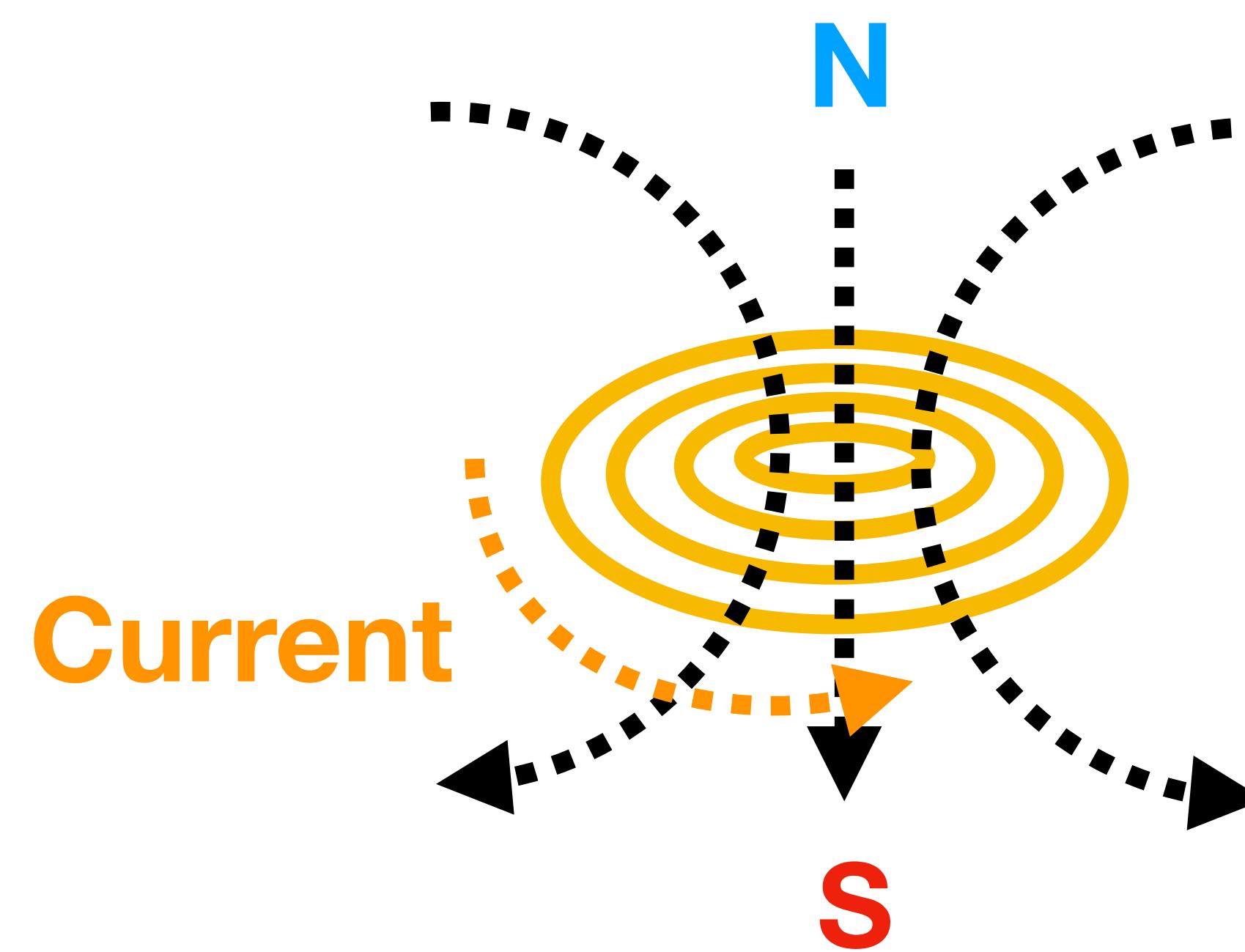


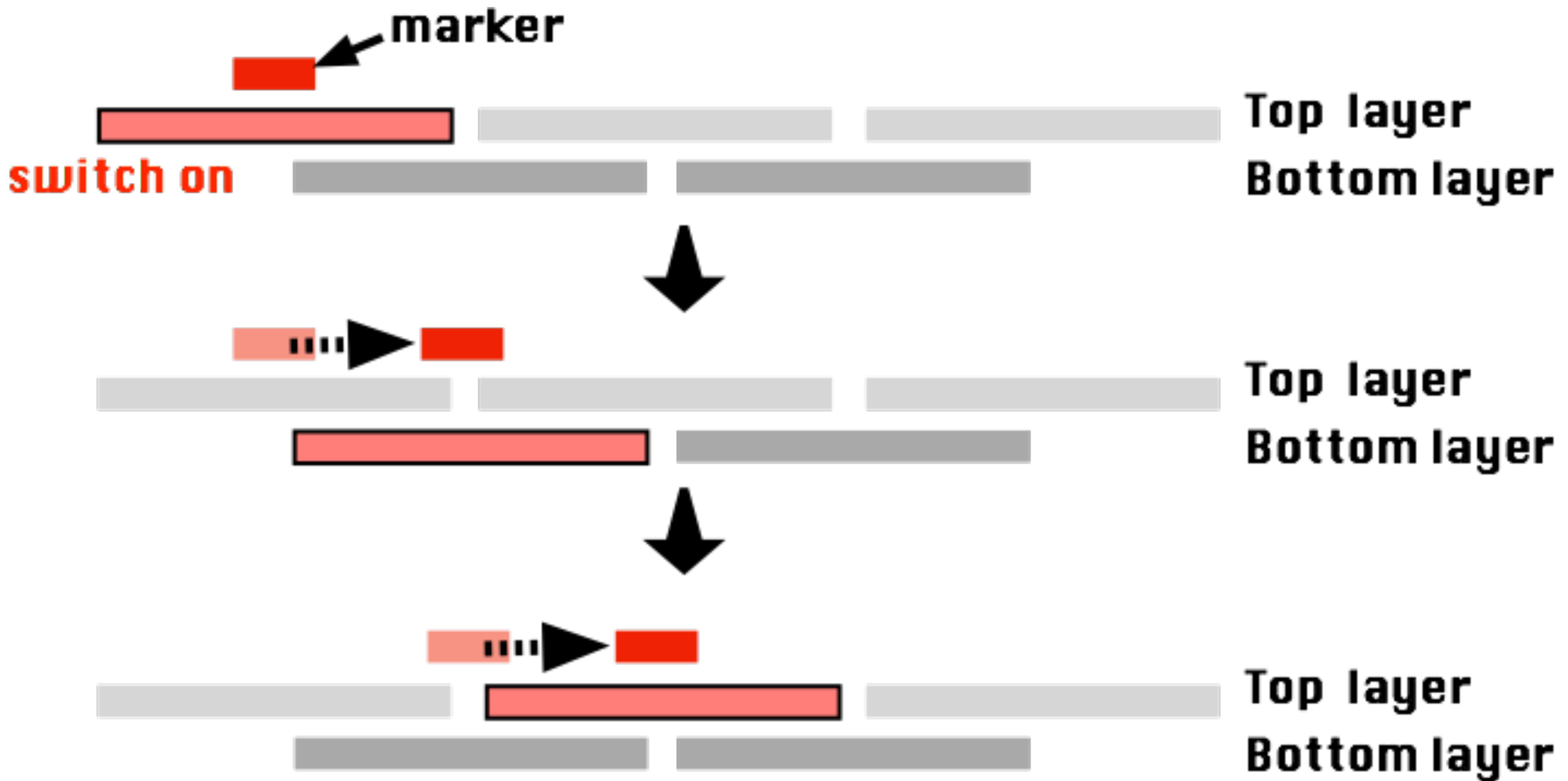
PCB (Printed Circuit Board) Electromagnetic Coils Arrays

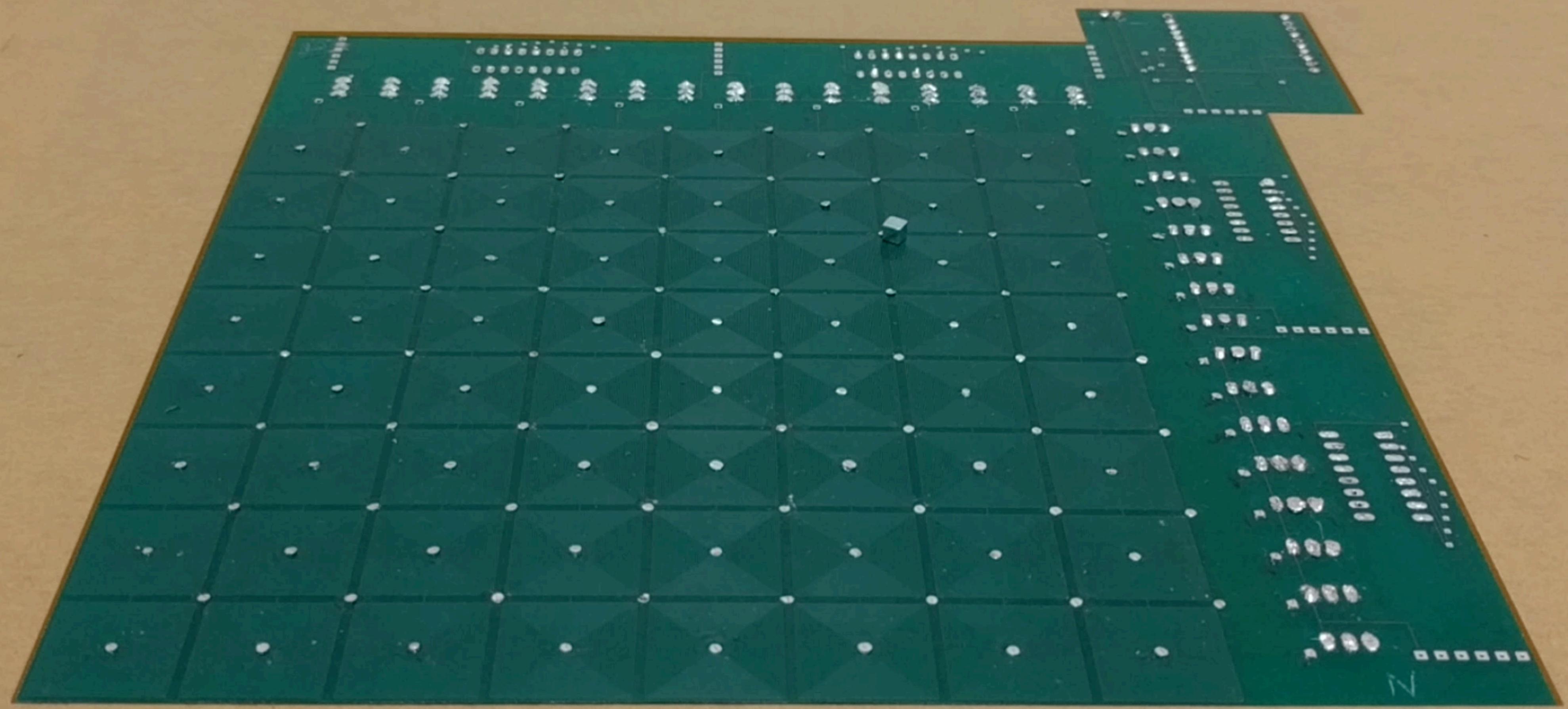


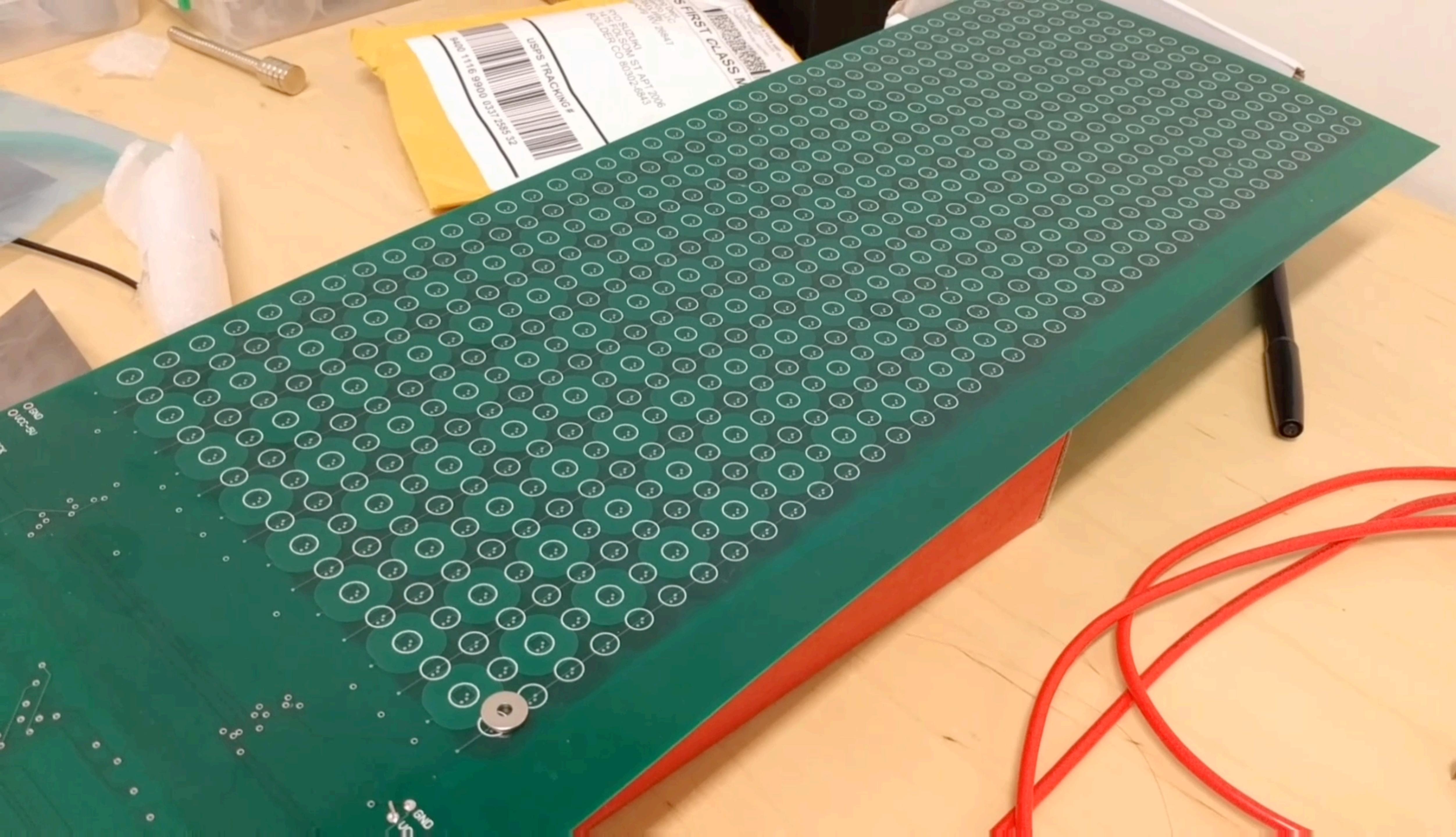


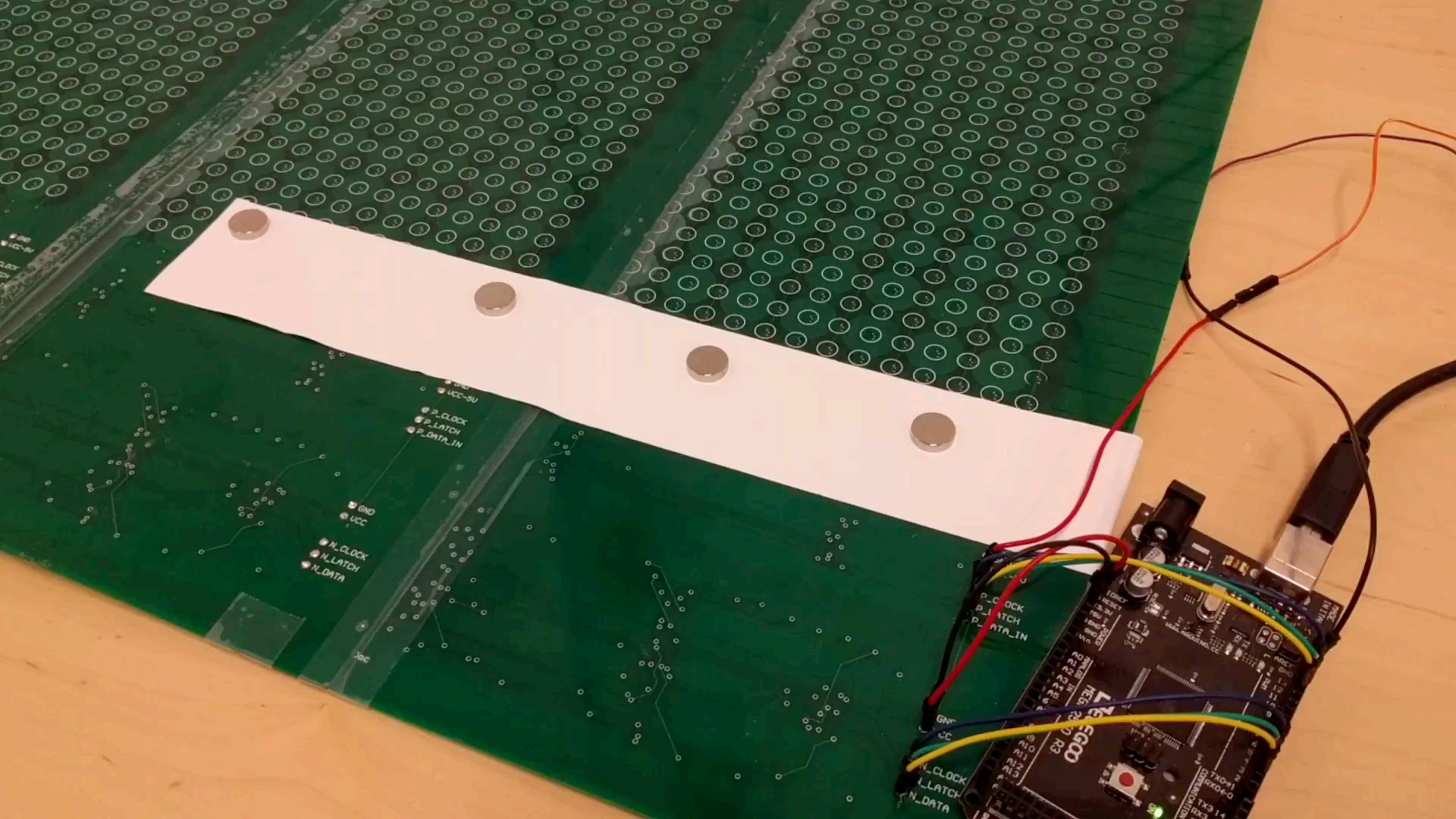
Current

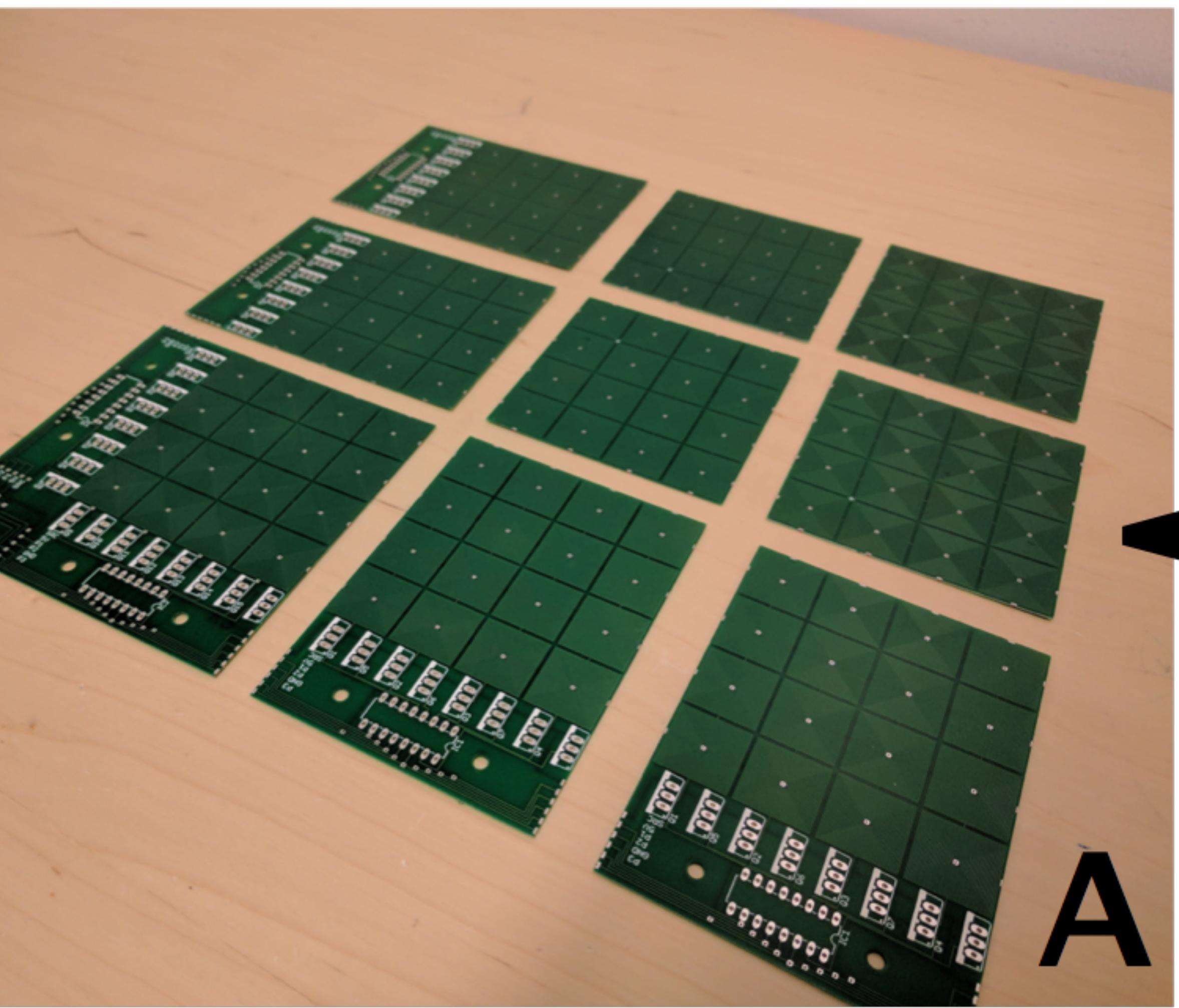




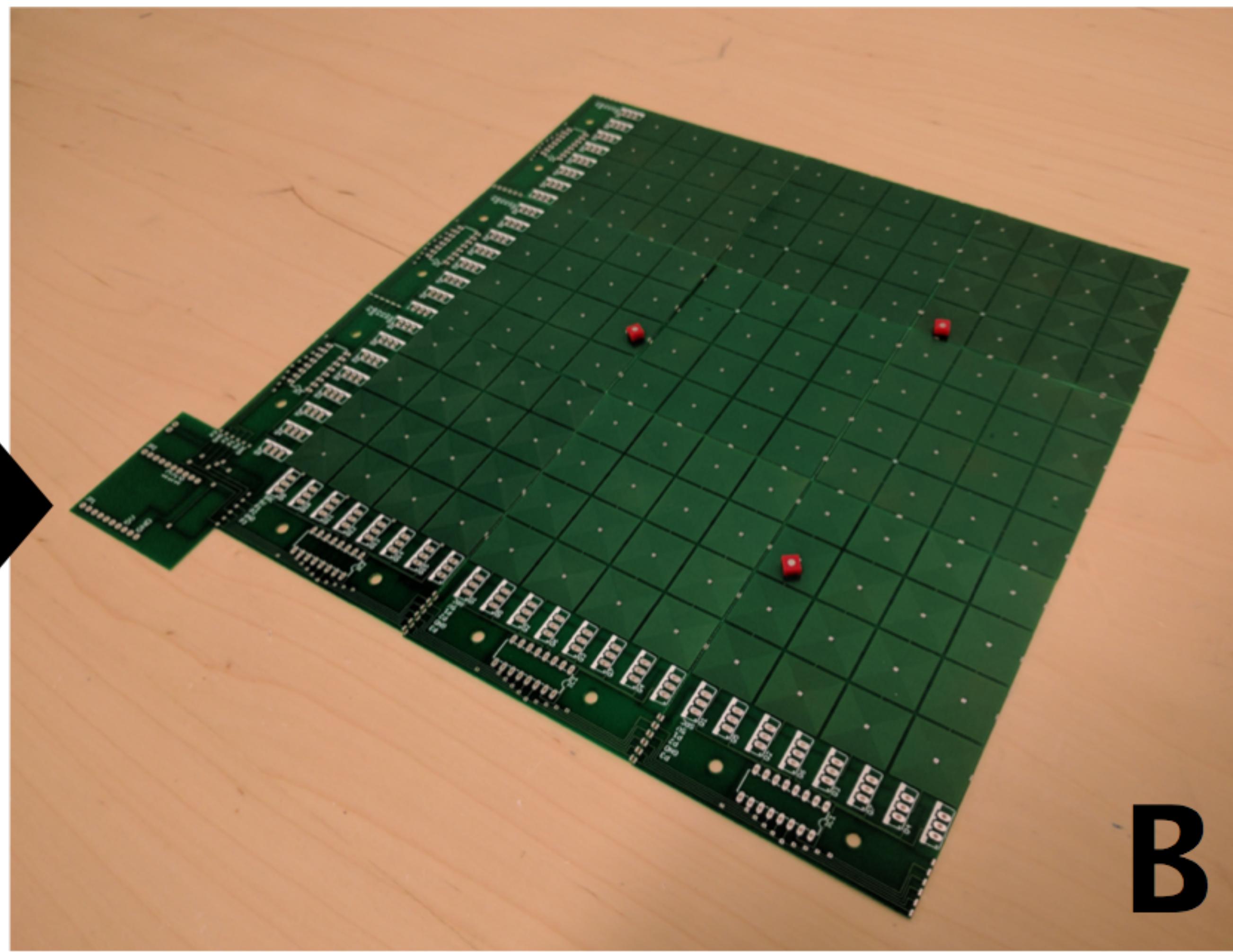




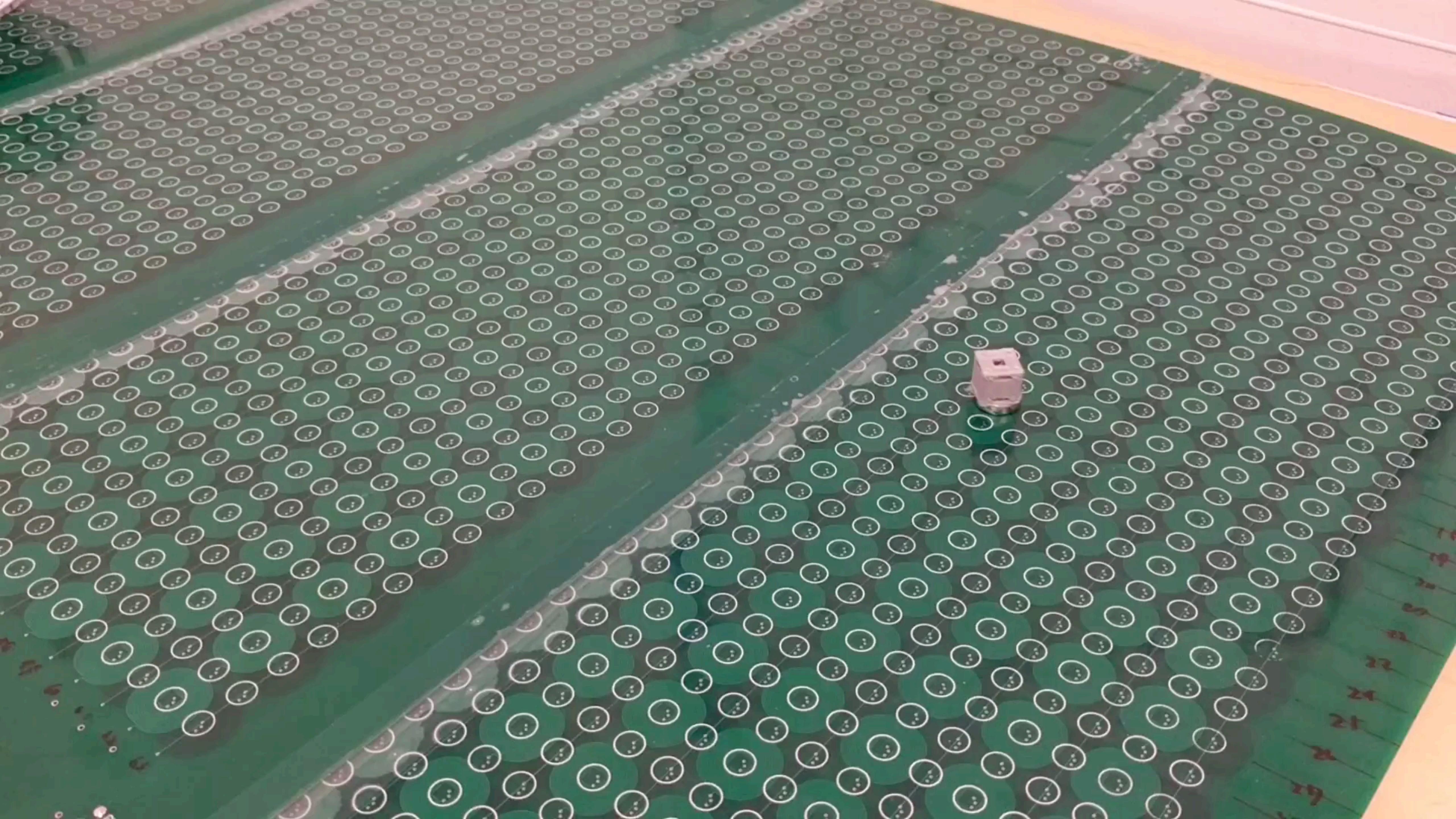




A



B



These designs are informed by

our **Formatative Study**

with 4 blind participants

1. Summary

2. Motivation

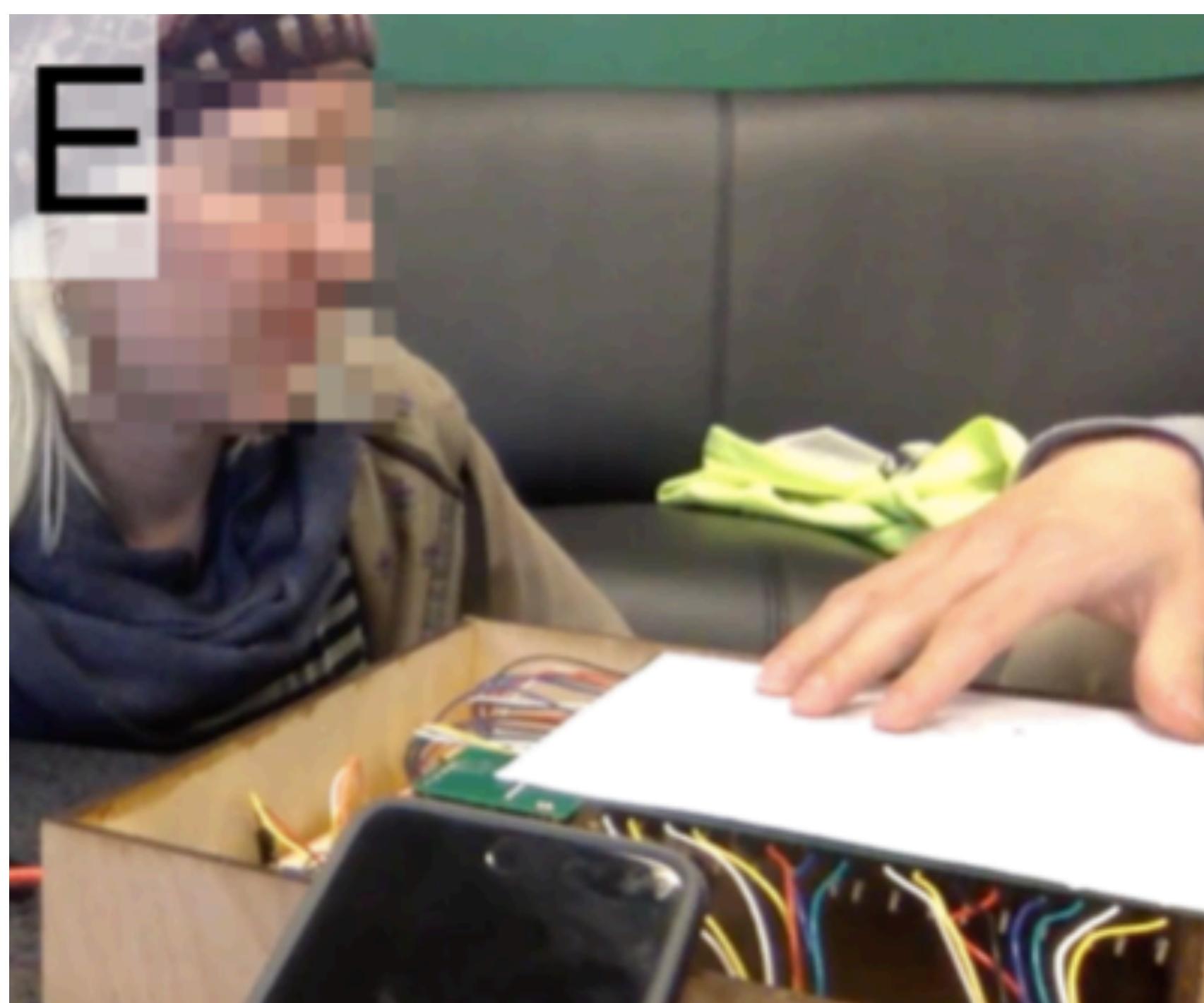
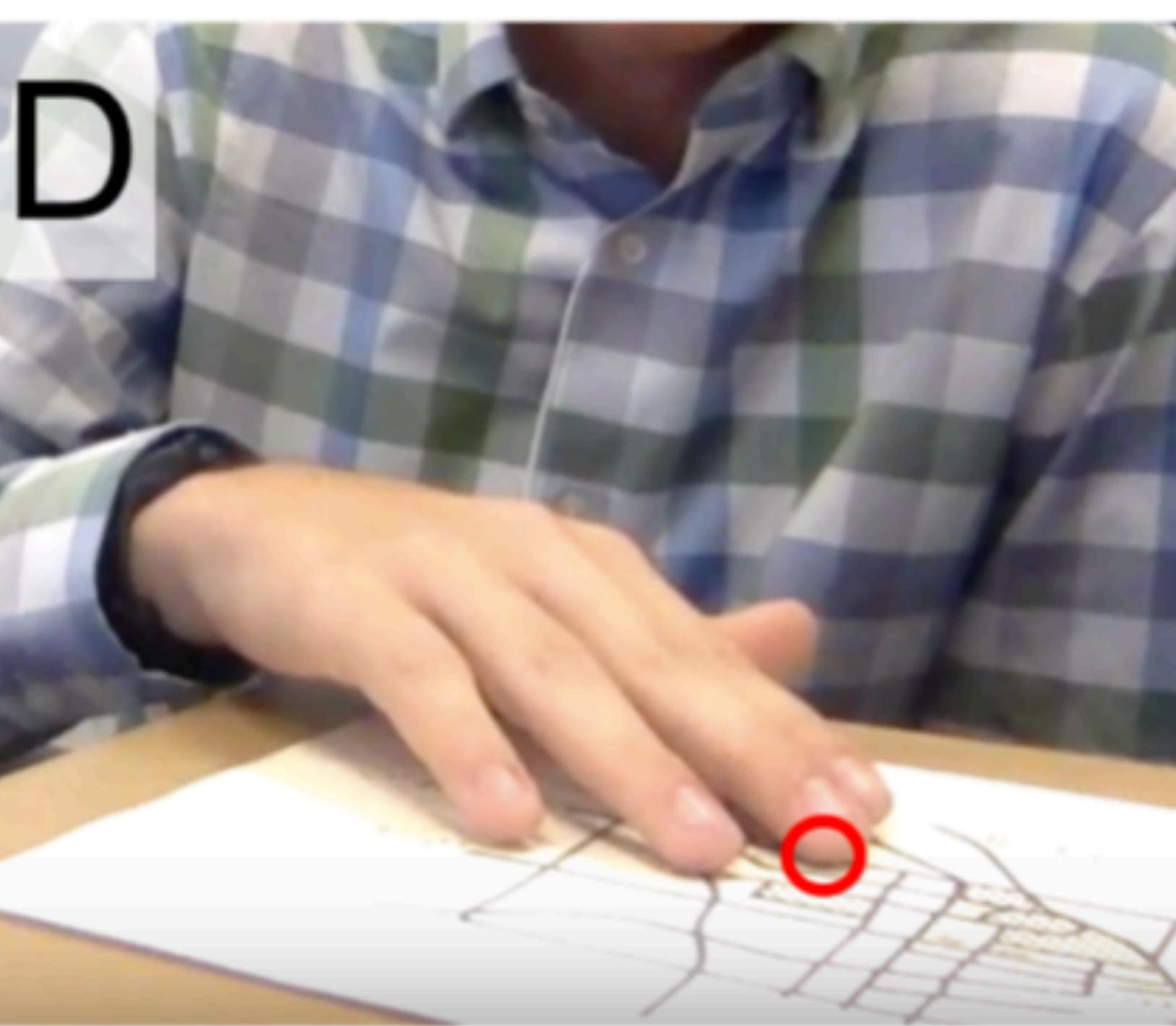
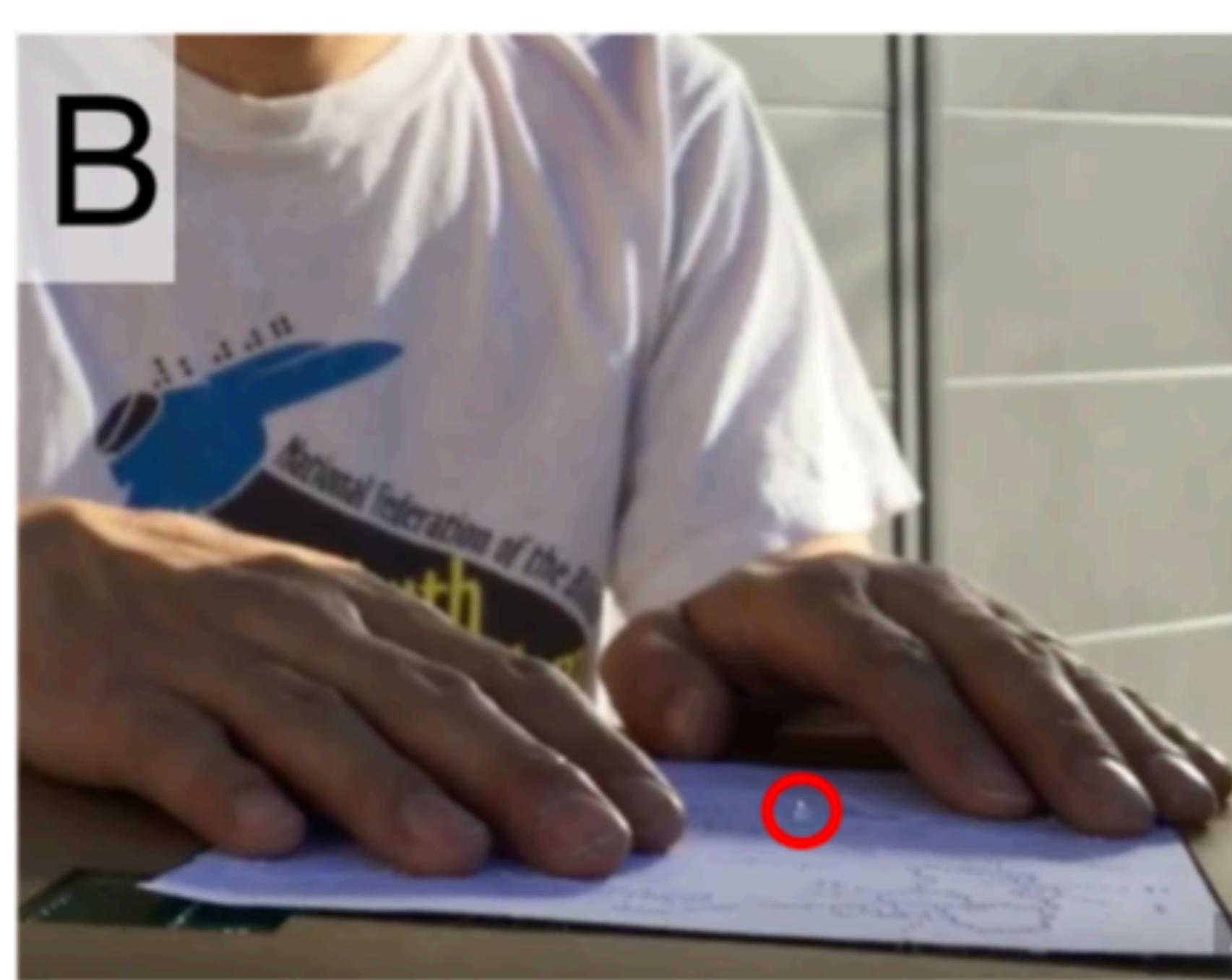
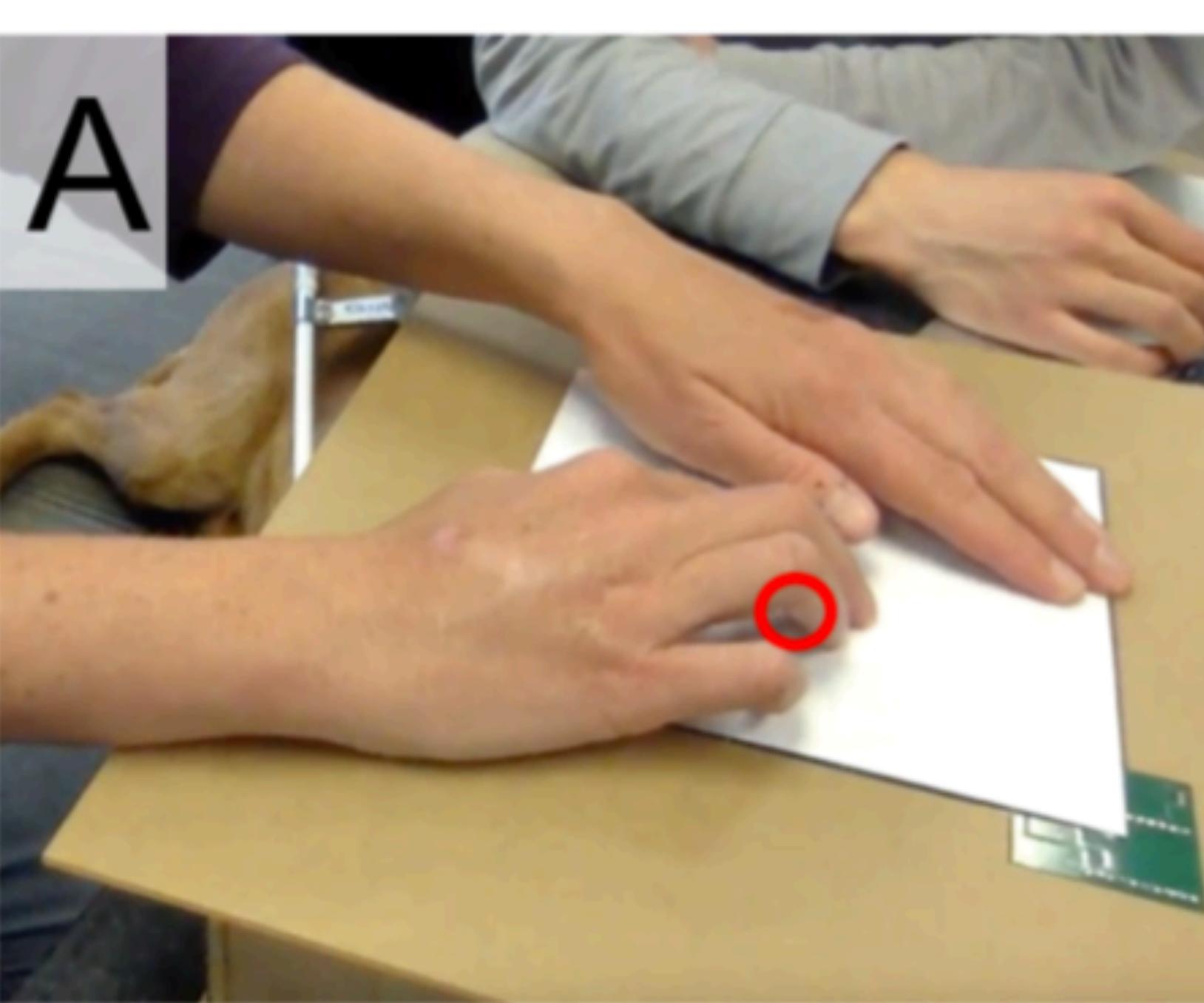
3. Design and Implementation

4. User Study

6 participants

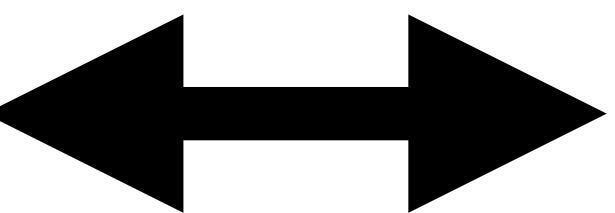
(4: blind, 2: low-vision, average age: 26.8)

Participant	P1	P2	P3	P4	P5	P6
Gender	Male	Male	Female	Female	Male	Female
Age	22	28	26	36	23	26
Visual Impairment Status	Blind	Blind	Blind	Blind	Low Vision	Low Vision
Frequency of Tactile Graphic	Medium	Medium	High	Medium	None	None
Familiarity with Science Graphics	None	Medium	Medium	Medium	None	None
Familiarity with Tactile Maps	High	High	Low	High	Low	Low
Braille Fluency	High	High	High	Medium	Low	Low



Find a specific point

without FluxMarker



with FluxMaker

1. Tactile map of East Europe area
2. Human brain model
3. Drawing hexagon

Findings

Real-time Spatial Navigation as Important Application

P1: “*The best application I could see is to have the marker move with the user following along, so that the teacher could trace a path out for me in real-time.*”

Increase an Independence

*P4: “It works better than having
another person poking at the spot.*

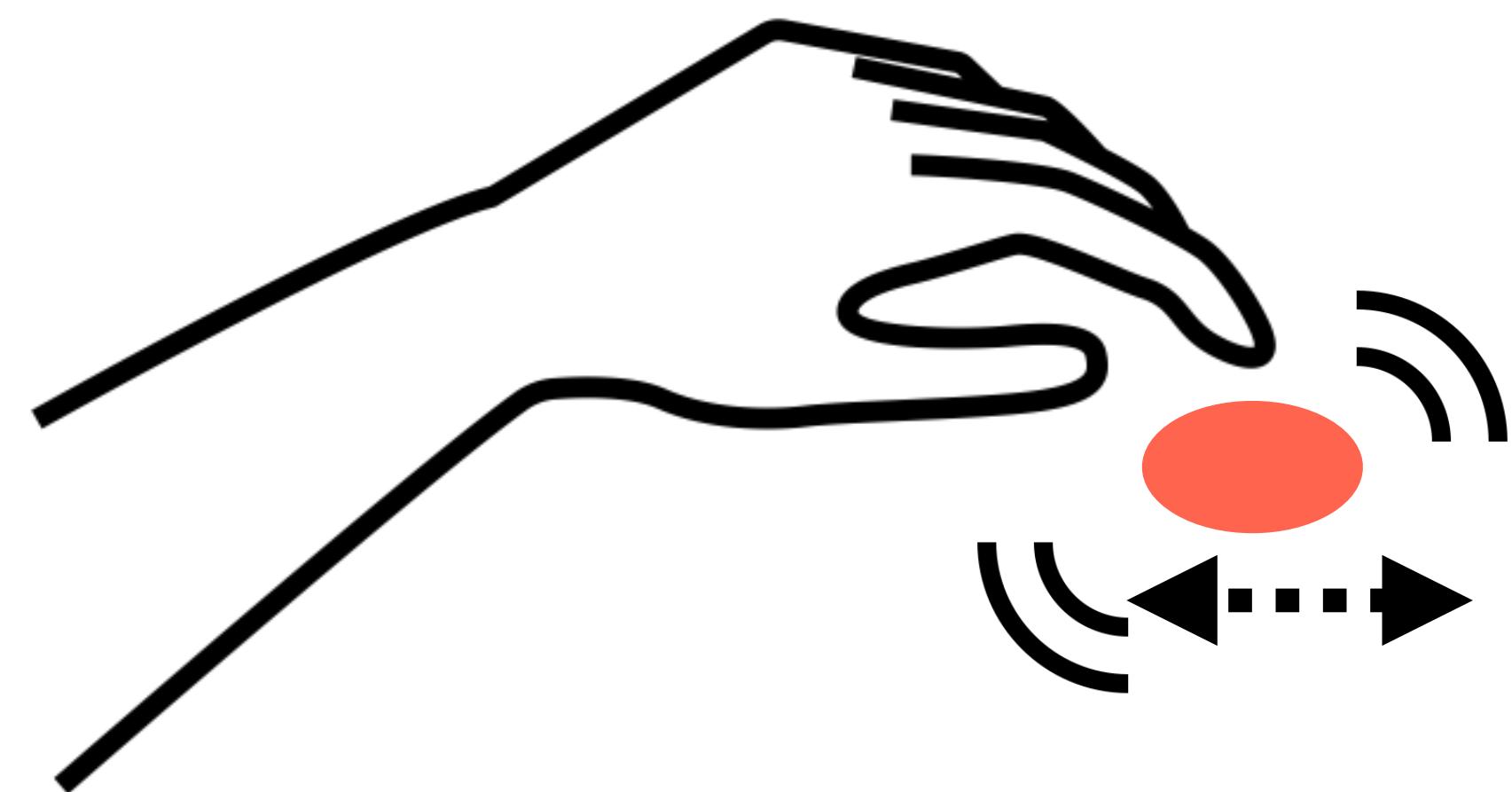
*Even if you start taking time to explore
around, they might think you are lost
— which you are not — and try to show
you around.*

**Educational application
for classroom use**

P6 “*This would be useful if it was synced up with a lecture and graphics, or even if it was synced with an instructors laser pointer; if it was tracking what was up on the board, and I could follow along, that would be amazing.*”

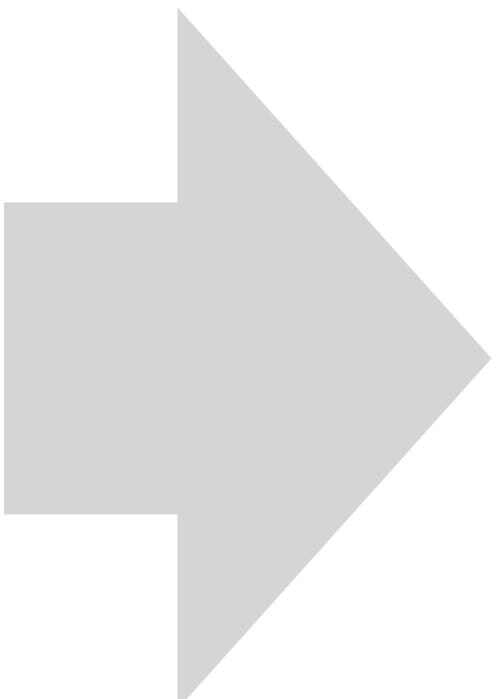
Limitations

Unstable Position

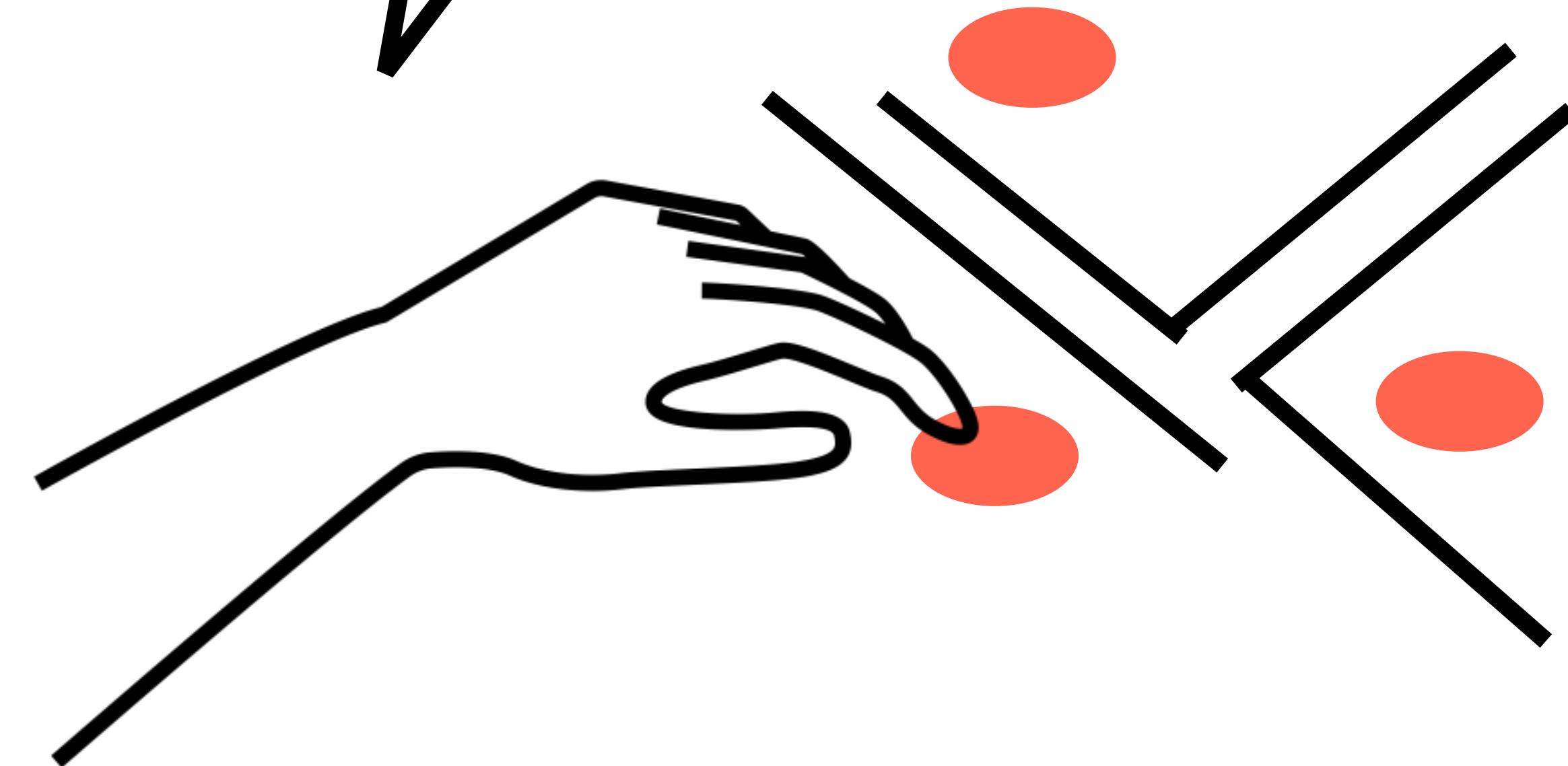


Touch Interaction

Show me the
nearby
restaurants



Tell me a menu and
open hours of this



Future Vision

UbiSwarm [Kim et al 2017]



Page 3 of 3
Permission to Take Part in a Human Research Study

What happens if I do not want to be in this research, or if I say yes, but I change my mind later?

Participants are welcome to leave at any time. Leaving will not be held against you. Partially answered

What happens to the information collected for the research?

During the interview, the researchers will collect data on subjective feedback about the experience. The data will be used to assess the development product qualitatively, to improve the usability of the technology, and to plan further development.

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Participants (80%) completion or less) will not be used for this research.

Interviews (80% completion or less) will not be held against you. Partially answered

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What else do I need to know?

This research is funded by a grant from the National Science Foundation.

Permission to Take Part in this Research:

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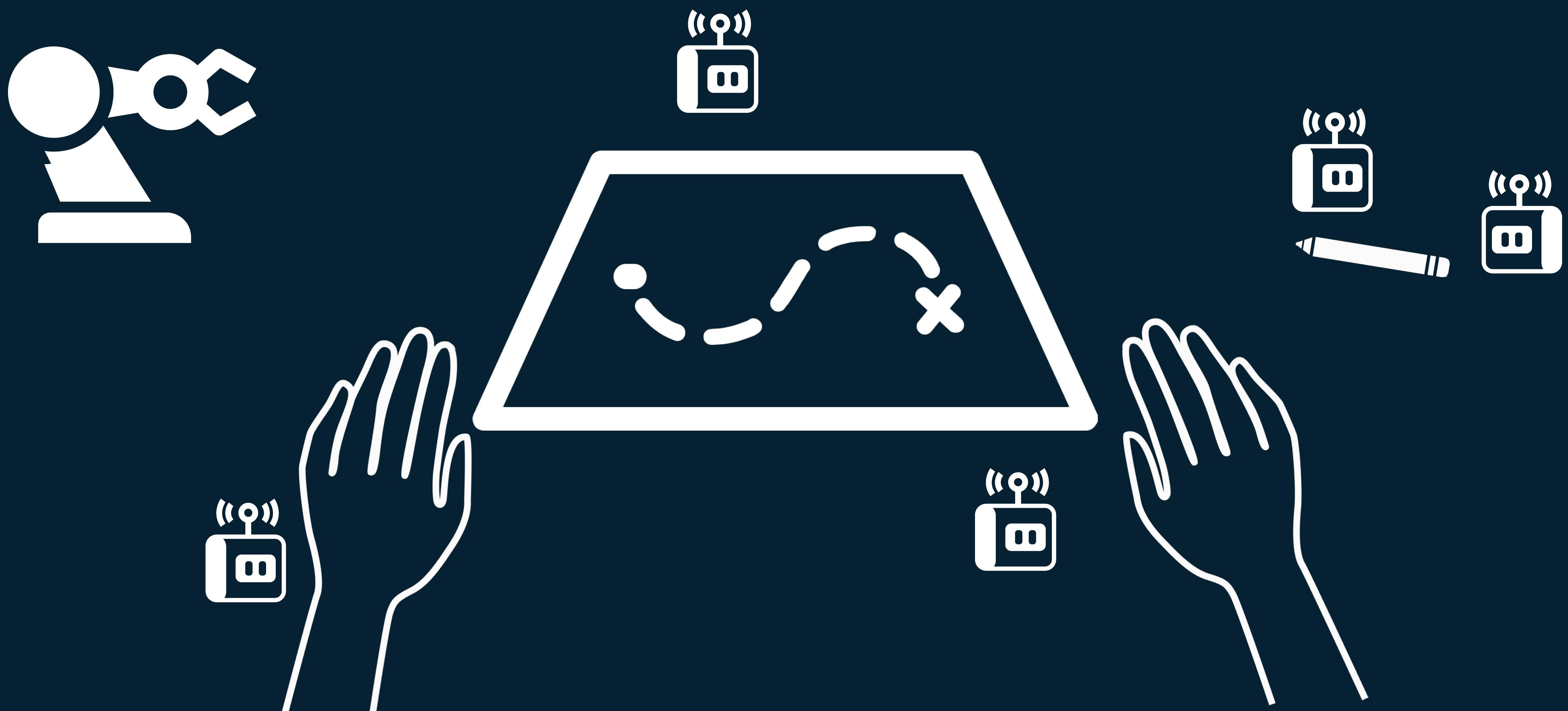
This research is funded by a grant from the National Science Foundation.

YES

NO

IRB Approval Date

Interactive Physical Assistant





University of Colorado
Boulder



FluxMarker: Enhancing Tactile Graphics with Dynamic Tactile Markers

Ryo Suzuki, Abigale Stangl, Mark D. Gross, Tom Yeh