



University of Colorado  
Boulder

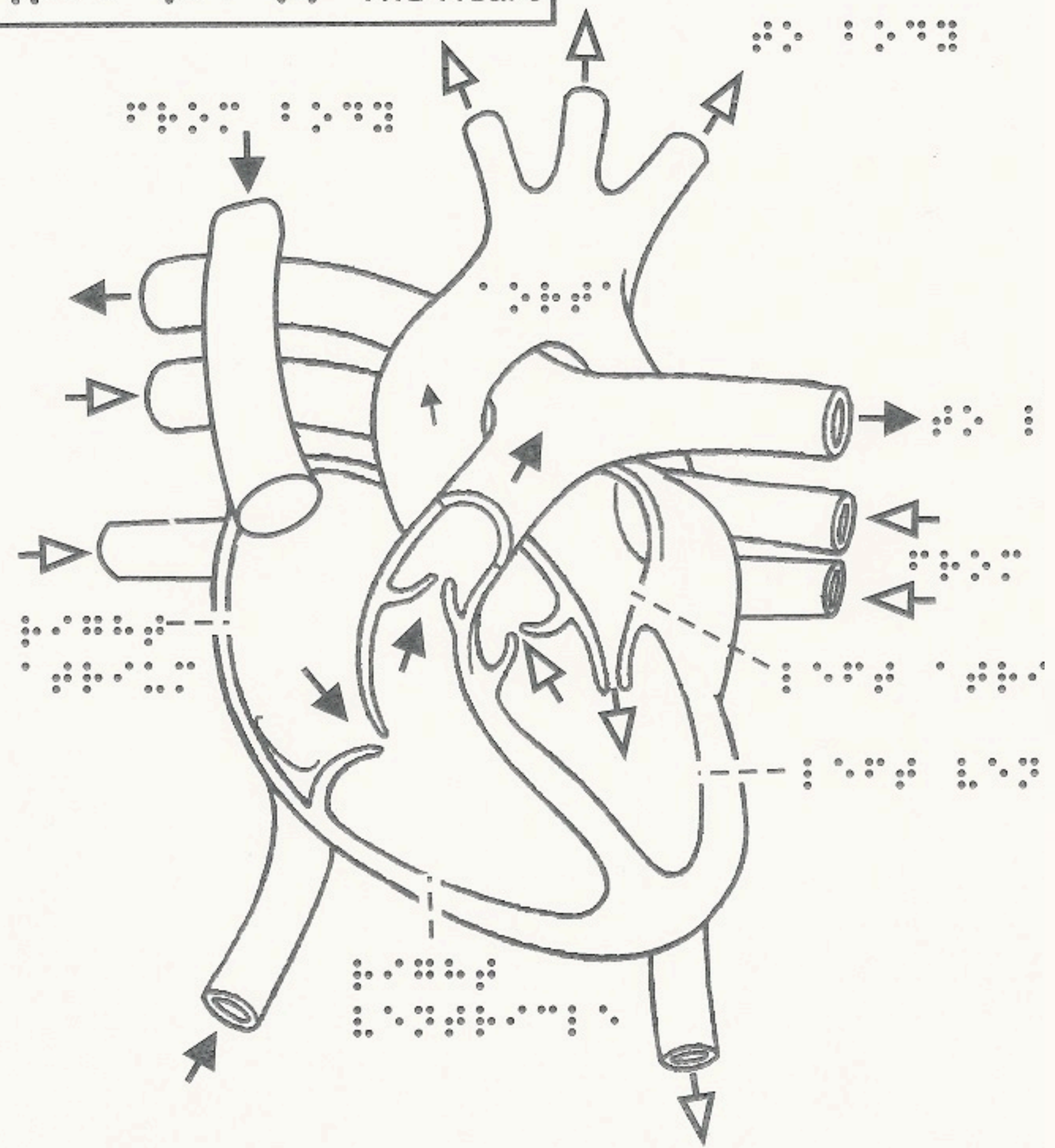


# **FluxMarker:** Enhancing Tactile Graphics with Dynamic Tactile Markers

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



The Heart

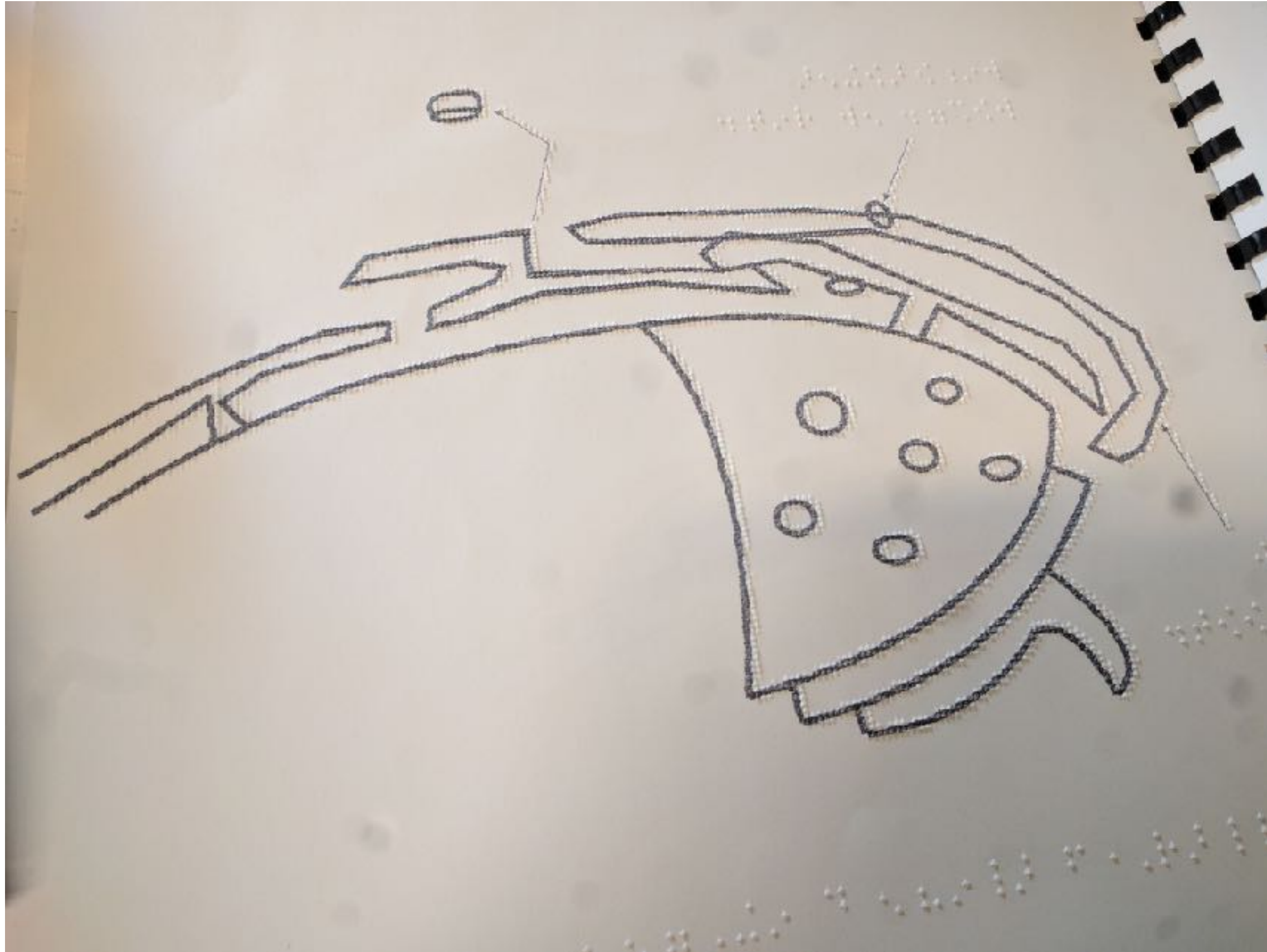


Classifying polygons

What polygon?	Number of sides	Example
Triangle	3	
Quadrilateral	4	
Pentagon	5	
Hexagon	6	



## Traditional Tactile Graphics



**static** and **not interactive**

## Refreshable Braille Display

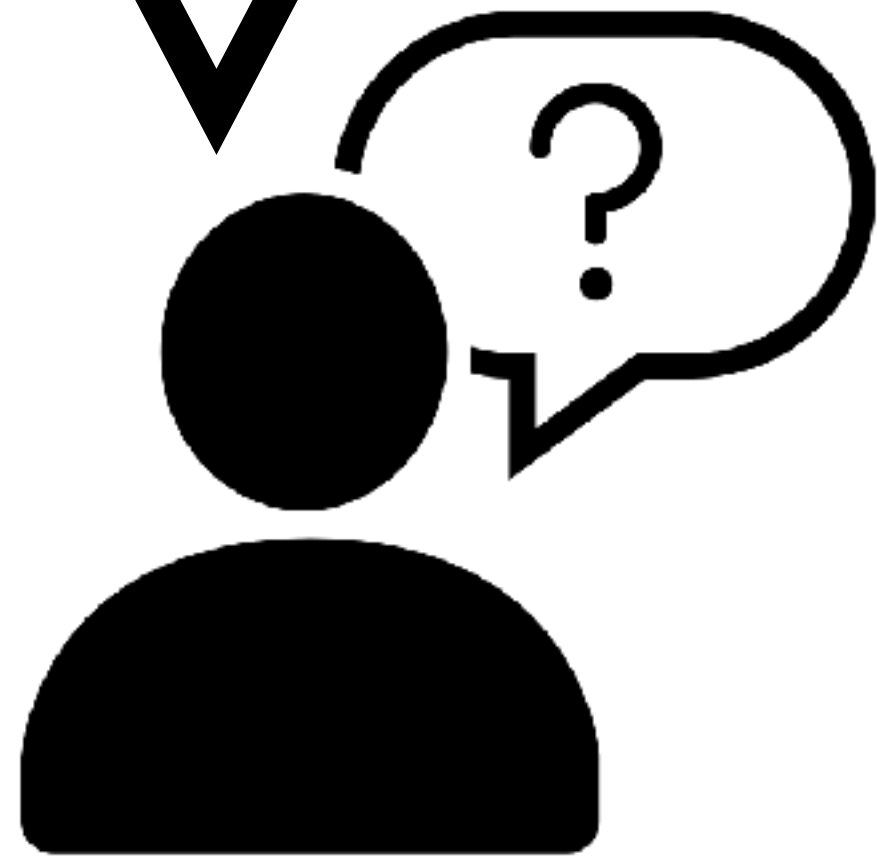


**expensive** and **small**



# static and not interactive

Are there any  
coffee shops  
around campus?











**Show me the nearest coffee shops?**

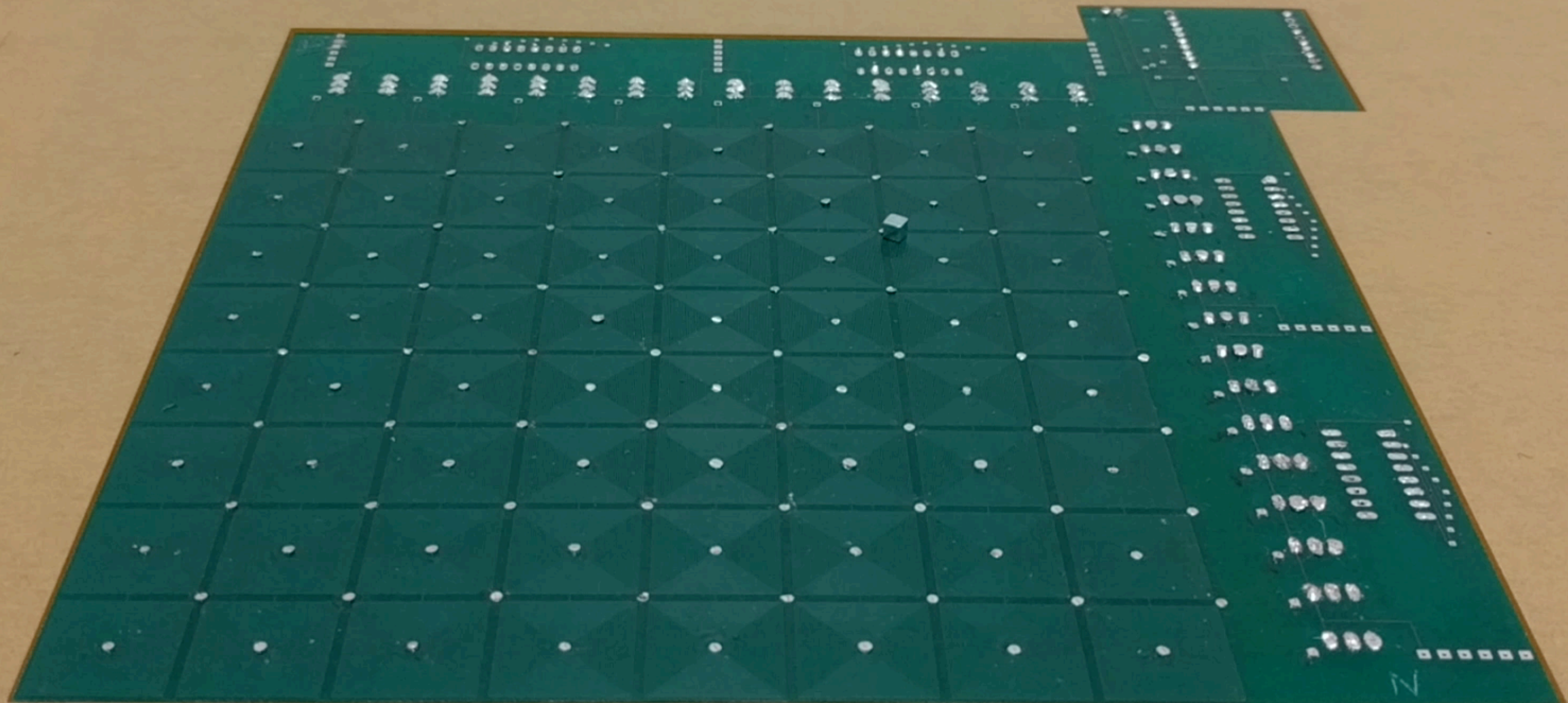


**Dynamic** **Tactile Markers** = **Interactive Tactile Output**





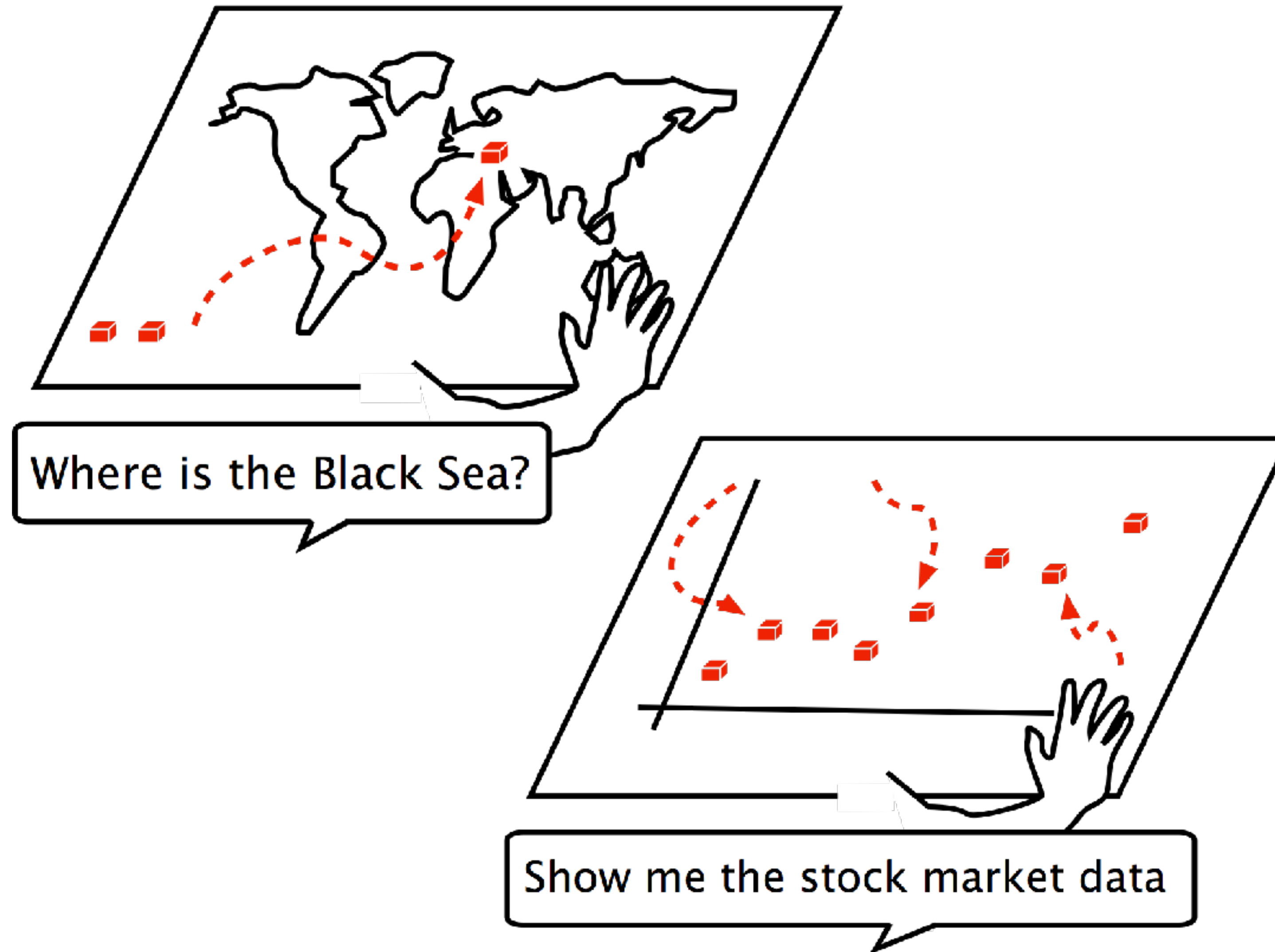
# low-cost + scalable



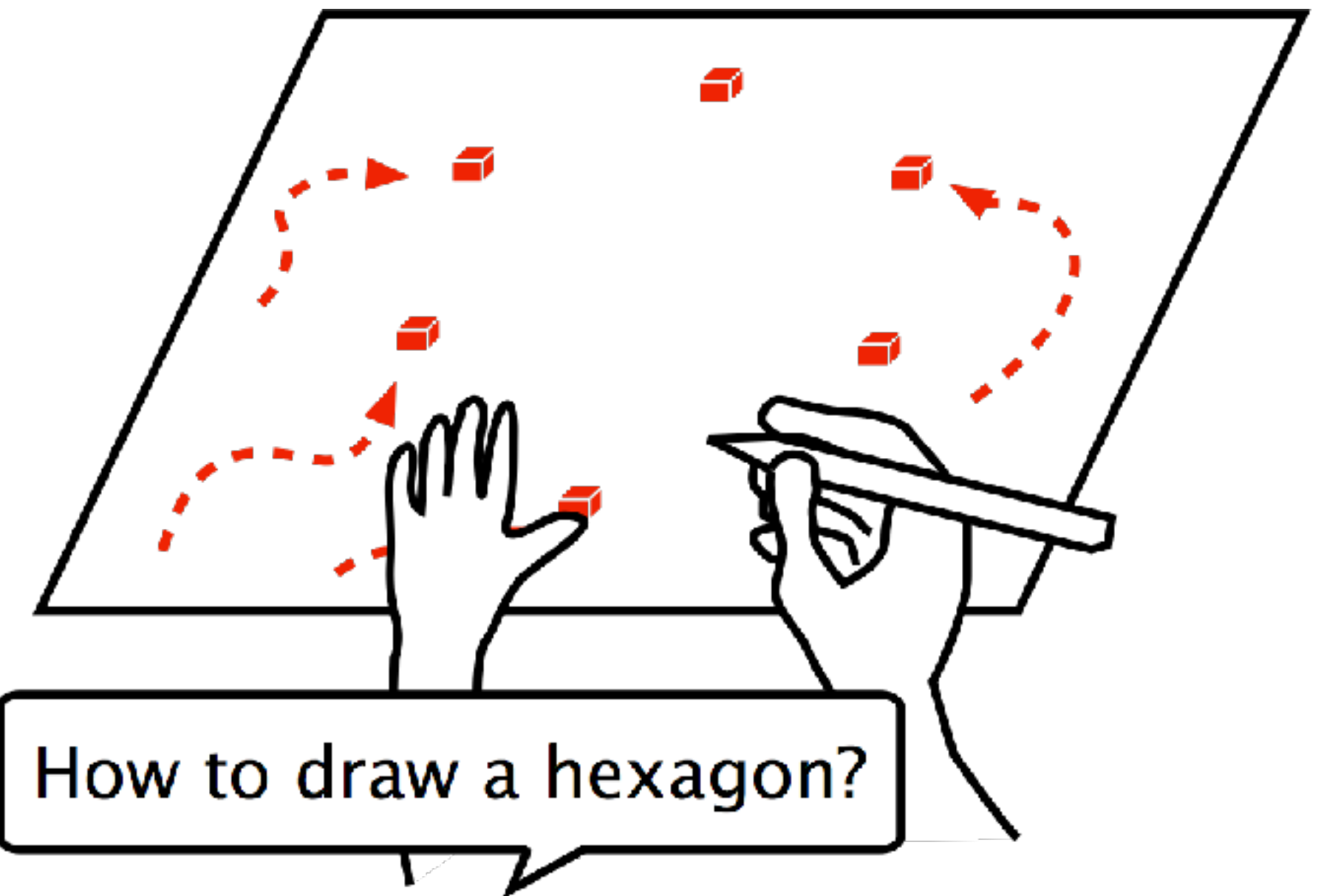
(15cm x 15cm: **\$40**, 100cm x 100cm: **\$200**)



# 1. Spatial Navigation



## 2. Data Analysis



## 3. Guided Drawing



1. Summary

## **2. Motivation**

3. Design and Implementation

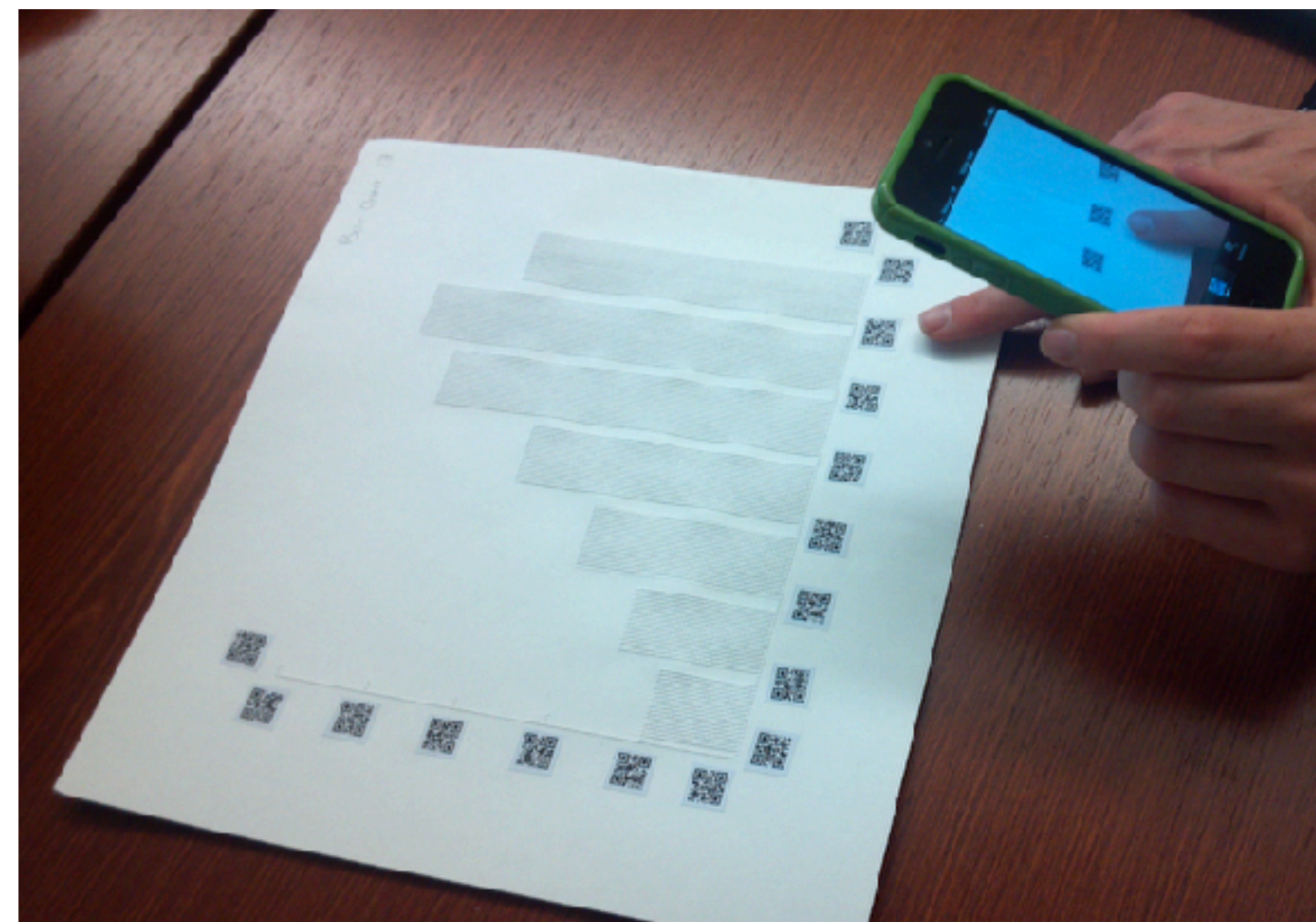
4. User Study



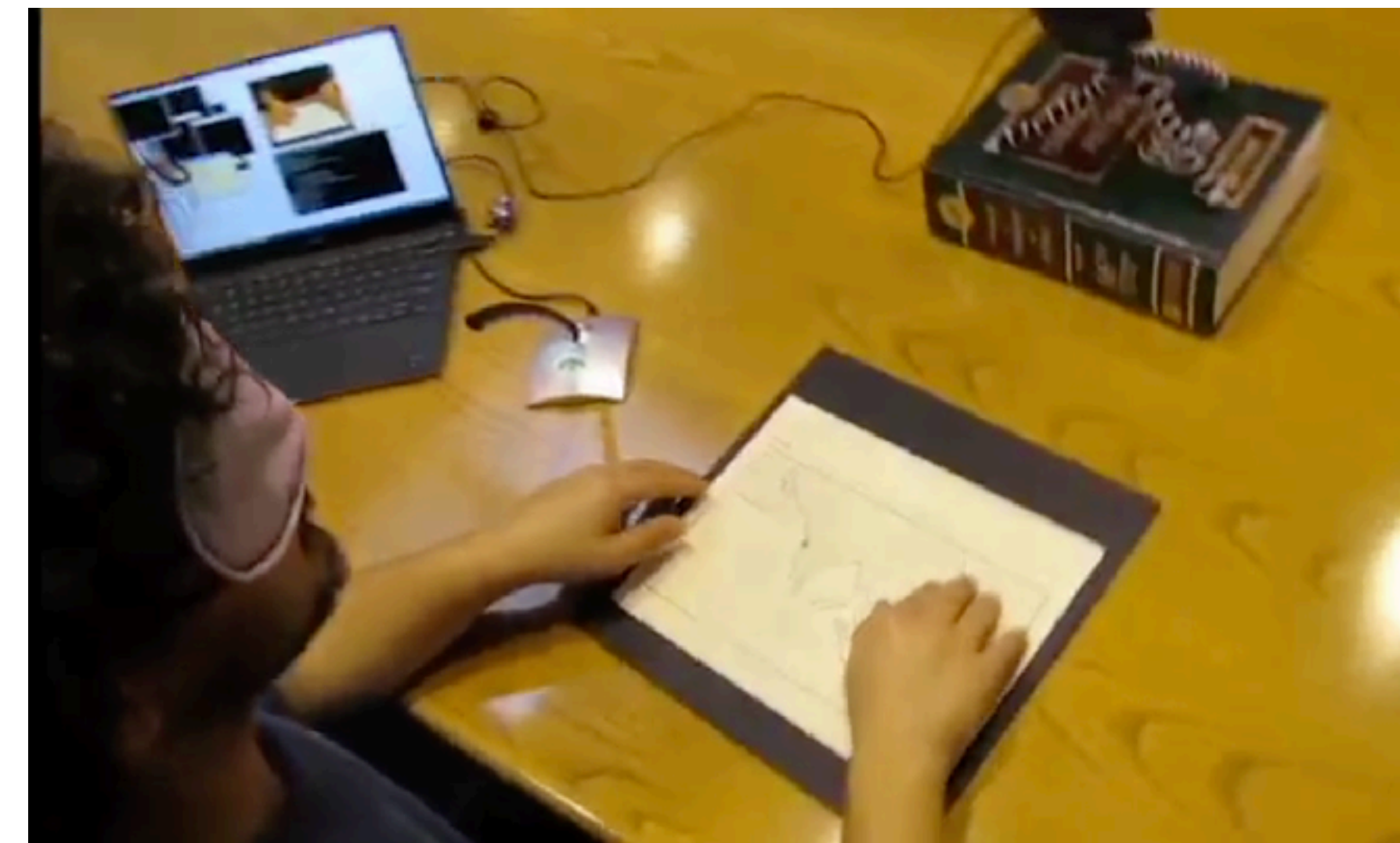
# Interactive Tactile Graphics



Talking Tactile Tablet [2001]



Baker et al. [ASSETS 2014]



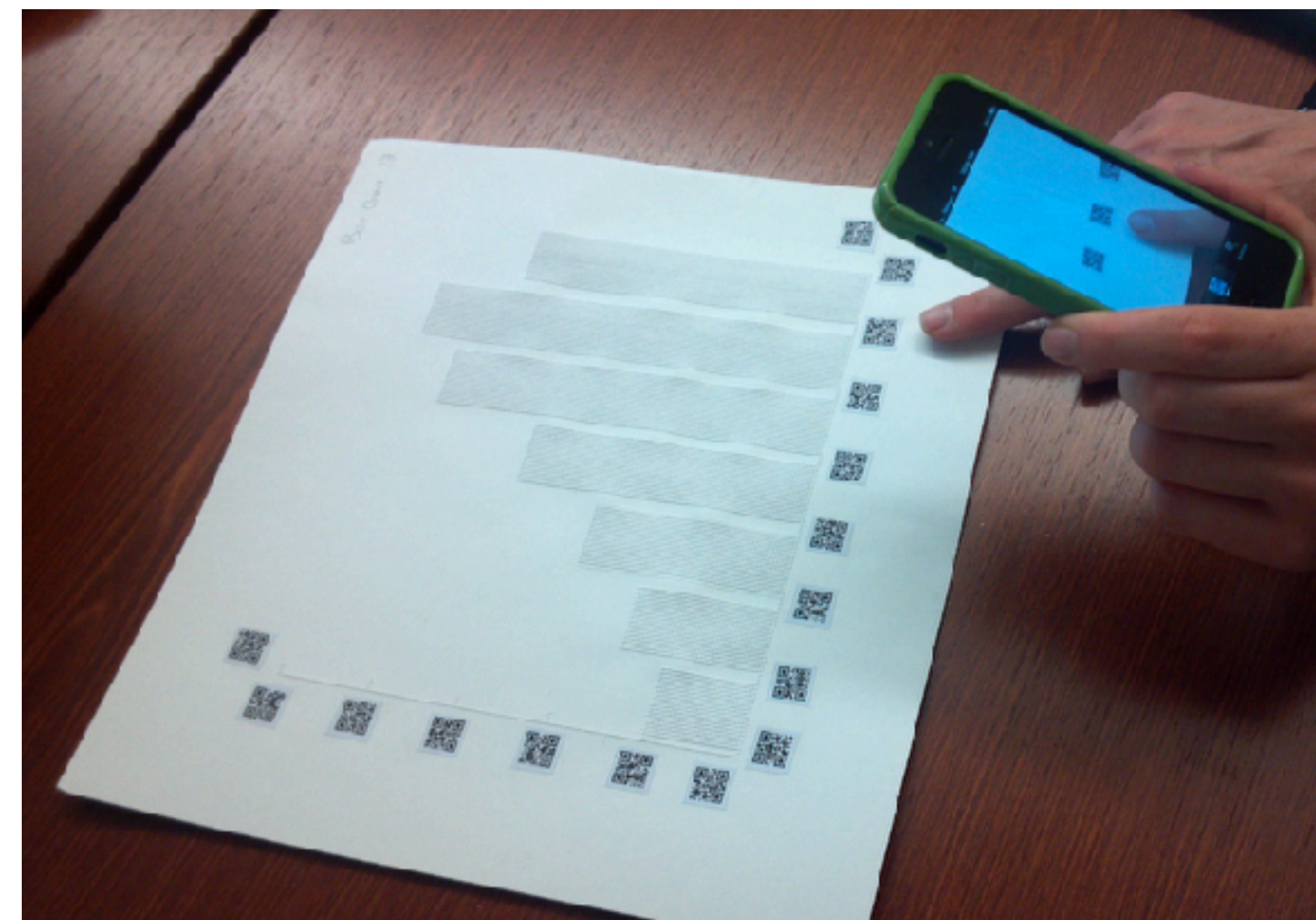
Fusco et al. [ASSETS 2015]



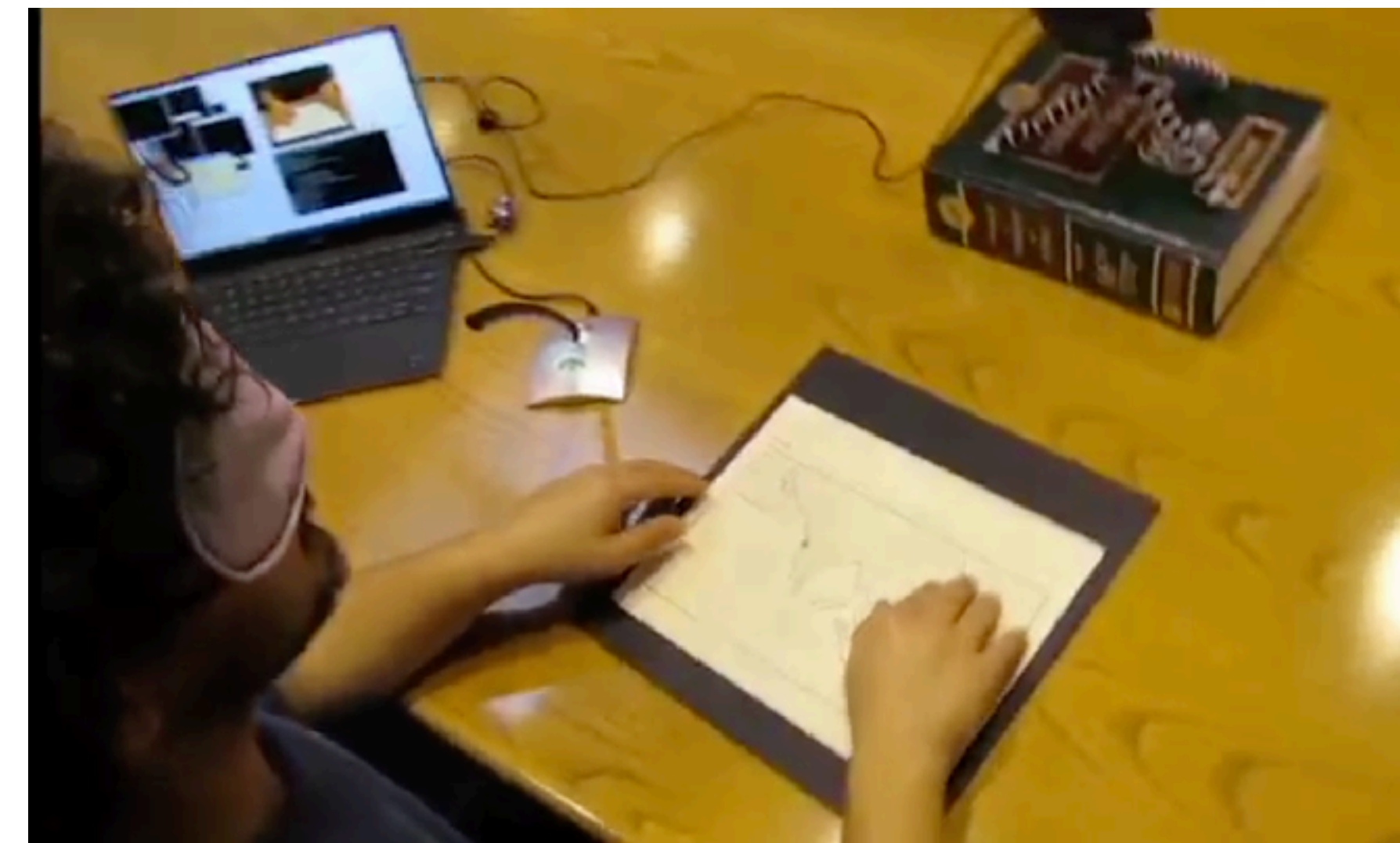
# Interactive Tactile Graphics = Audio Output



Talking Tactile Tablet [2001]



Baker et al. [ASSETS 2014]



Fusco et al. [ASSETS 2015]





**Spatial and Physical Guides**



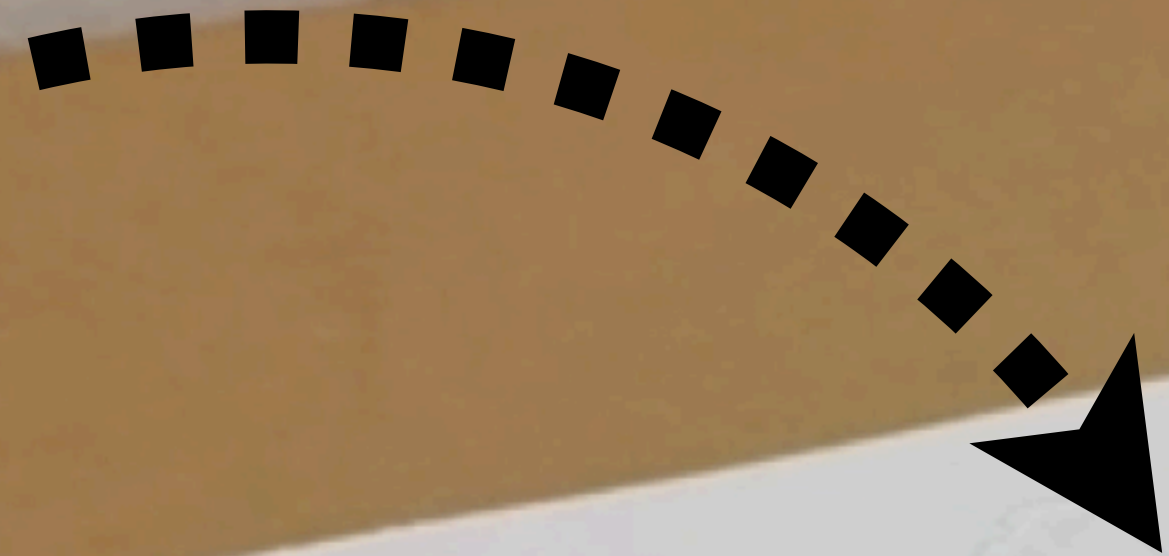
# Audio Output



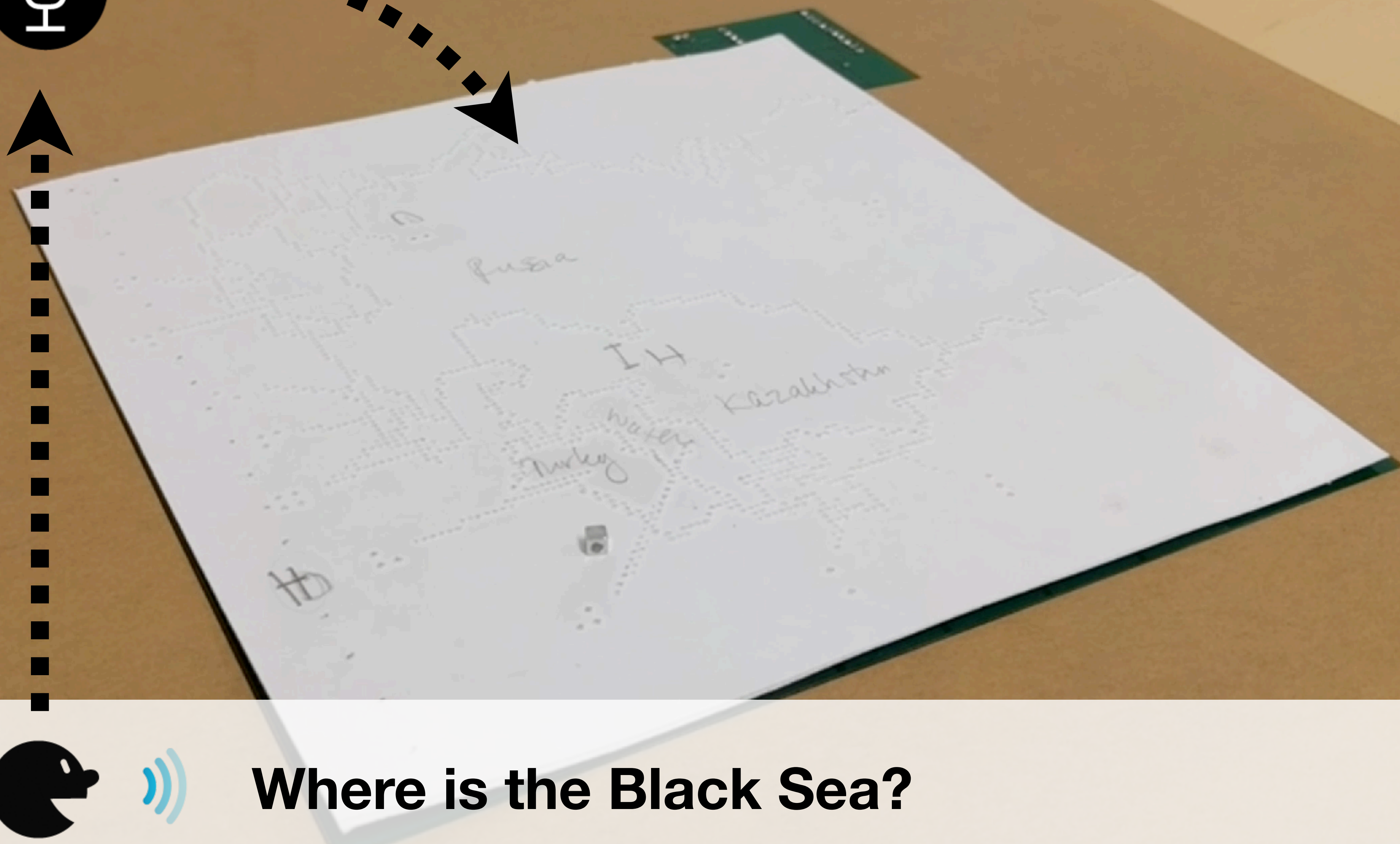
# Tactile Output







**Where is the Black Sea?**





keyword: **coffee shops**

specify

annotations

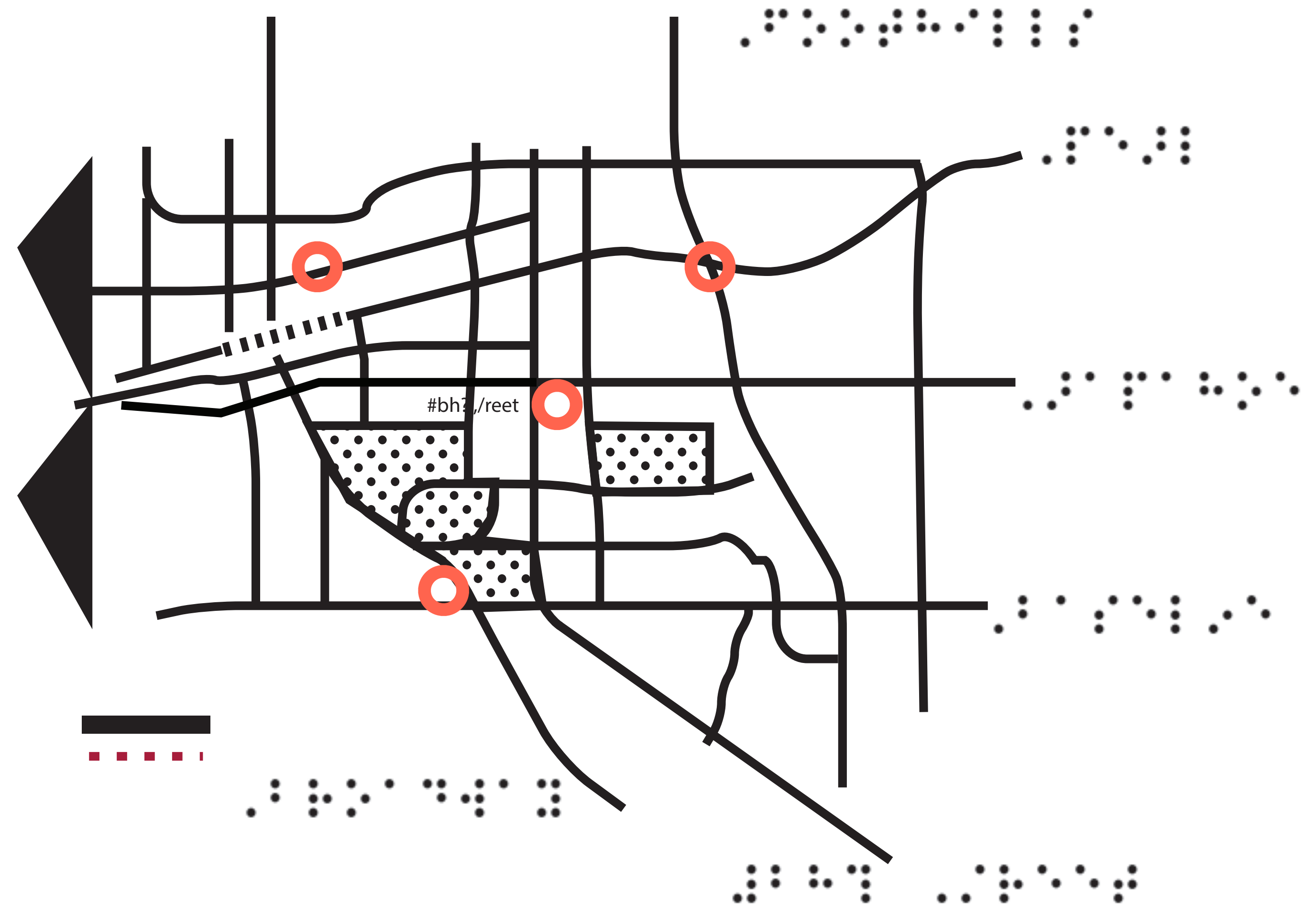


designer





keyword: **coffee shops**



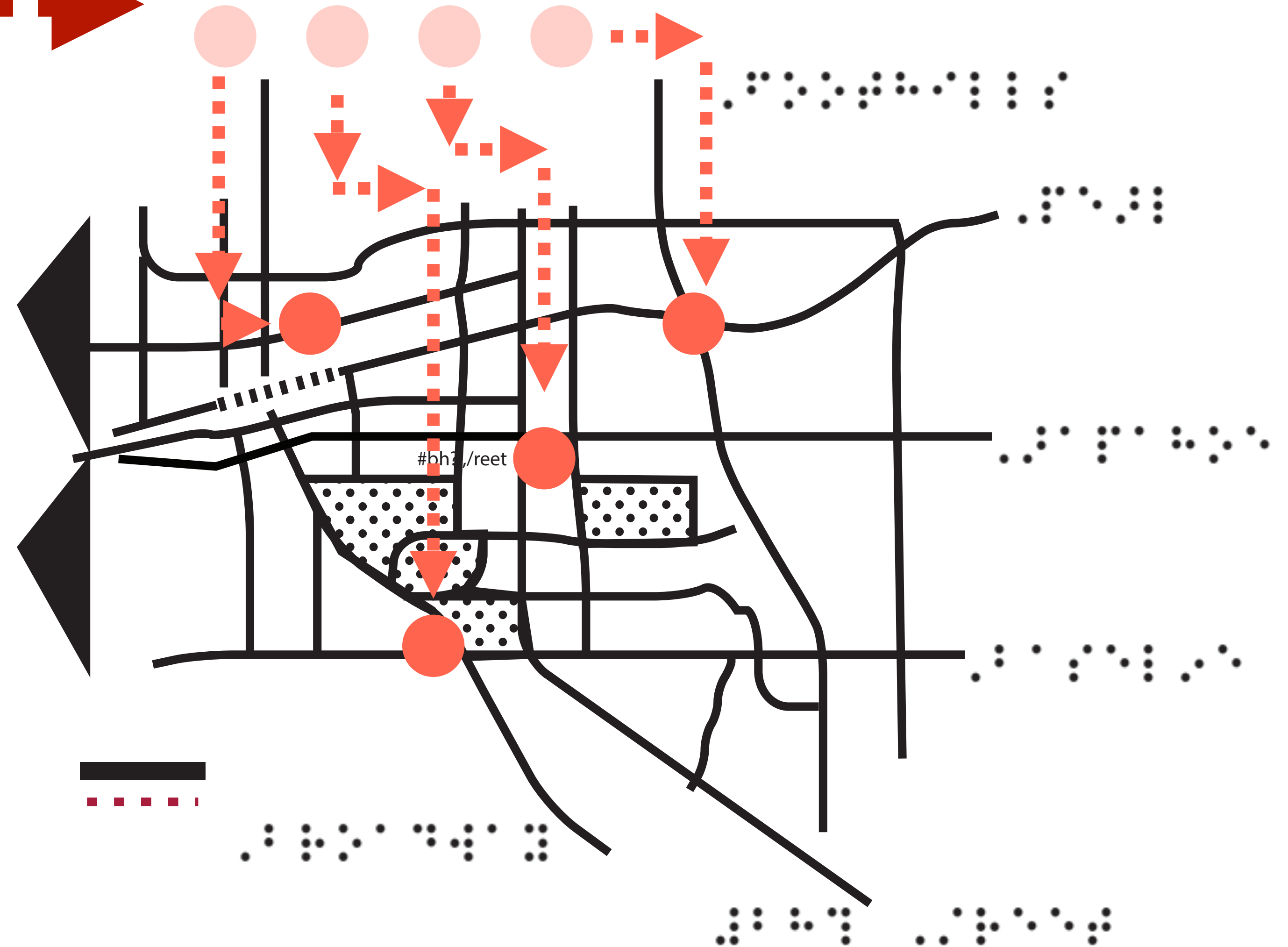
blind user



“Show me the nearest  
**coffee shops?**”



keyword: **coffee shops**  initial positions



blind user



“Show me the nearest  
**coffee shops?**”



1. Summary

2. Motivation

# **3. Design and Implementation**

4. User Study

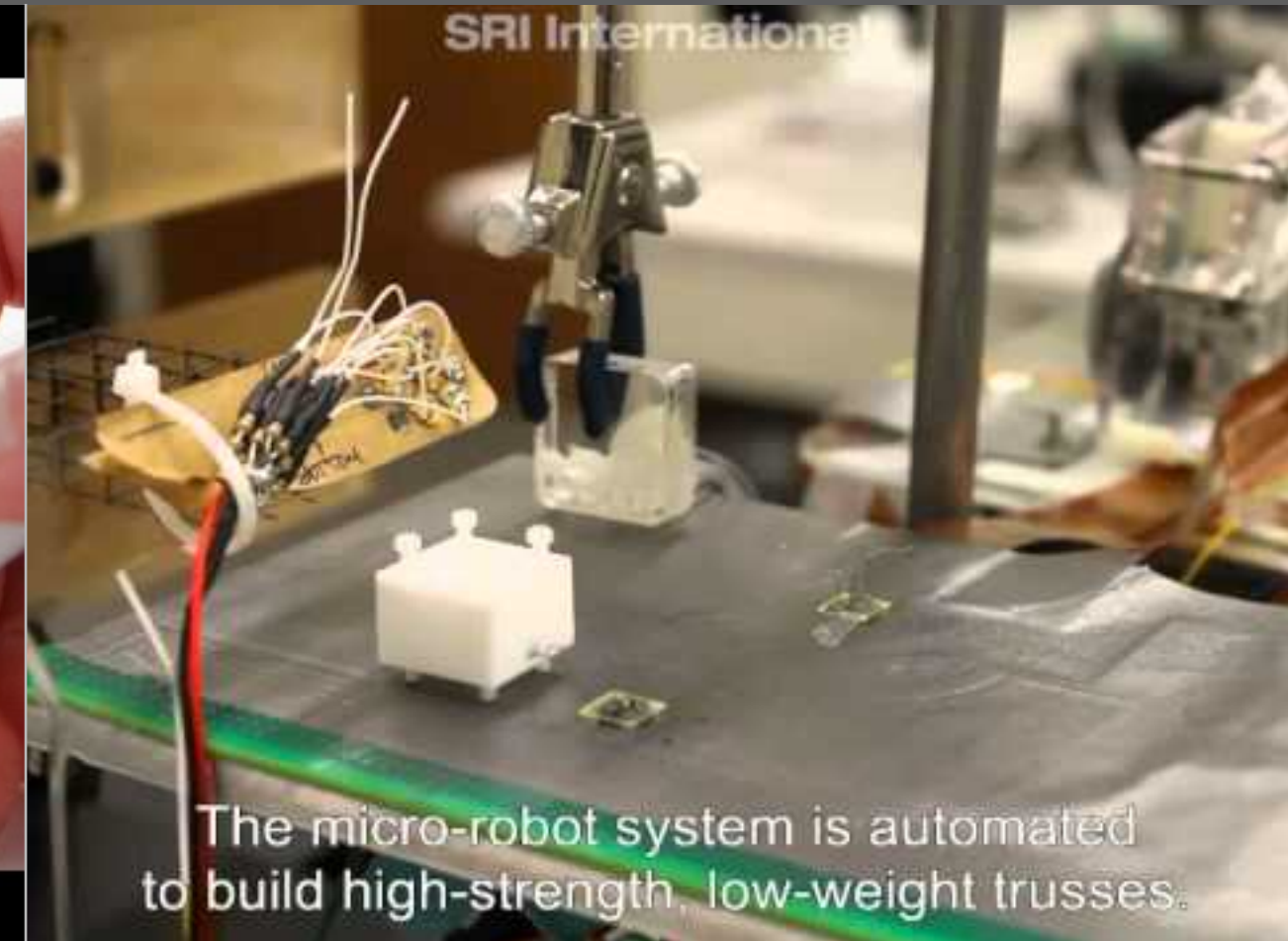
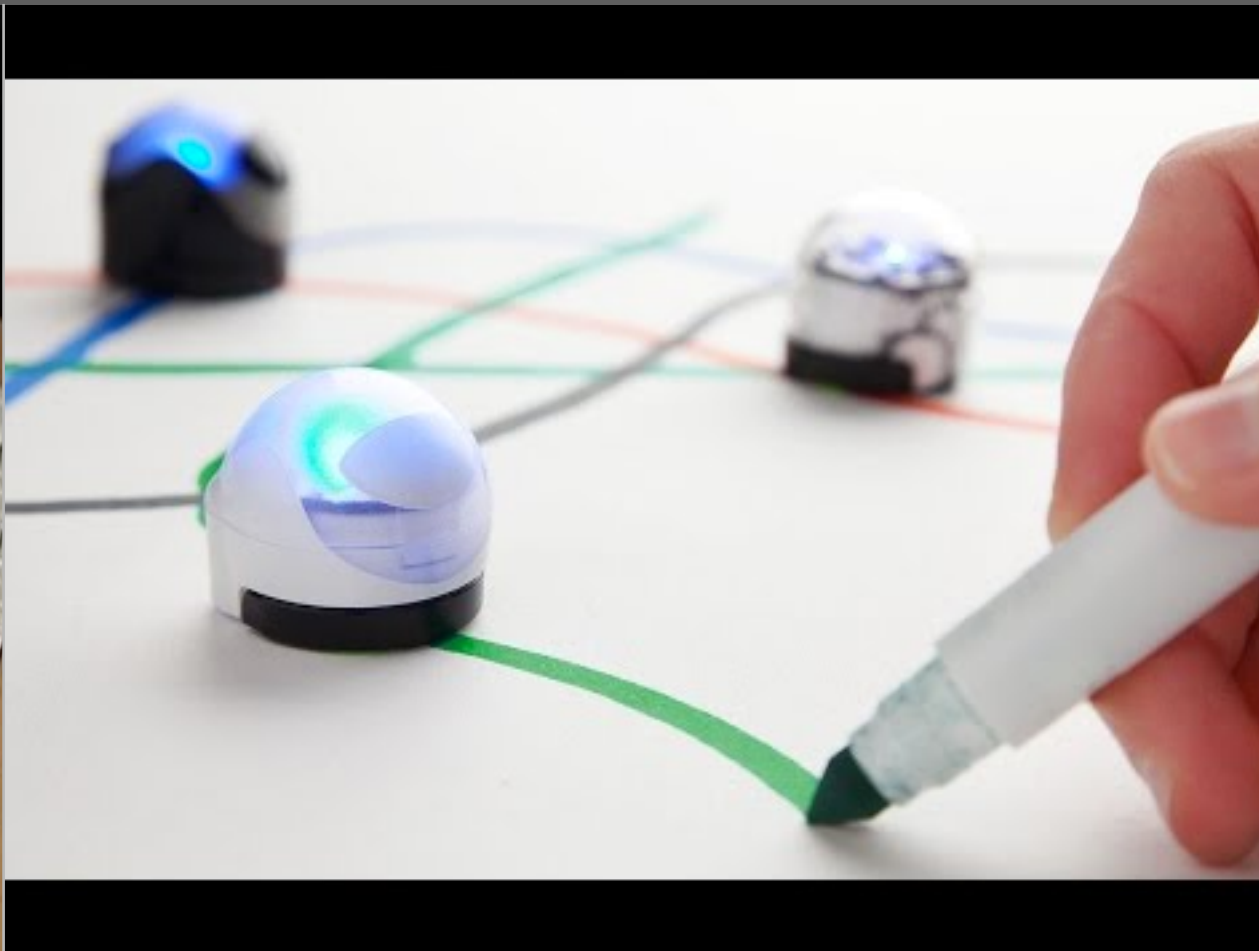
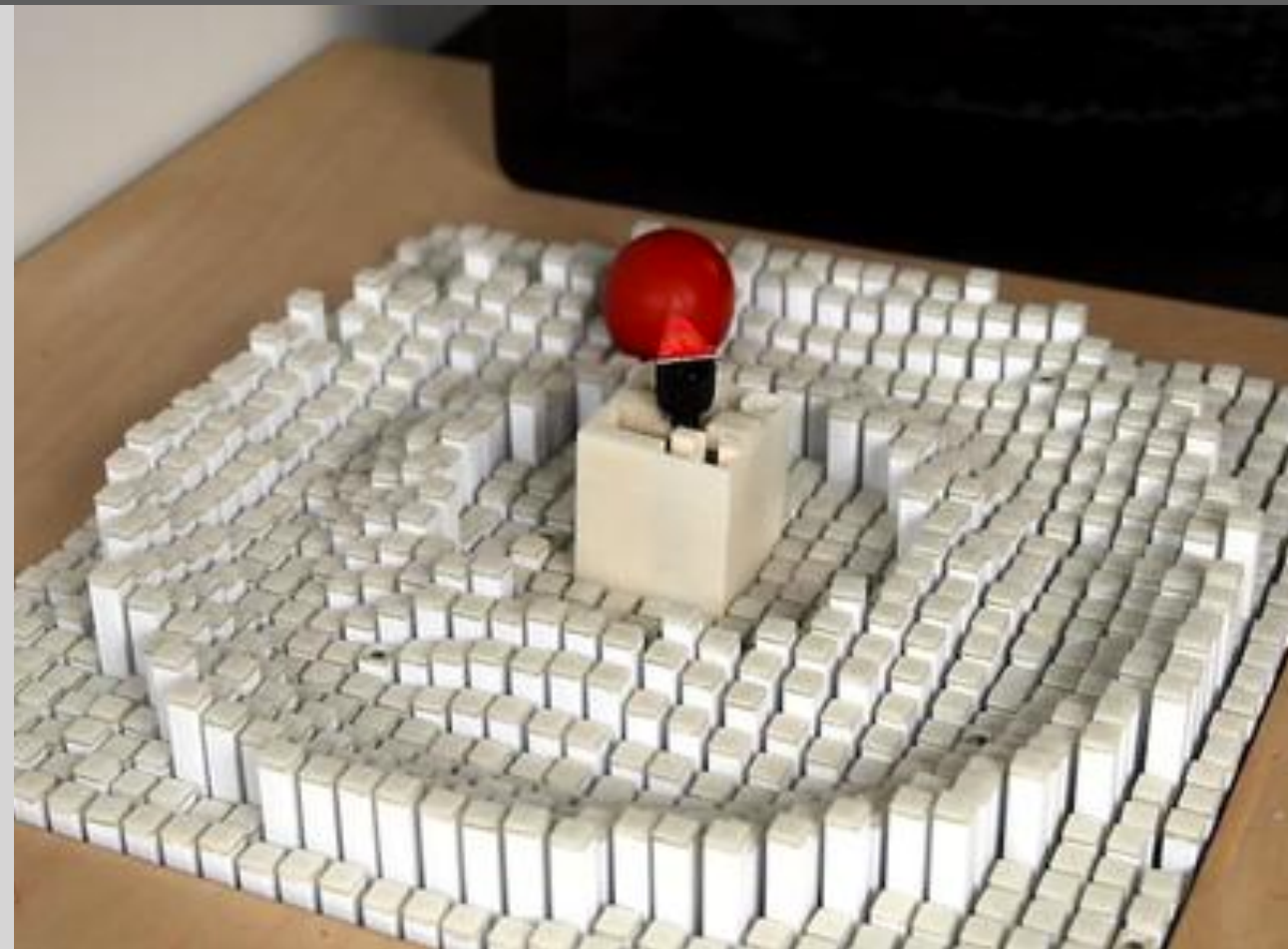


Pin-based

Movable Robots

Electro-magnetic

Example



Cost and Scalability

✗  
(10x10 = \$500)

✓  
(each marker = \$50)

✓  
(PCB = \$10-20)

Resolution /  
Size of Markers

△  
(resolution: 1-3cm)

△  
(size: 3-5 cm)

✓  
(size: 0.5-1cm)

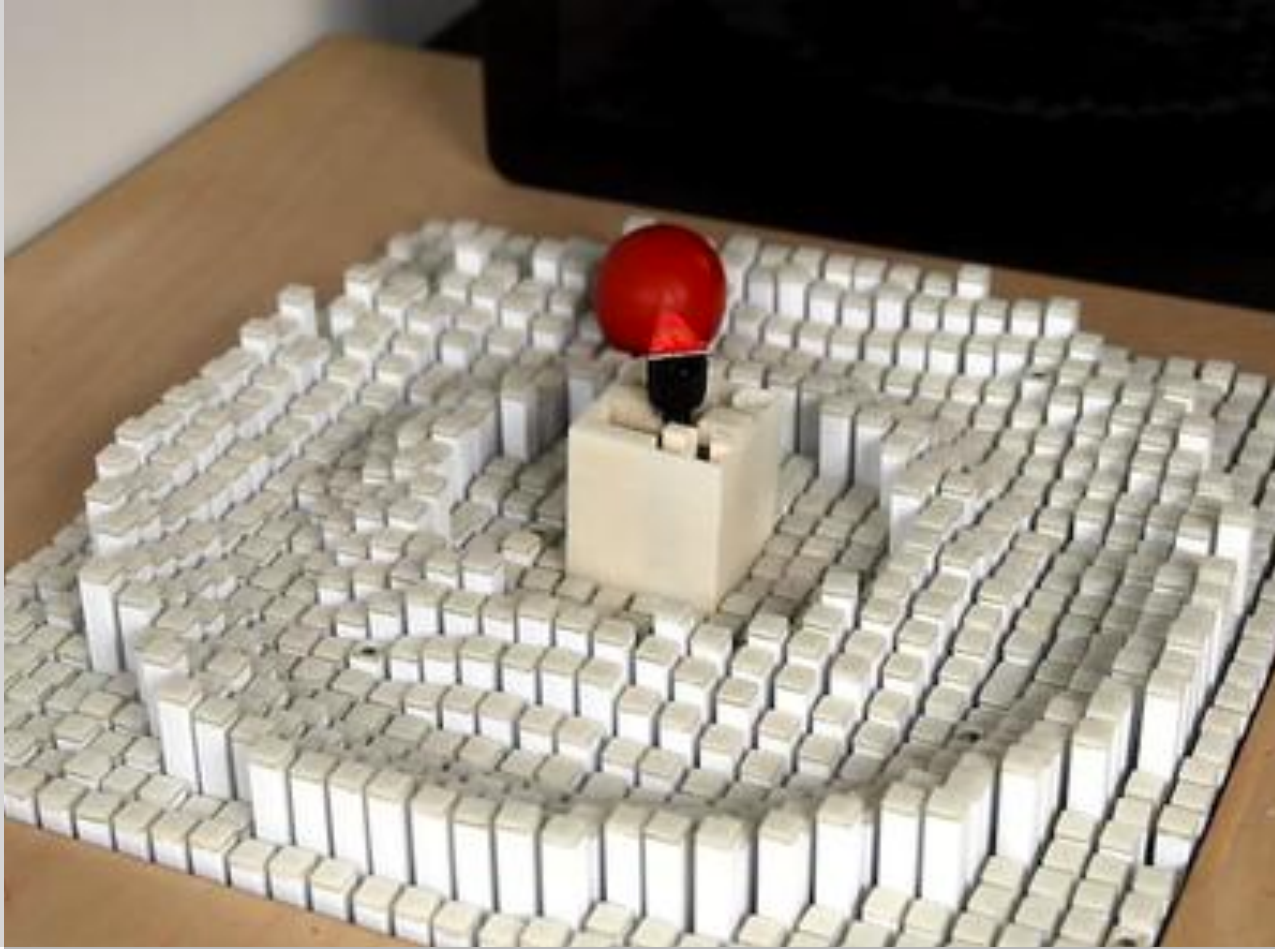


Fabrication Complexity

✓

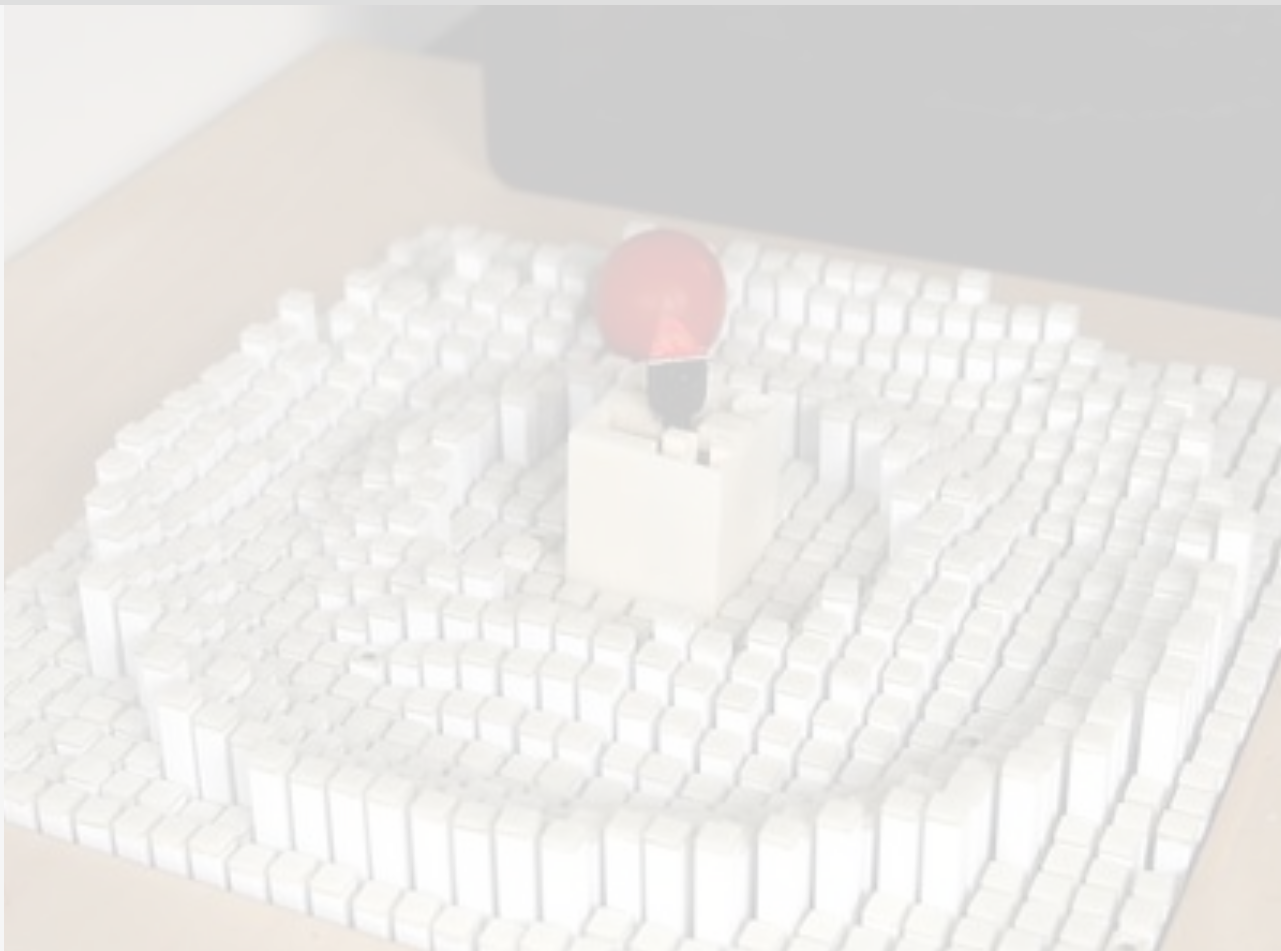
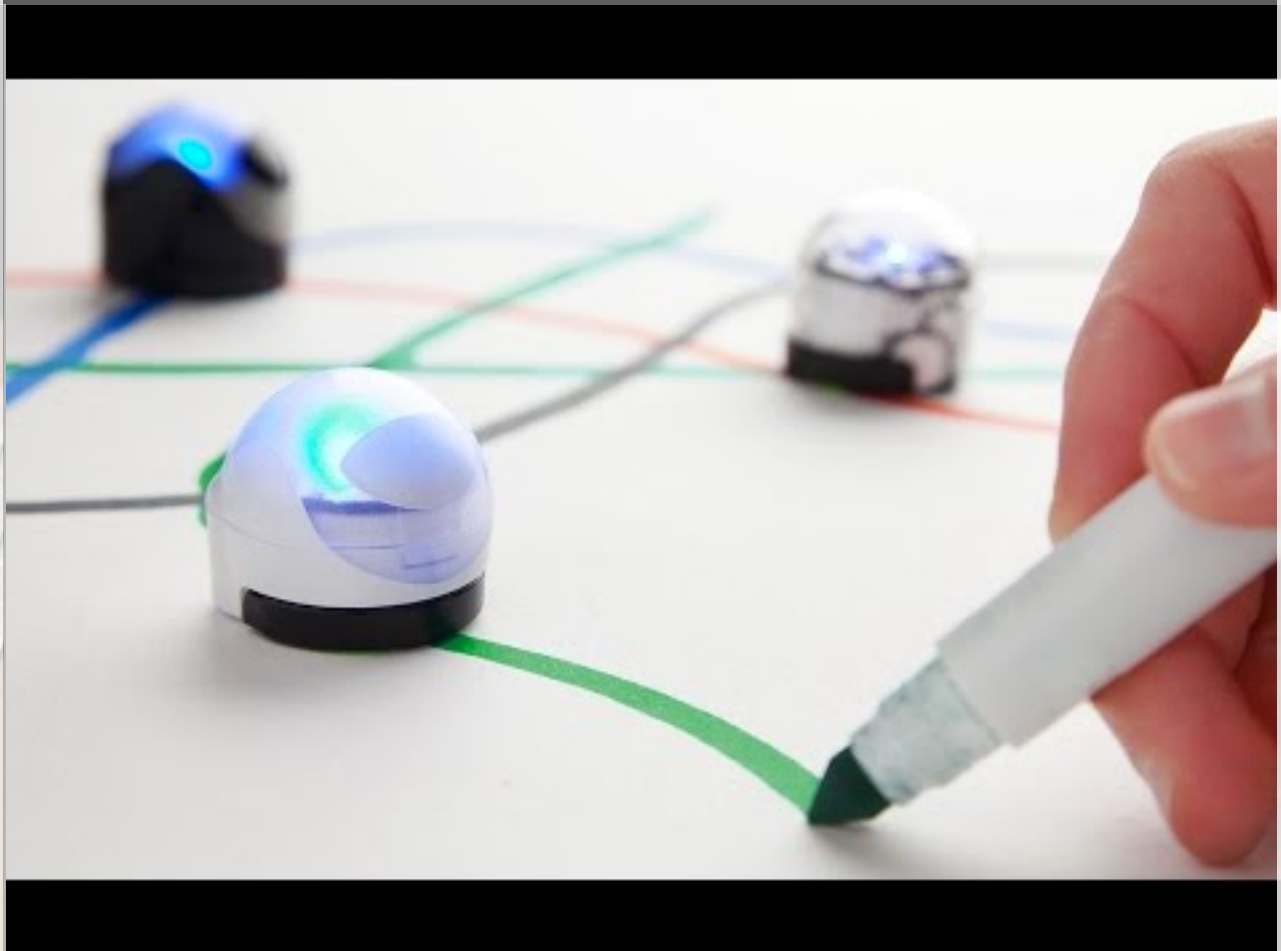

✓

?

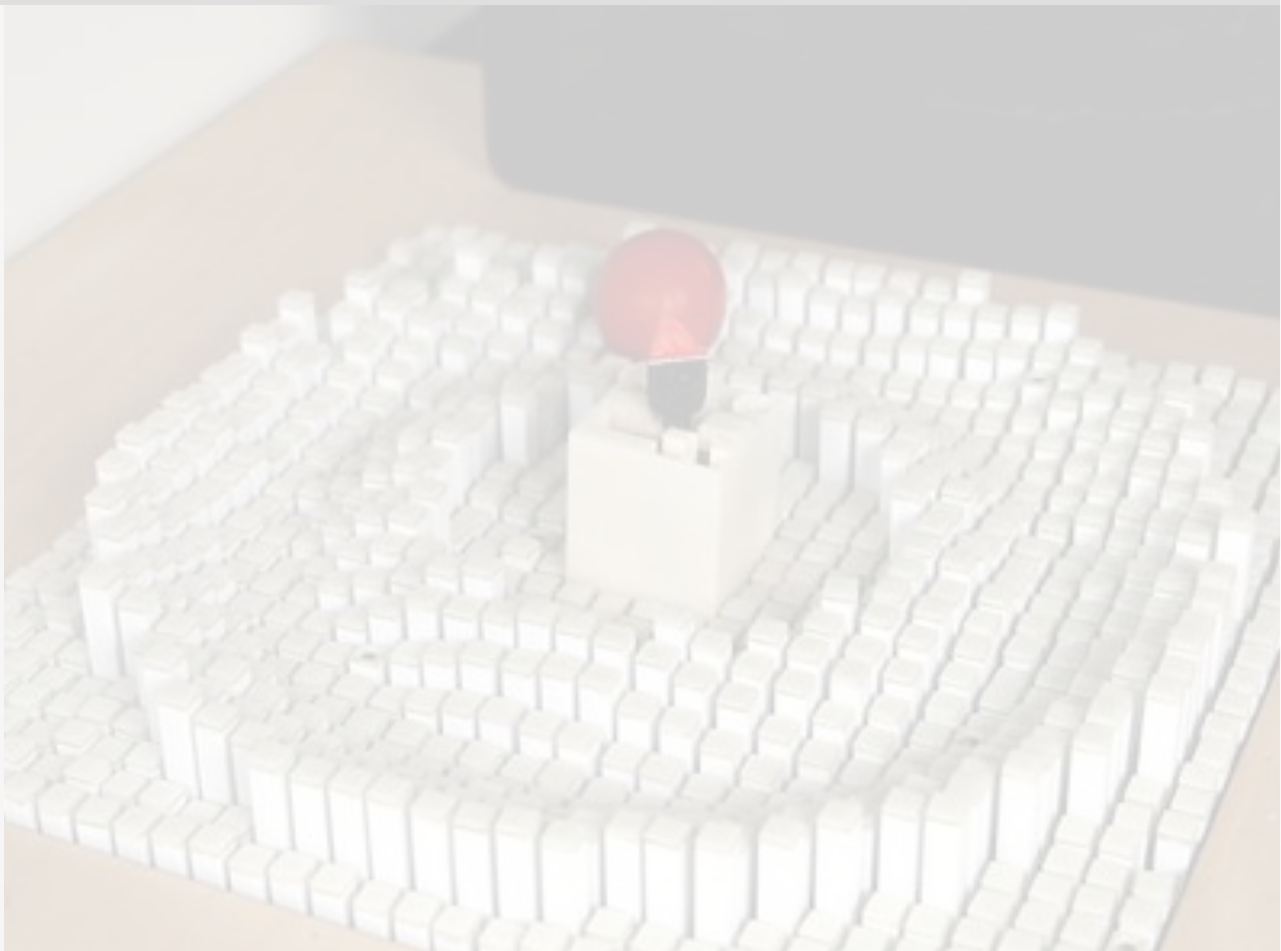

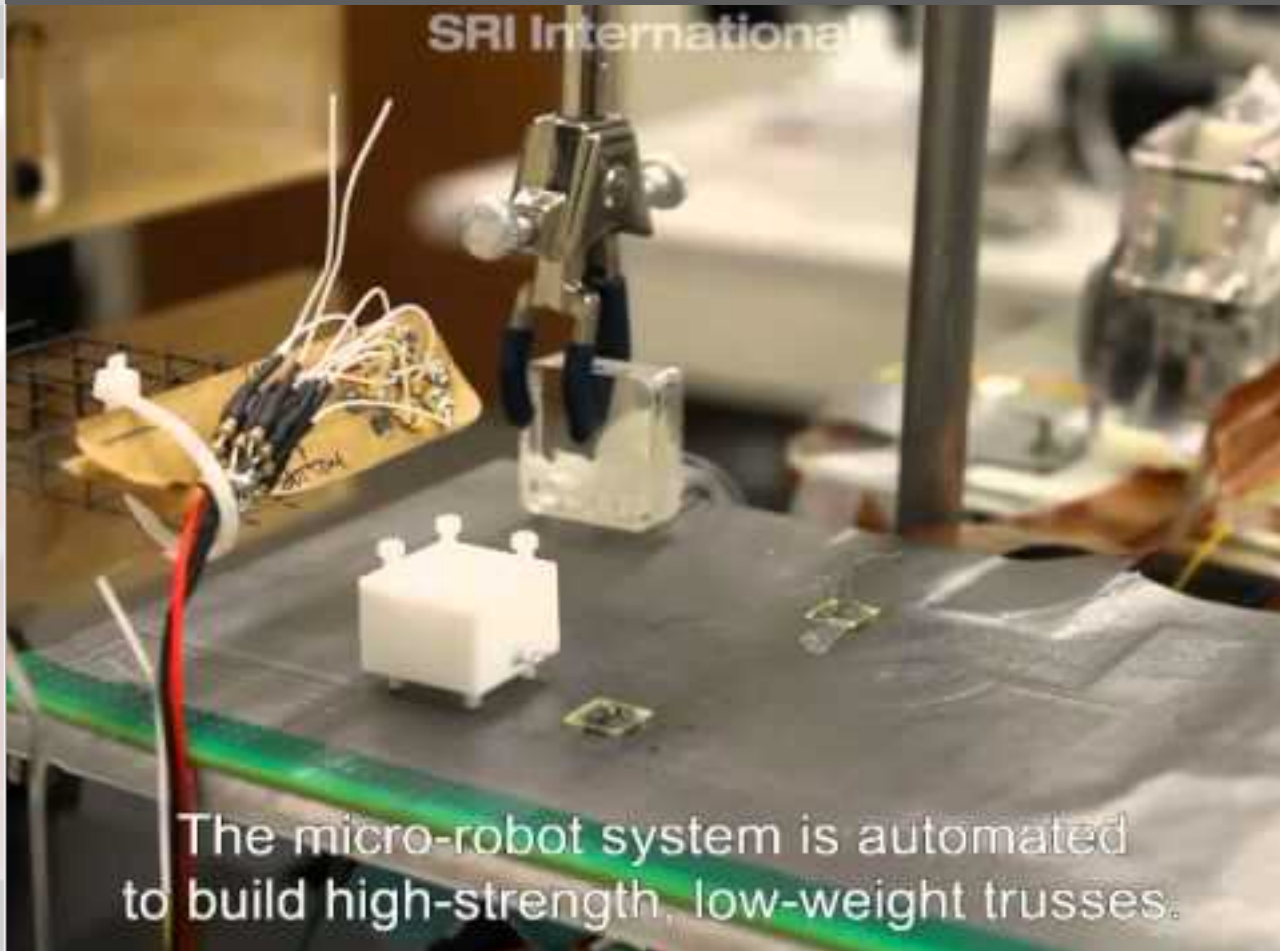


	Pin-based	Movable Robots	Electro-magnetic
Example			
Cost and Scalability	✗ (10x10 = \$500)	✓ (each marker = \$50)	✓ (PCB = \$10-20)
Resolution / Size of Markers	△ (resolution: 1-3cm)	△ (size: 3-5 cm)	✓ (size: 0.5-1cm)
Fabrication Complexity	✓	✓	?

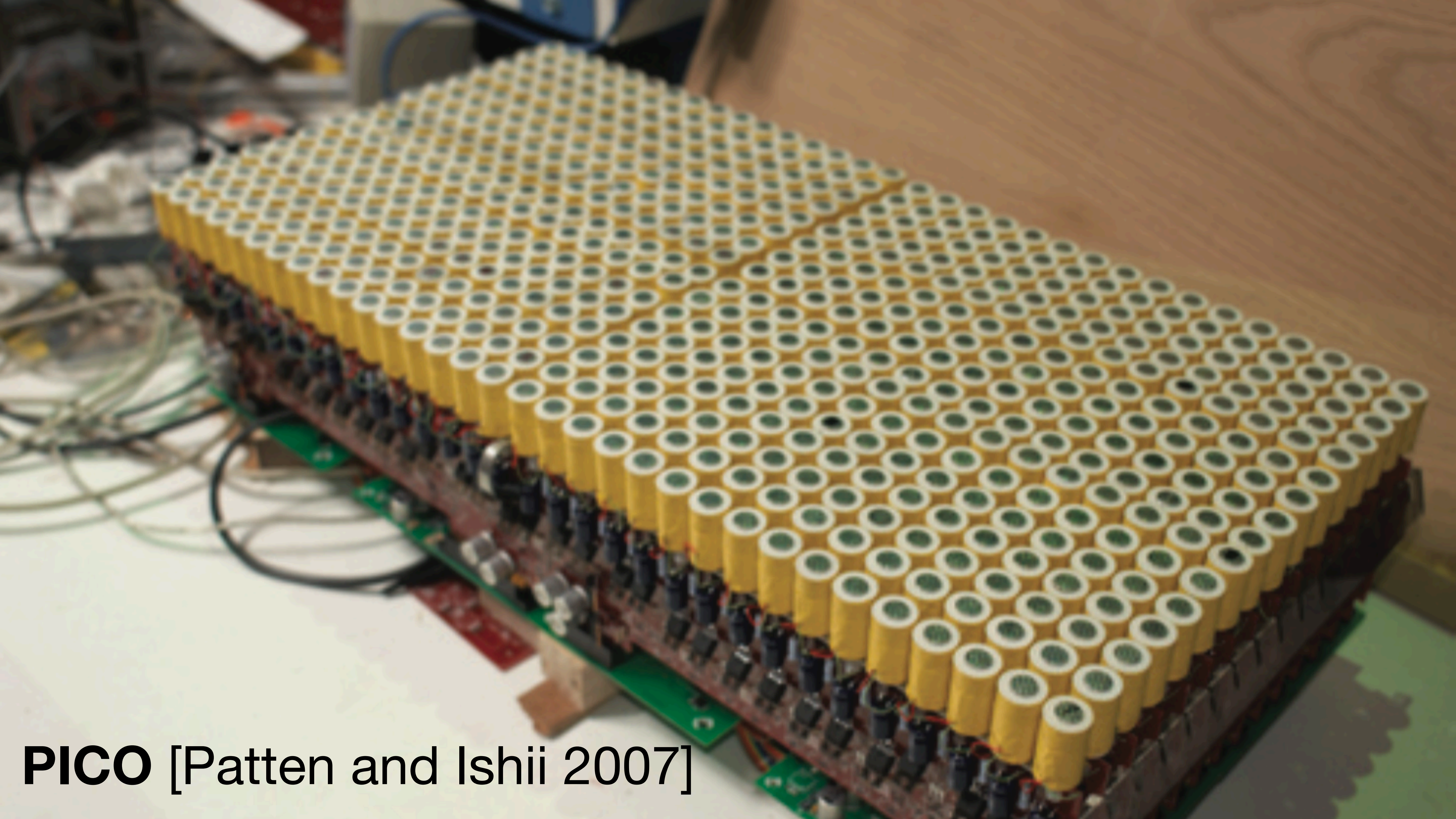


	Pin-based	Movable Robots	Electro-magnetic
Example			 <p>The micro-robot system is automated to build high-strength, low-weight trusses.</p>
Cost and Scalability	✗ (10x10 = \$500)	✓ (each marker = \$50)	✓ (PCB = \$10-20)
Resolution / Size of Markers	△ (resolution: 1-3cm)	△ (size: 3-5 cm)	✓ (size: 0.5-1cm)
Fabrication Complexity	✓	✓	?



	Pin-based	Movable Robots	Electro-magnetic
Example			 <p>The micro-robot system is automated to build high-strength, low-weight trusses.</p>
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Resolution / Size of Markers	△ (resolution: 1-3cm)	△ (size: 3-5 cm)	✓ (size: 0.5-1cm)
Fabrication Complexity	✓	✓	?





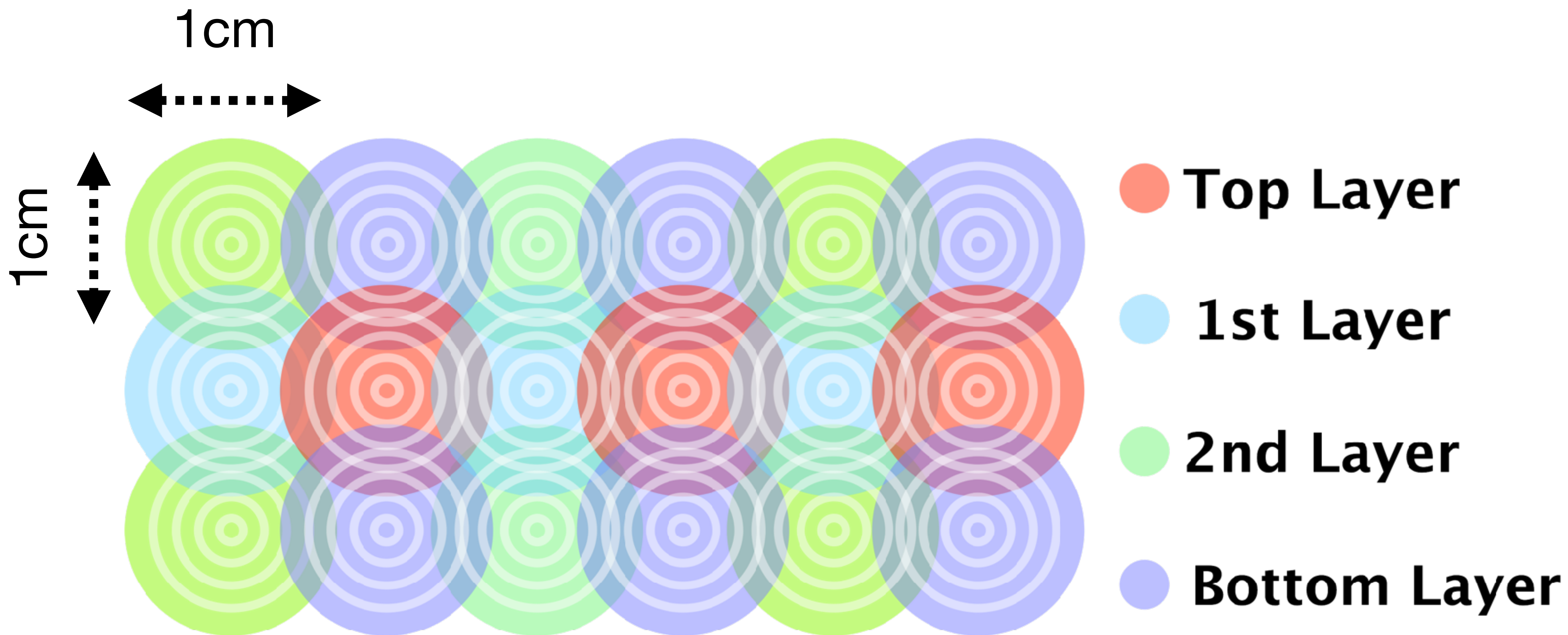
**PICO** [Patten and Ishii 2007]



A close-up photograph of a green printed circuit board (PCB). The board features a grid of small, circular holes and intricate copper traces. Three red, square-shaped components are mounted on the board. Along the right edge, there is a vertical strip of white connectors, each with multiple pins. On the left side, there are several white rectangular components, possibly connectors or test points, with labels like '029', '033', and '032' visible. The background is a blurred wooden surface.

# **PCB (Printed Circuit Board) Electromagnetic Coils Arrays**

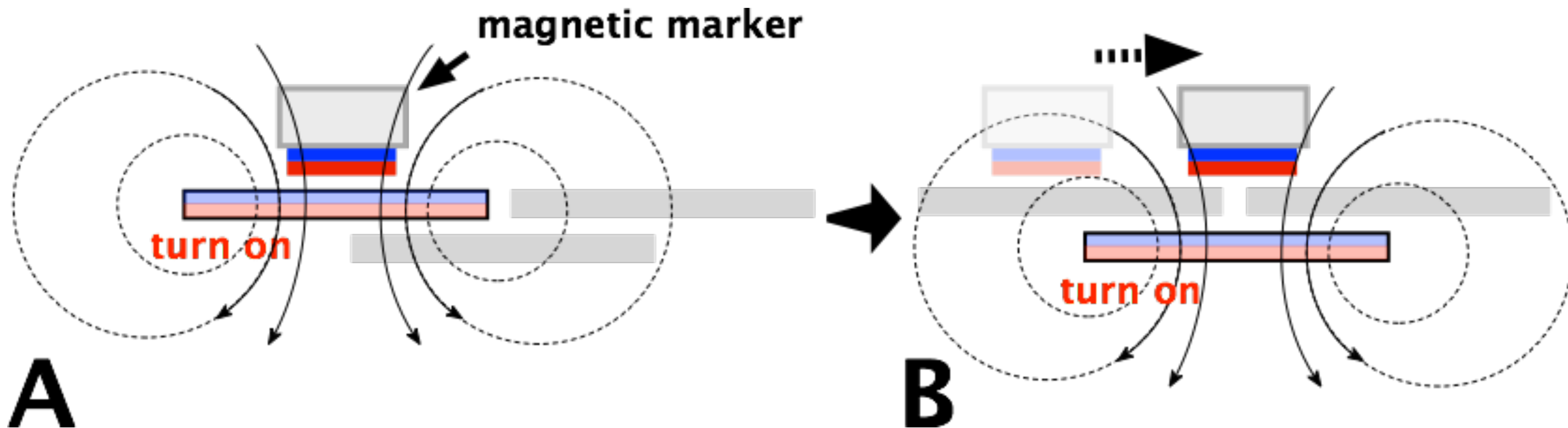
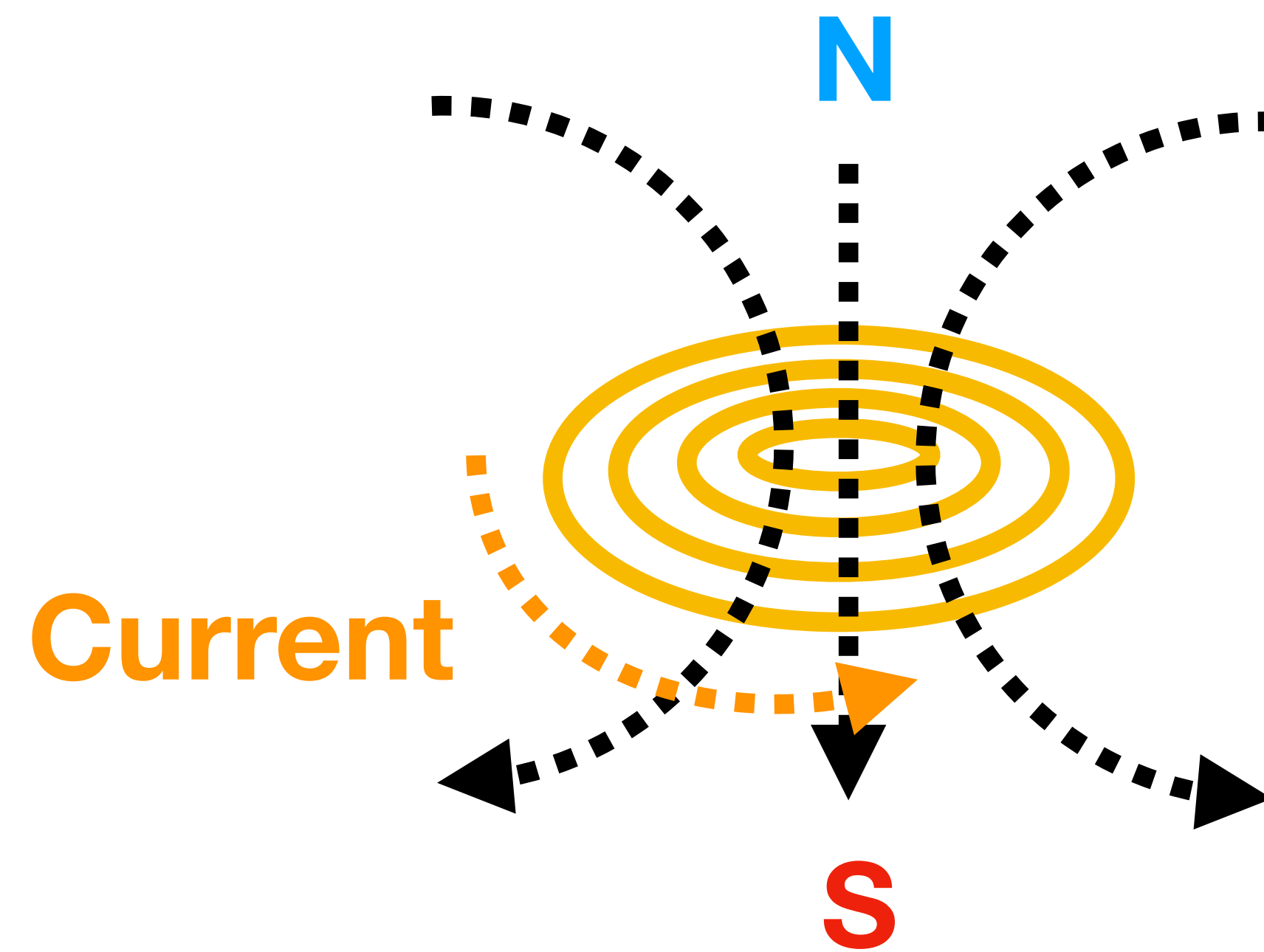




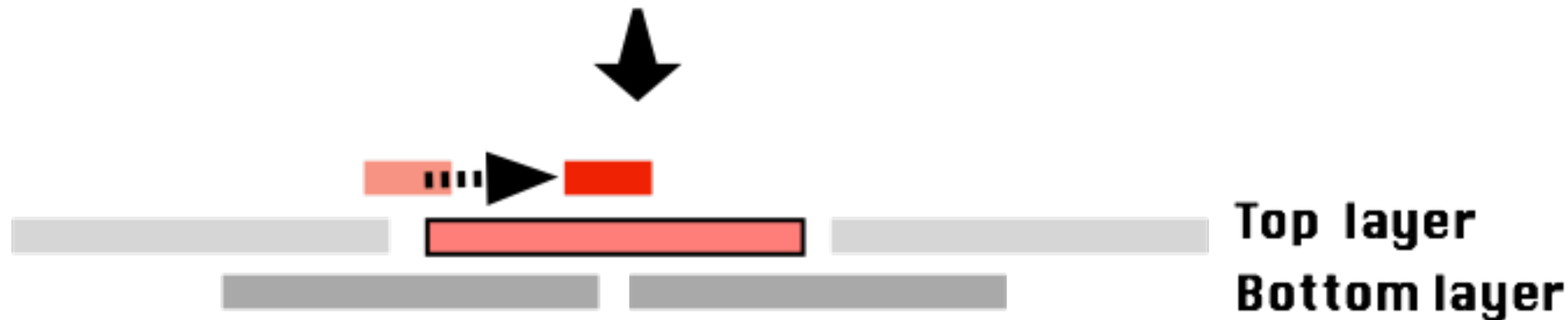




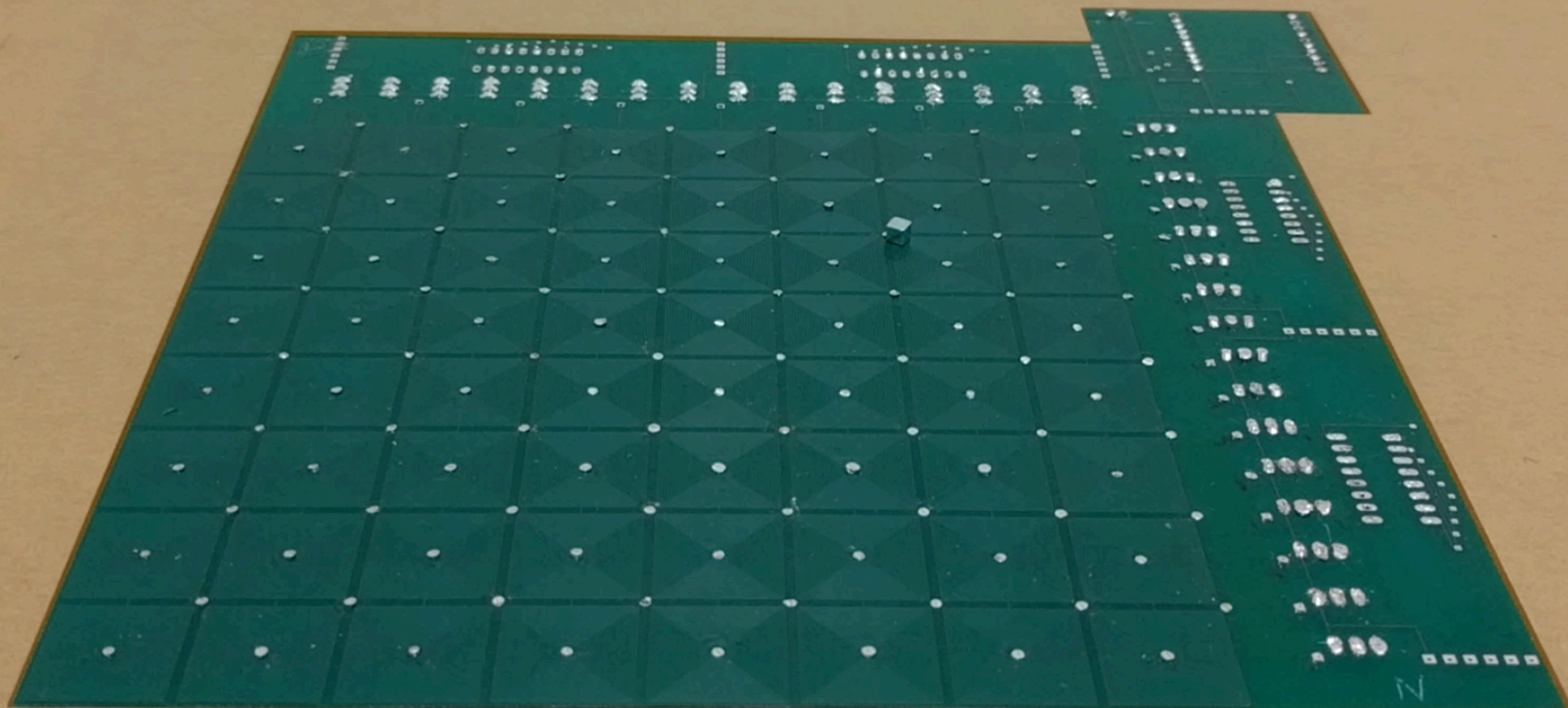




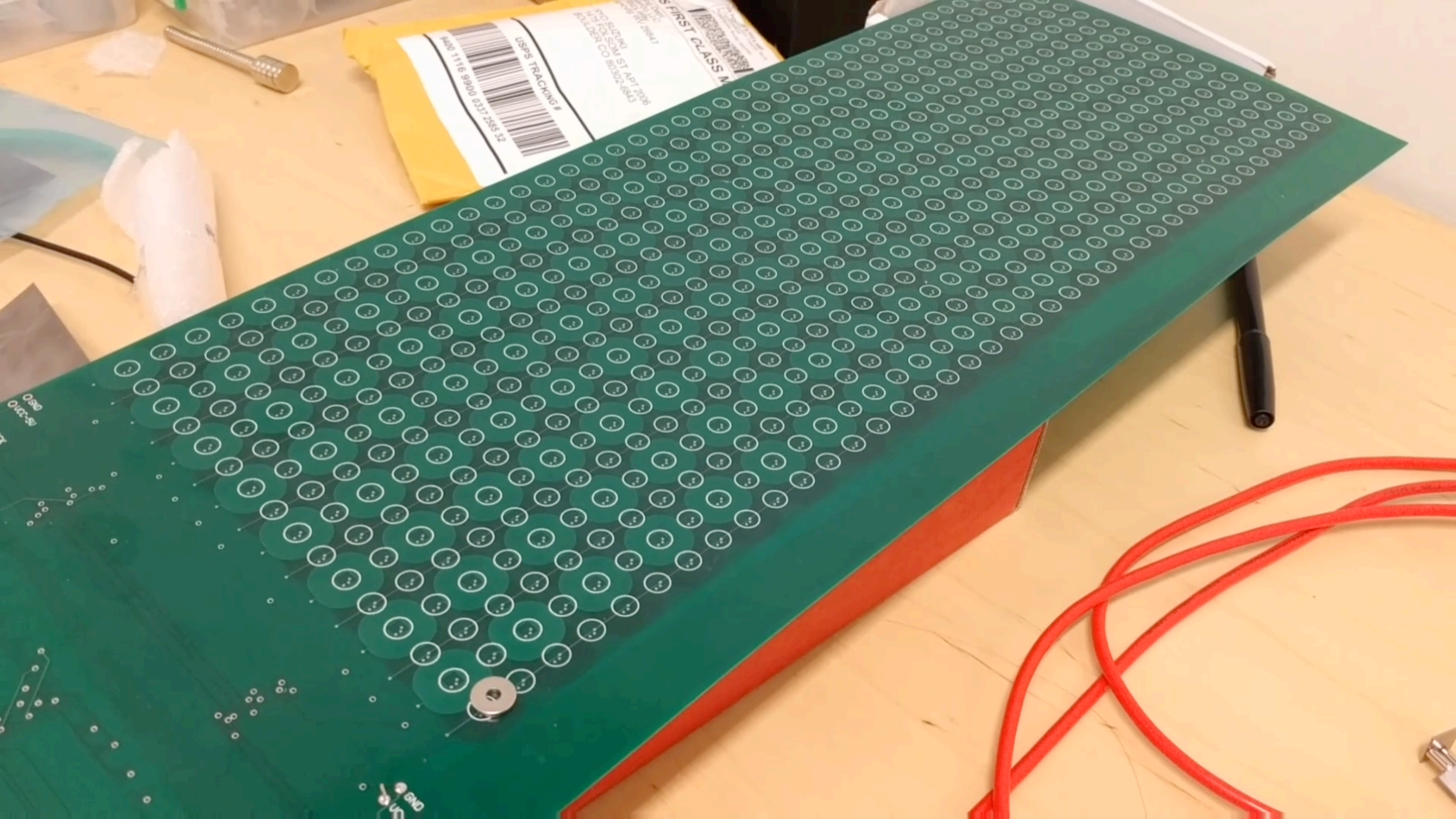






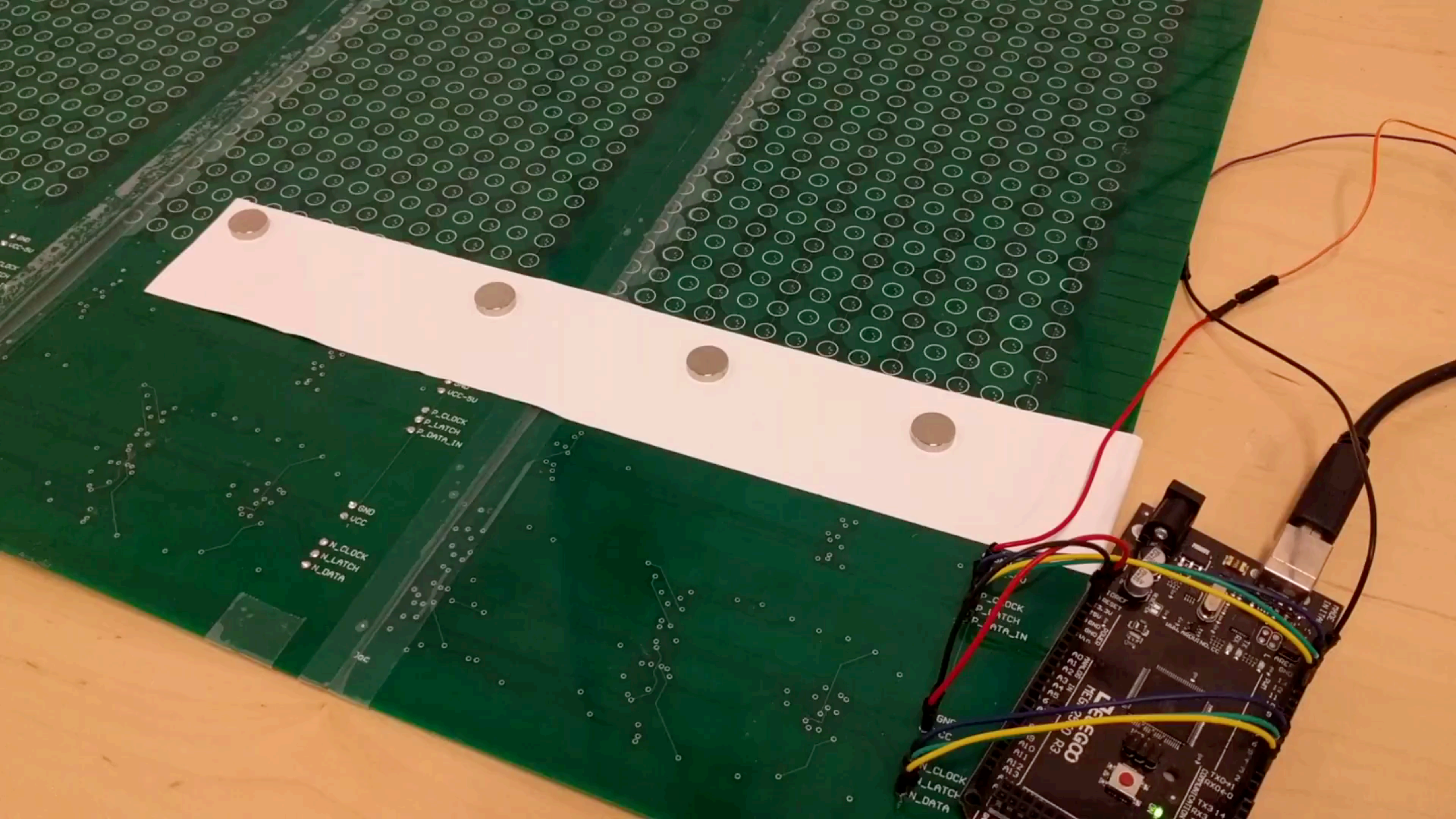




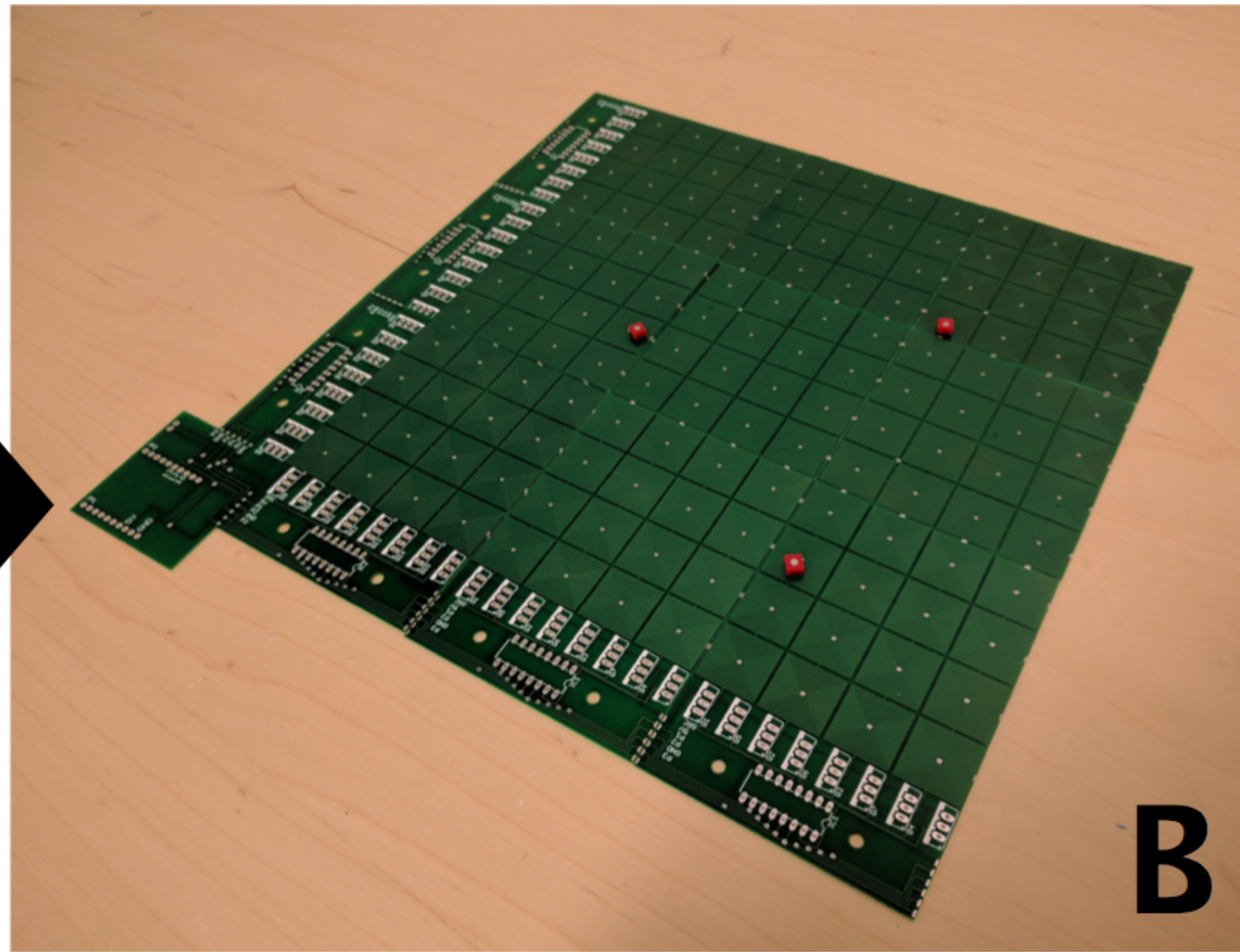
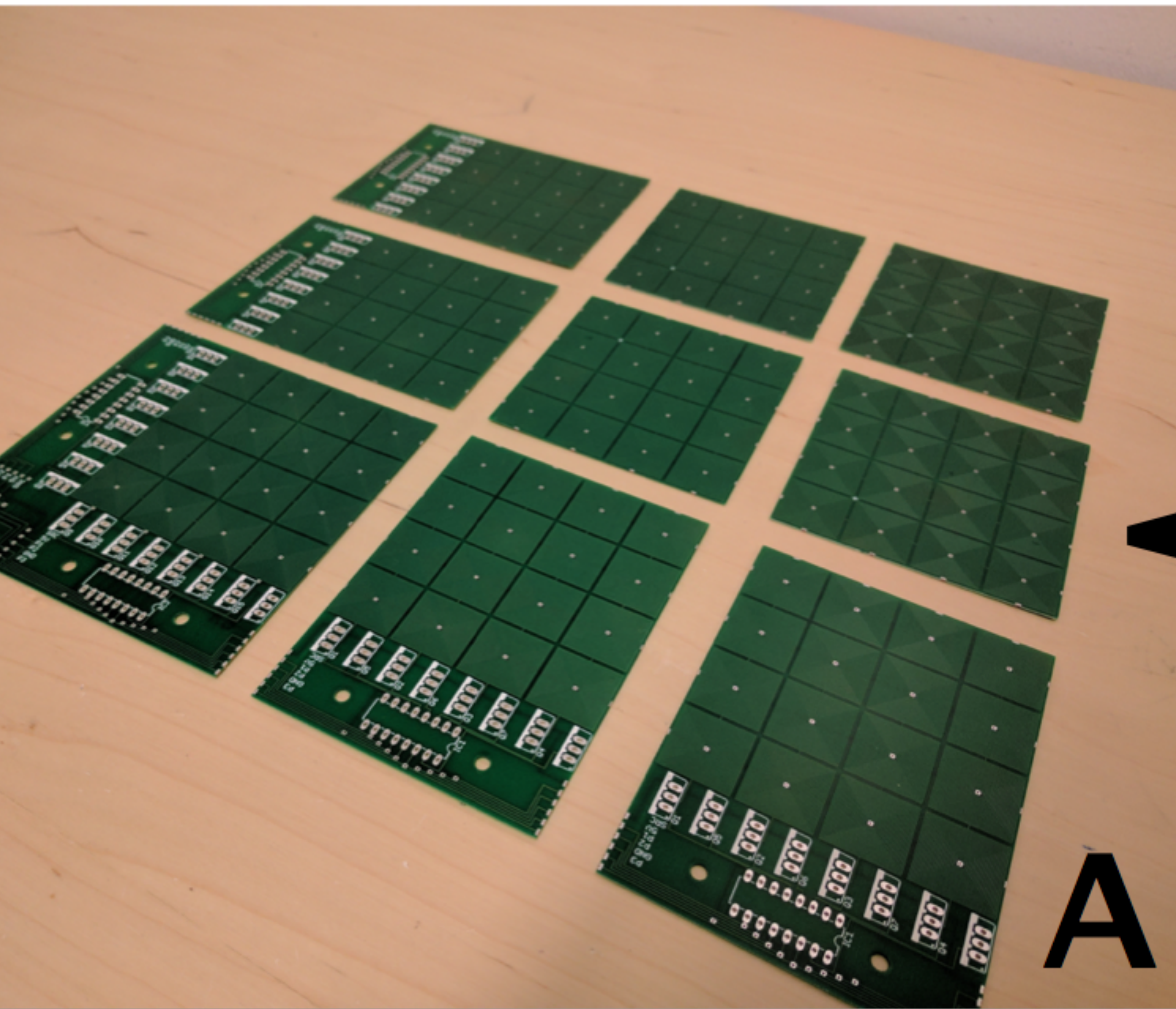


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PO BOX 1116 99000 0337 2585 52  
FOLLOWS CO 80302-6843

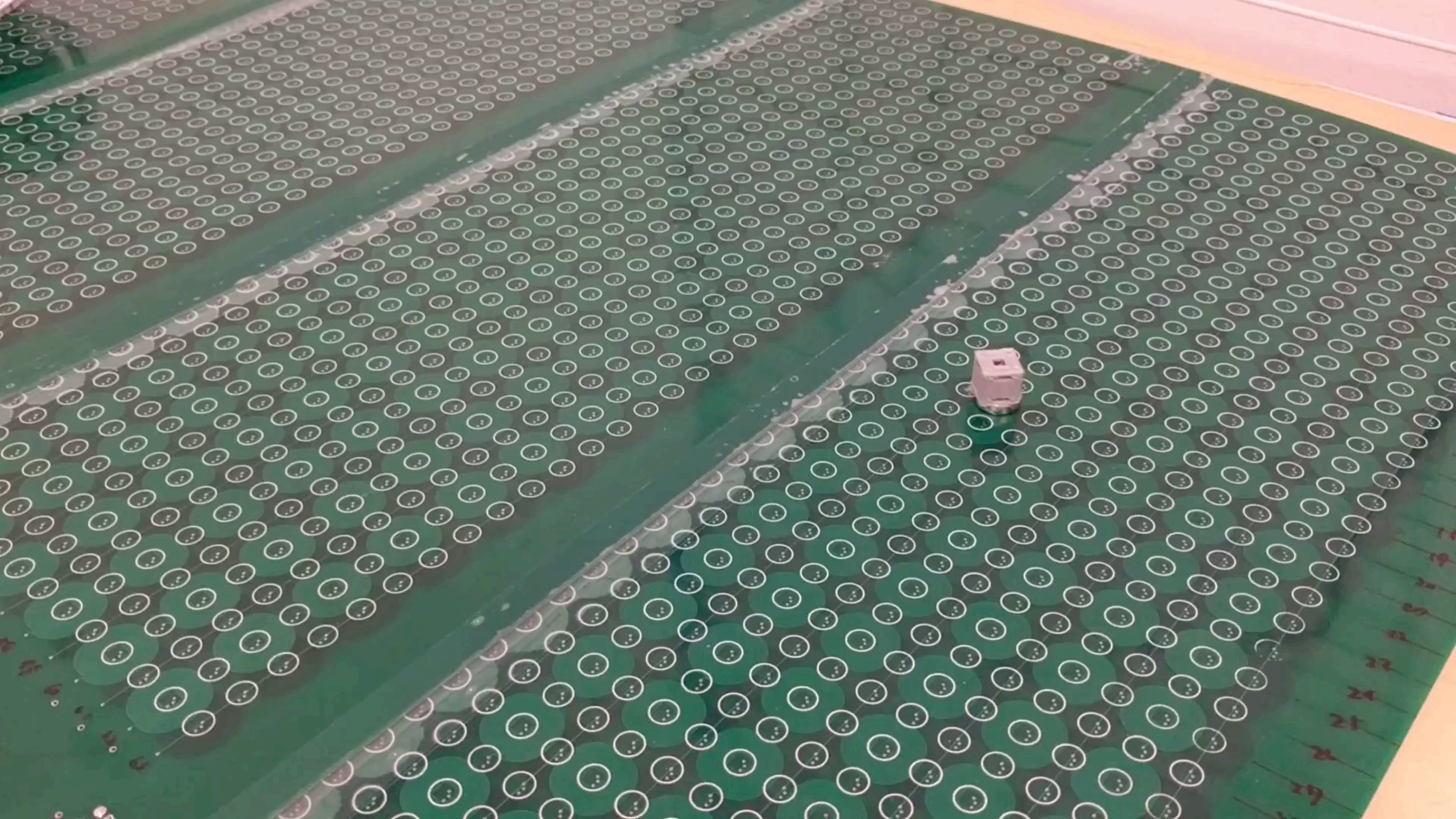














These designs are informed by  
our **Formative Study**  
with **4** blind participants



1. Summary

2. Motivation

3. Design and Implementation

# **4. User Study**

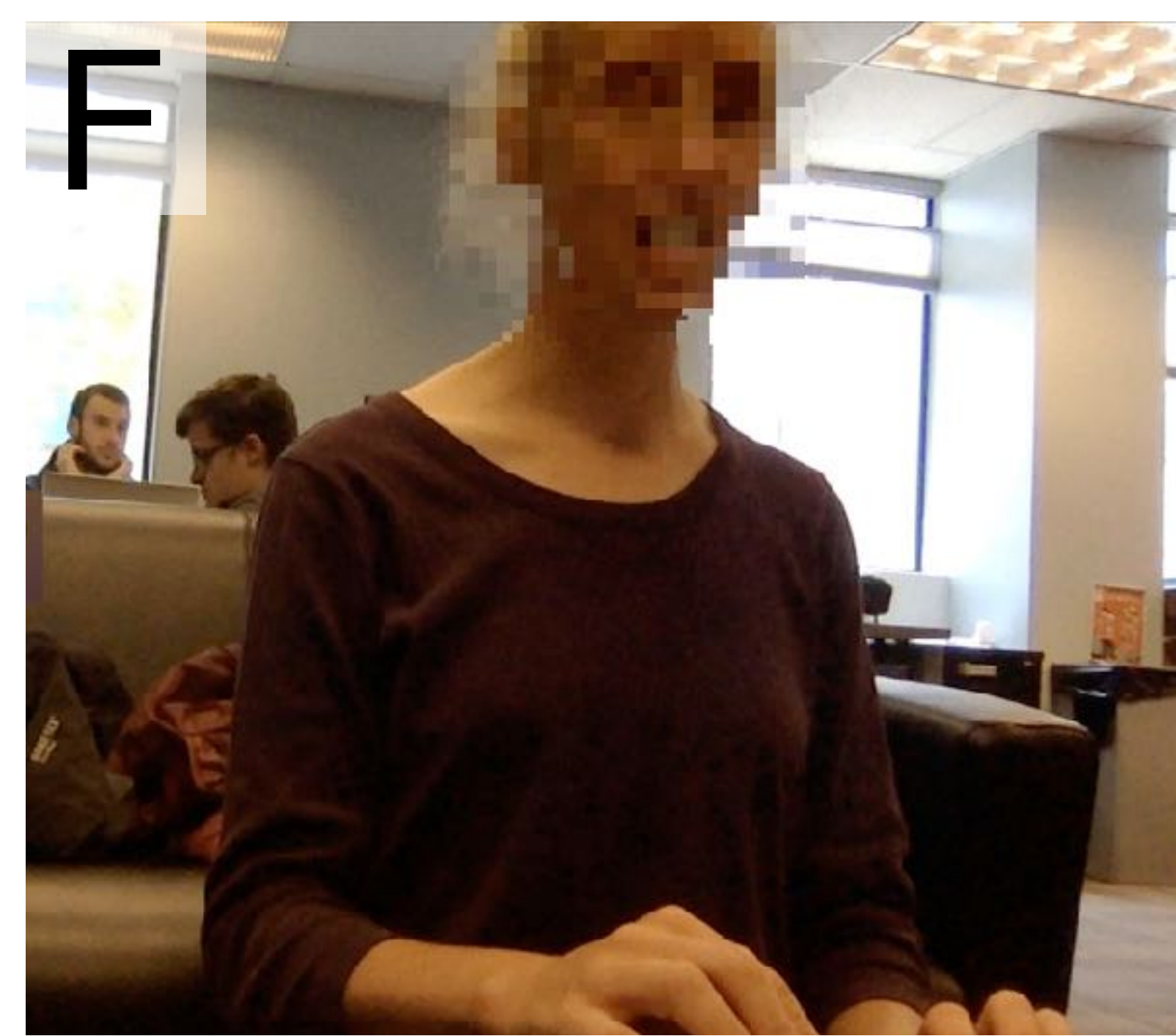
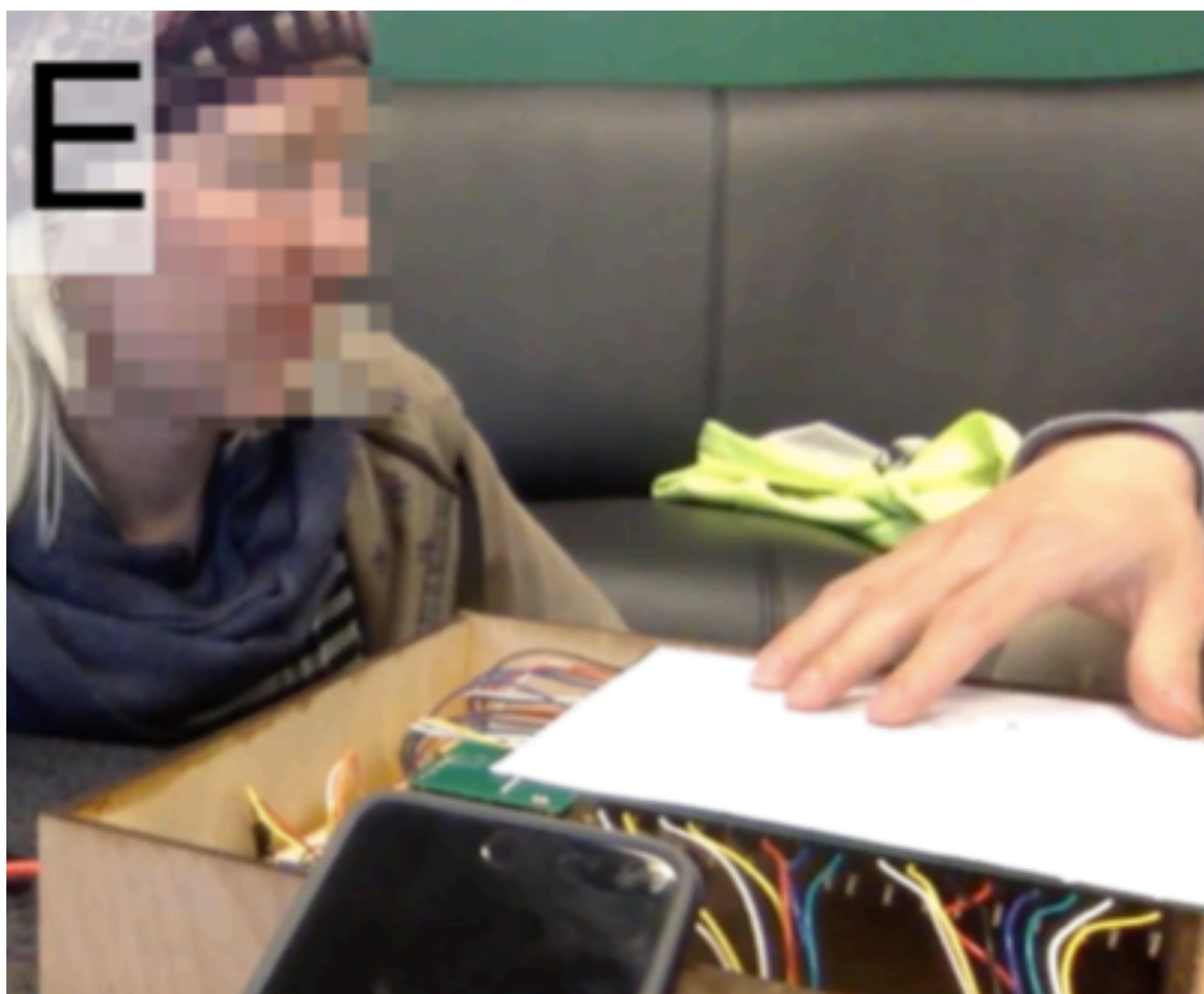
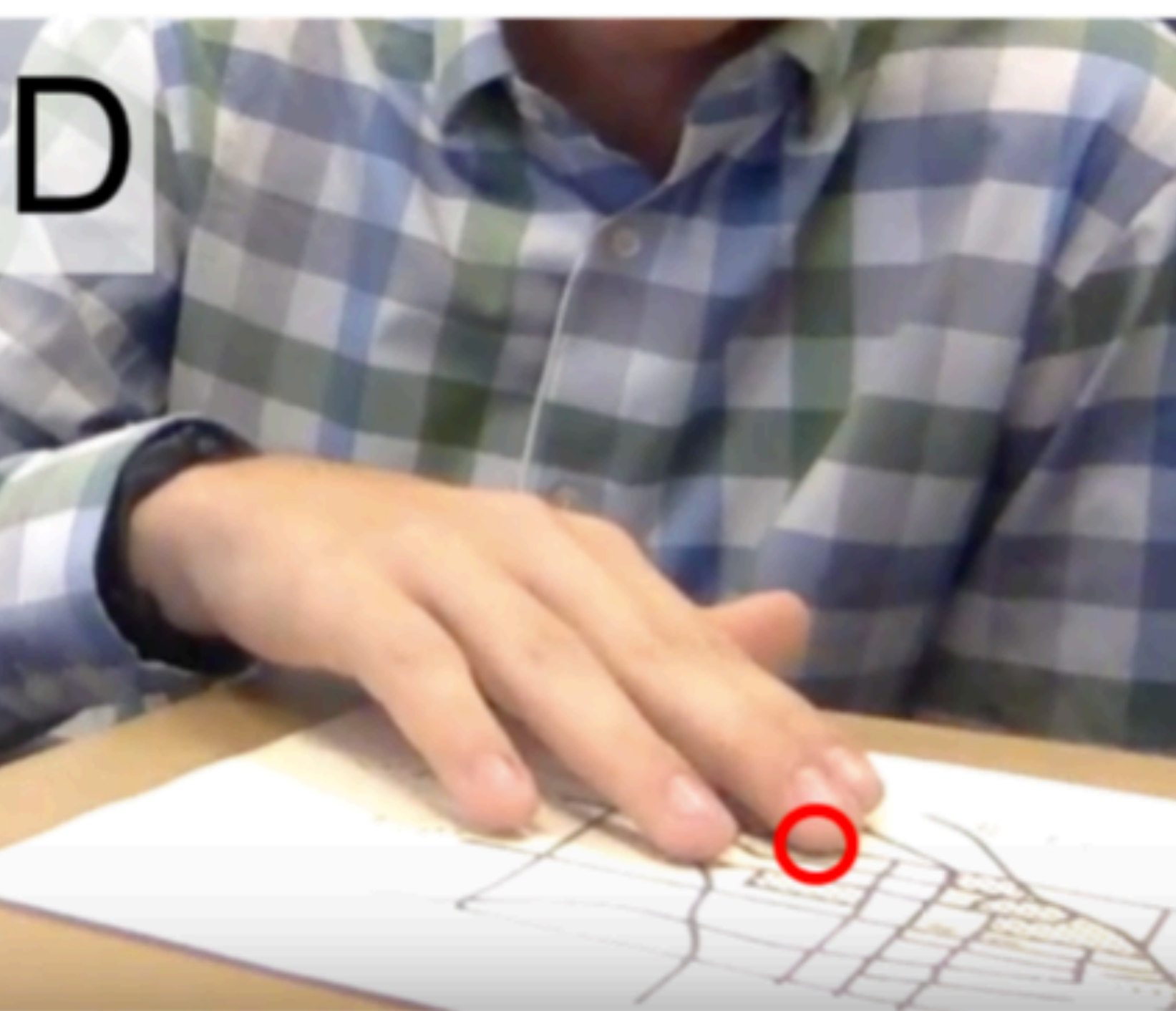
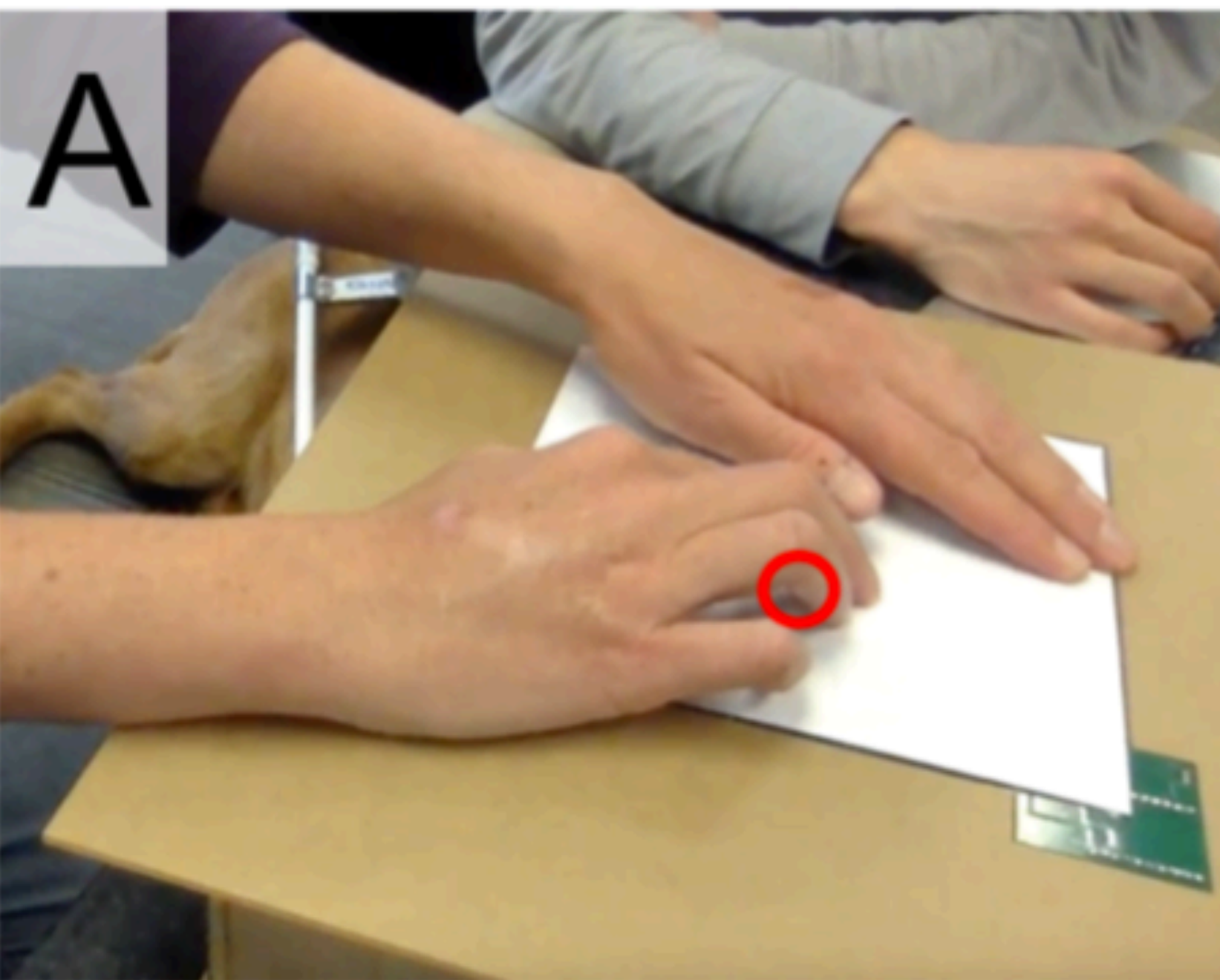


# 6 participants

(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



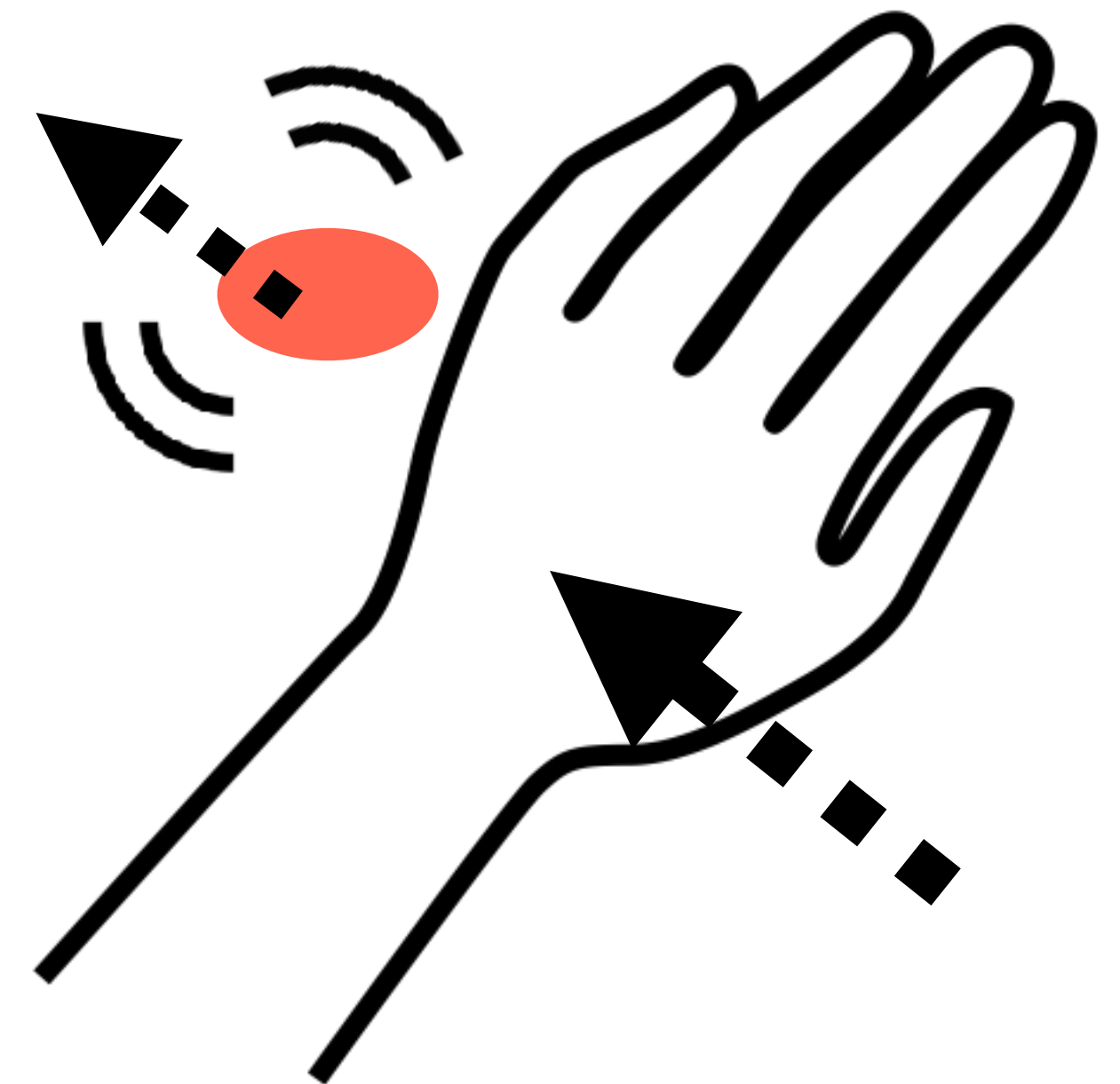
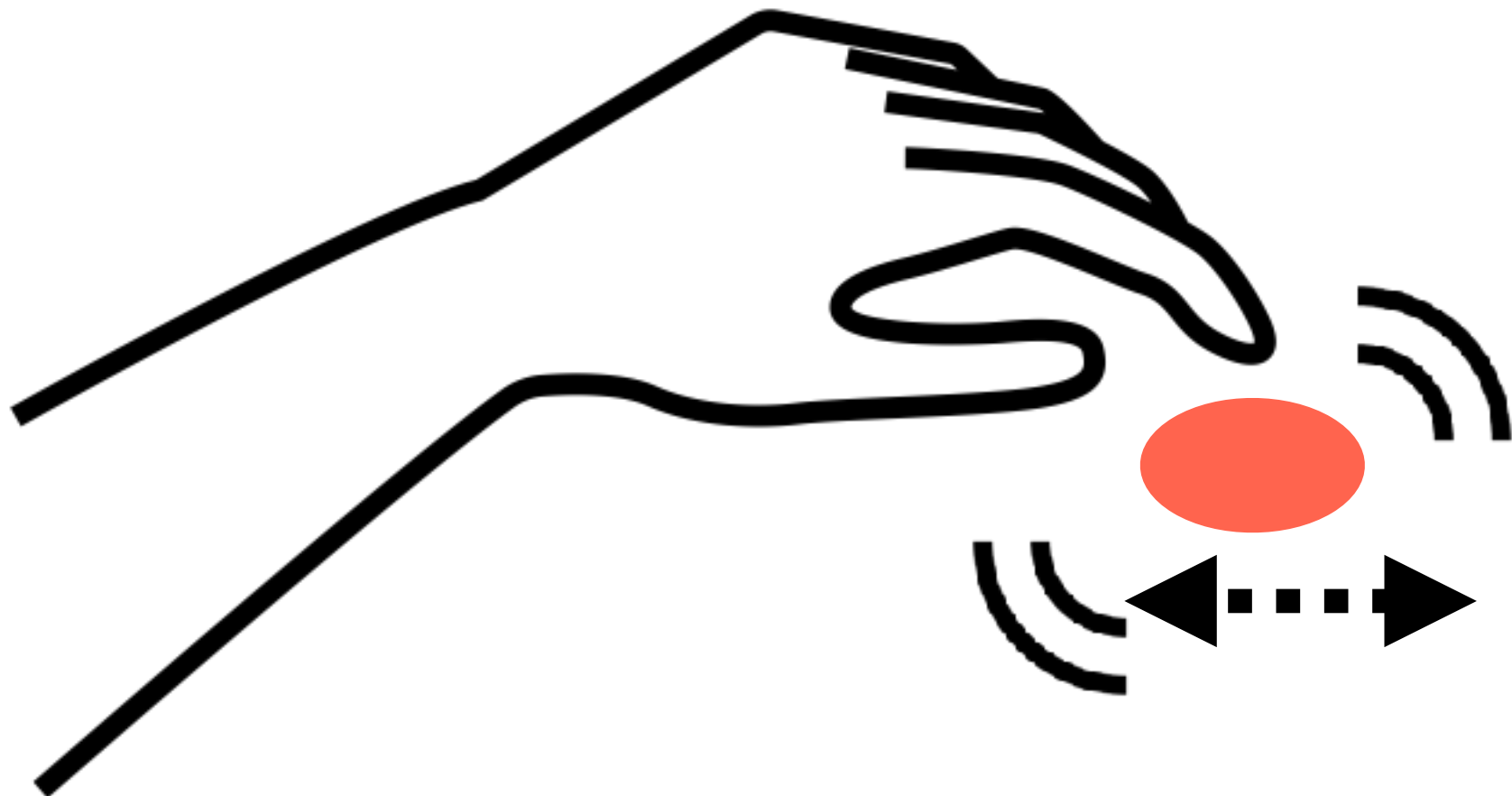
*P6 “This would be useful if it was **synced up with a lecture and graphics**, or even if it was **synced with an instructors laser pointer**; if it was tracking what was up on the board, and I could follow along, that would be amazing.”*



# Limitations

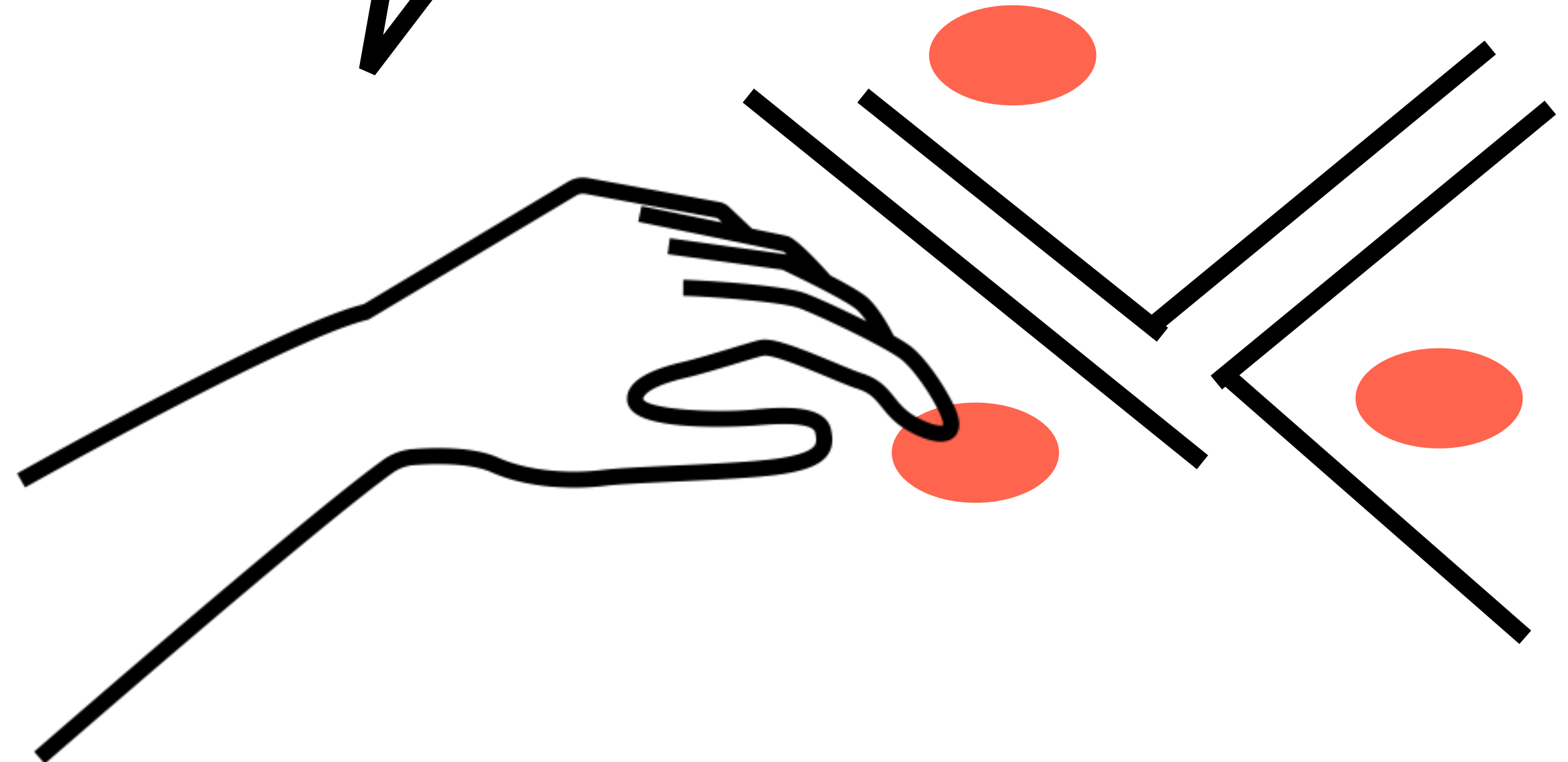
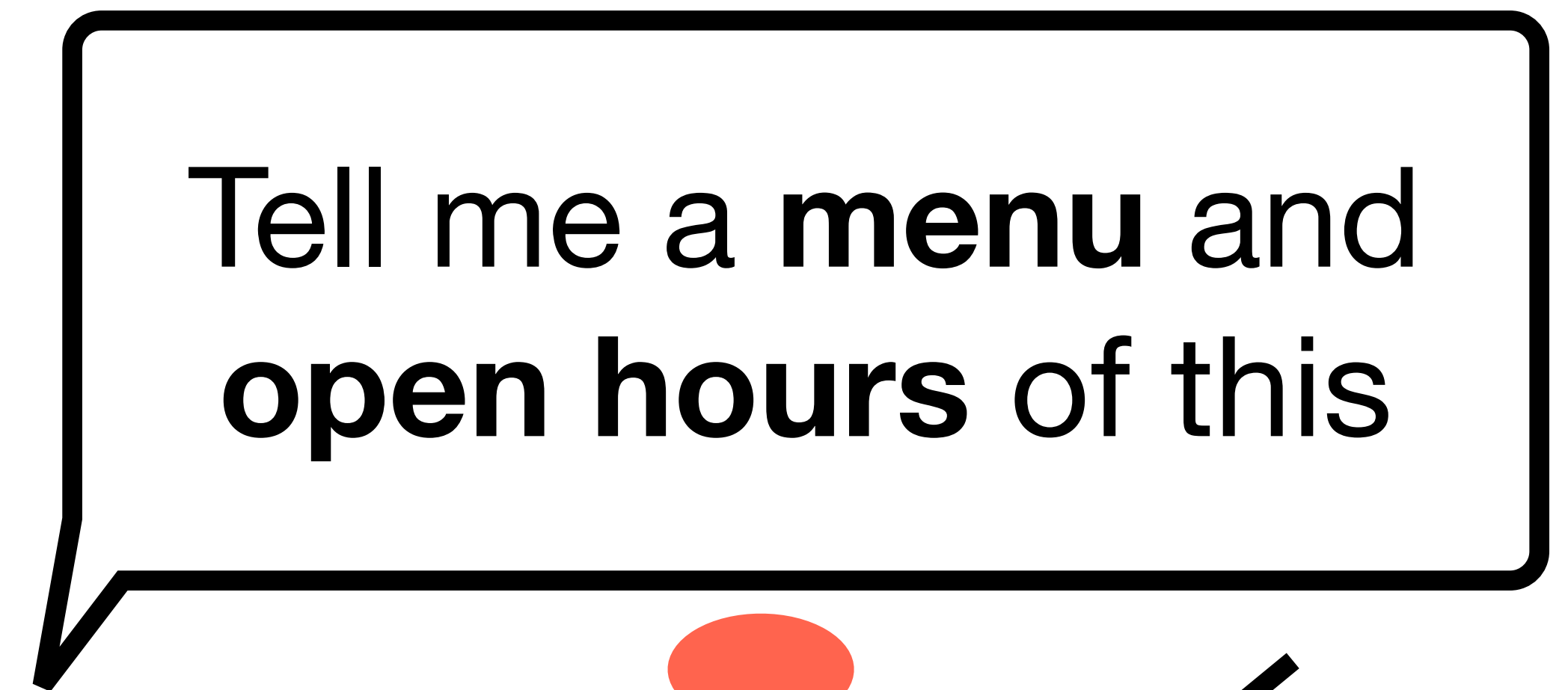
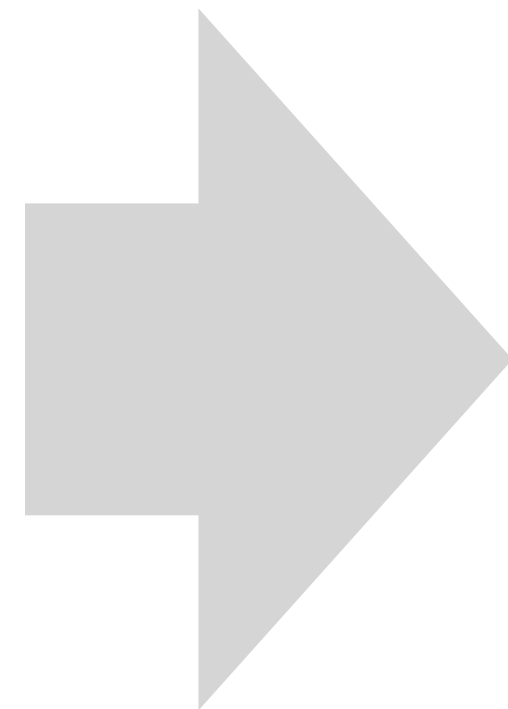
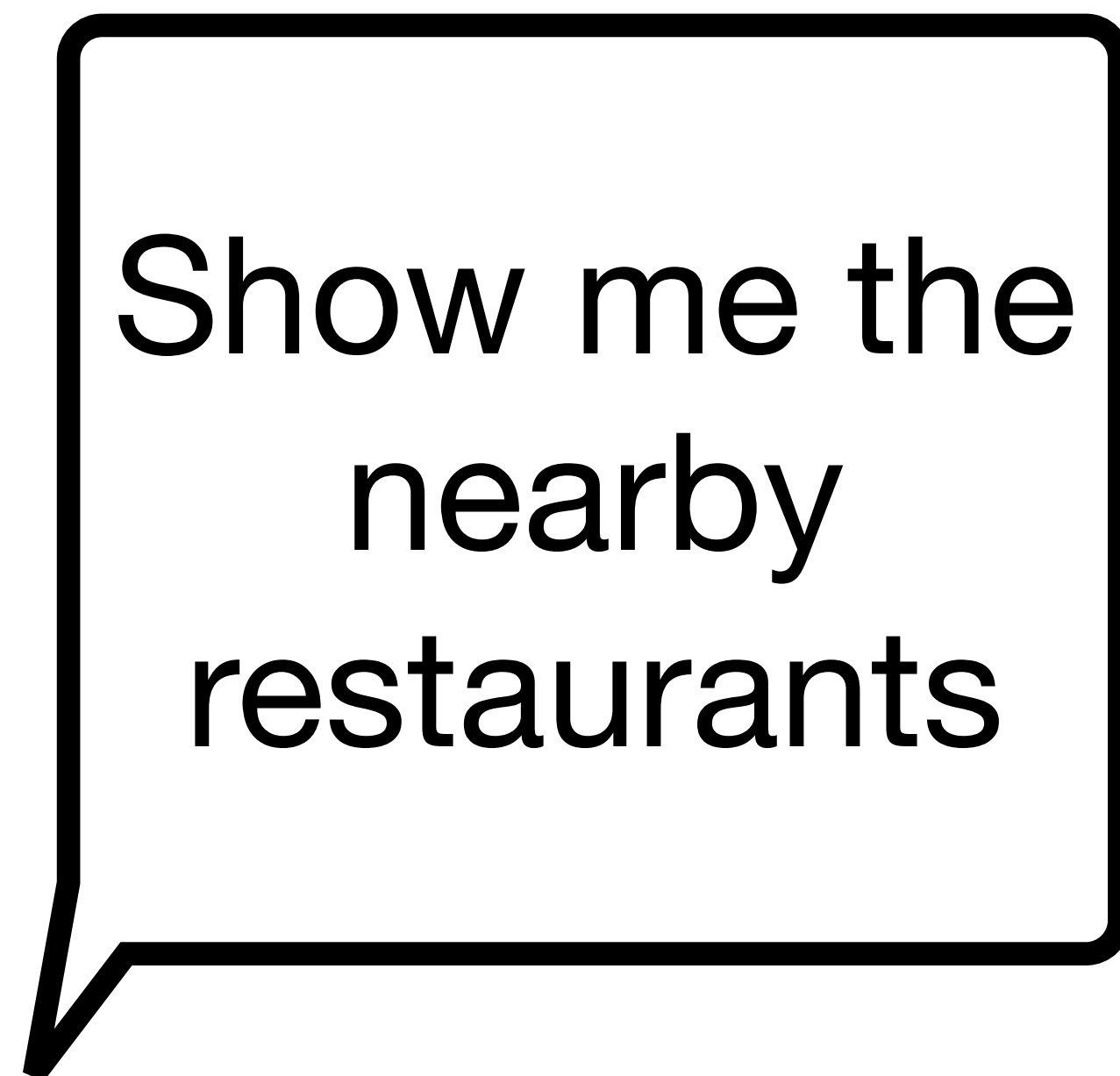


# Unstable Position





# Touch Interaction





# Future Vision



**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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**What else do I need to know?**

Editors will be made to limit the use and disclosure of your personal information, including research study results, as people who have a need to review this information. We cannot promise complete secrecy.  
Organization that may impact and copy your information include the IRB and other representatives of this organization. No identifiable information about participants will be shared in reports; direct identifiers will be removed from the data to ensure anonymity.  
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:  
Your signature (typing in your name and date) documents your permission to take part in this research.

YES

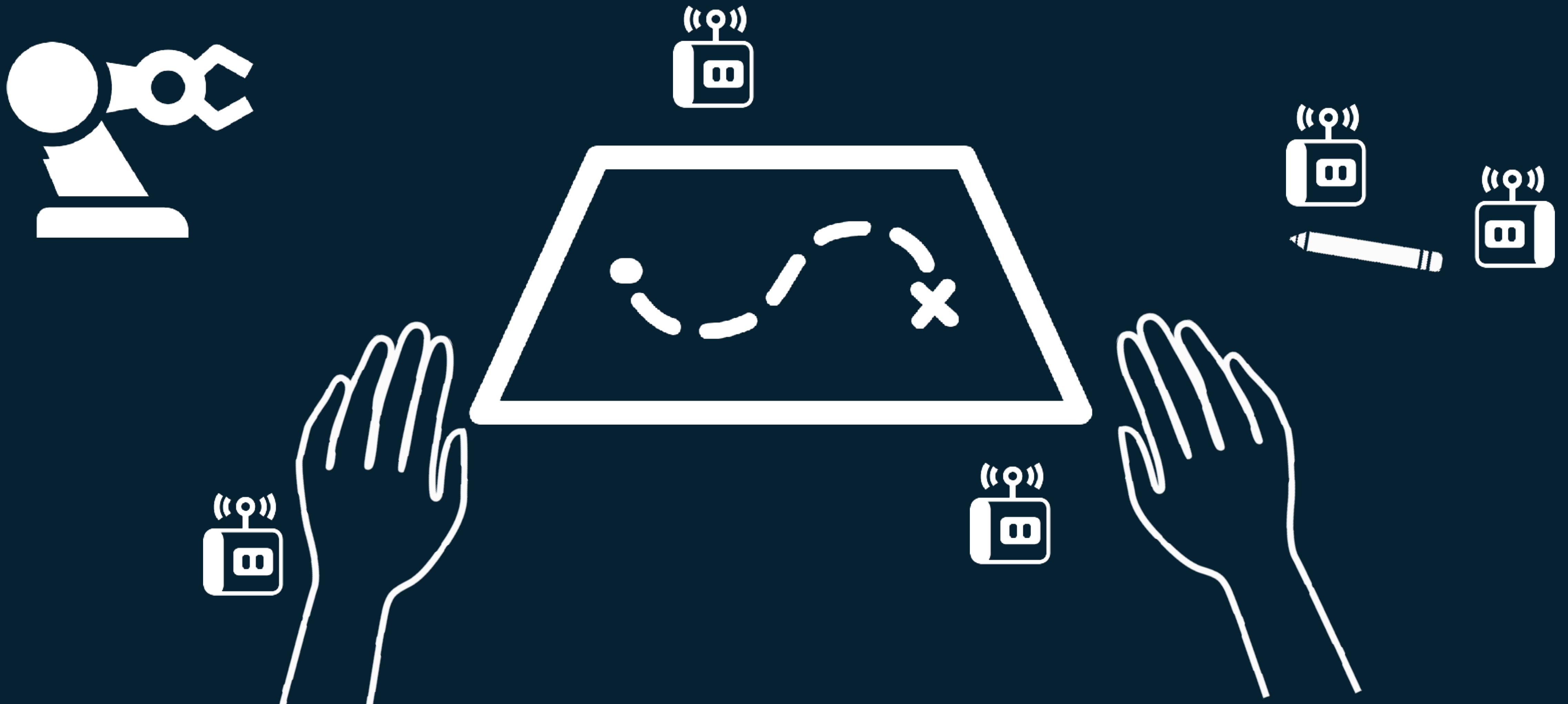
NO

IRB Approval Date

Signature \_\_\_\_\_  
Date \_\_\_\_\_  
I agree to take part in this research



# Interactive Physical Assistant







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Boulder



# **FluxMarker:** Enhancing Tactile Graphics with Dynamic Tactile Markers

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