

# Zooids: Building Blocks for Swarm User Interfaces

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<https://github.com/ShapeLab/SwarmUI>







Claytronics, Goldstein et al, 2005

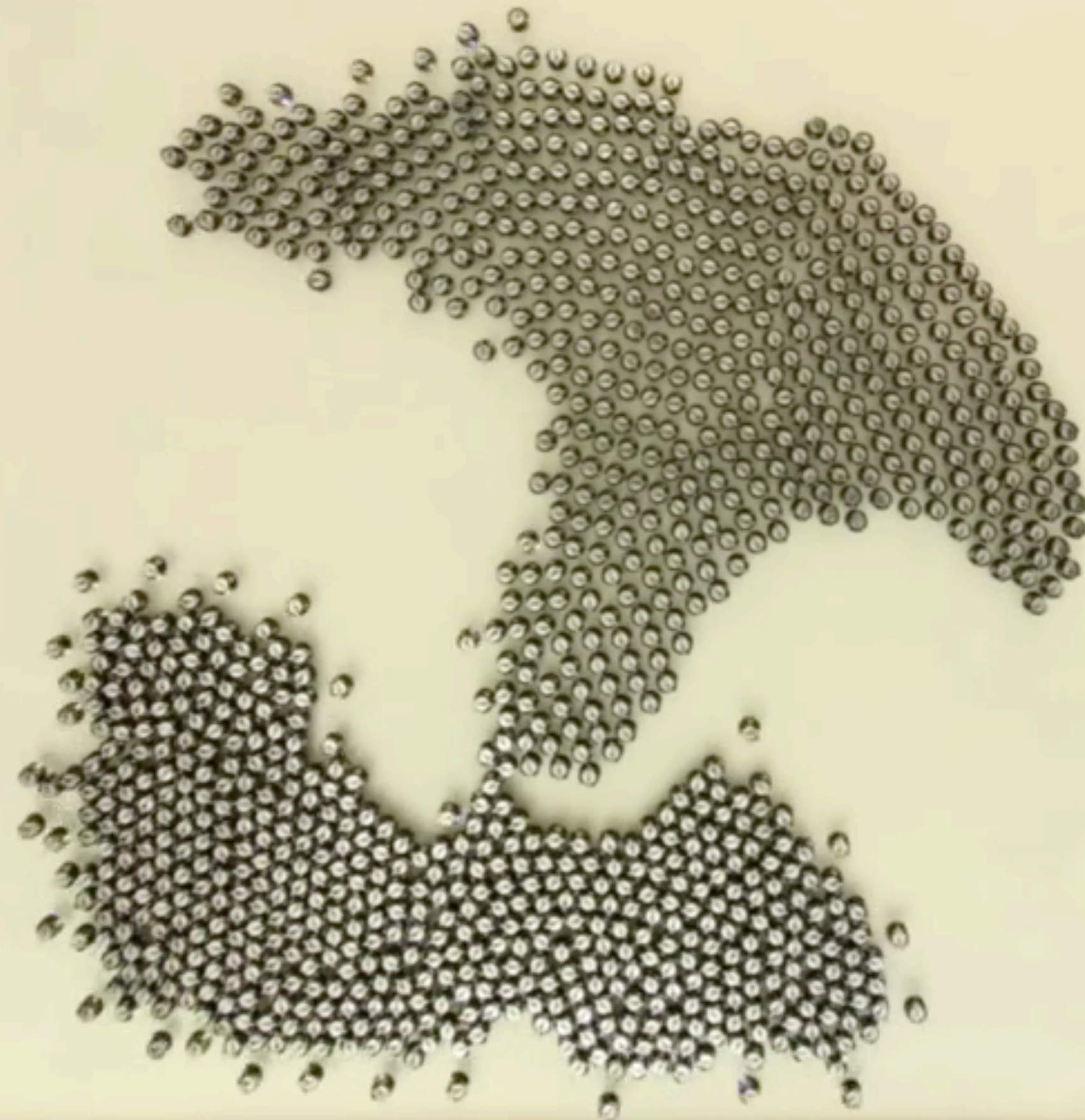


Radical Atoms, Ishii et al., 2012





Harvard University  
Self-Organizing Systems  
Research Group



Programmable Self-Assembly in a Thousand Robot Swarm, Rubenstein et al., 2014



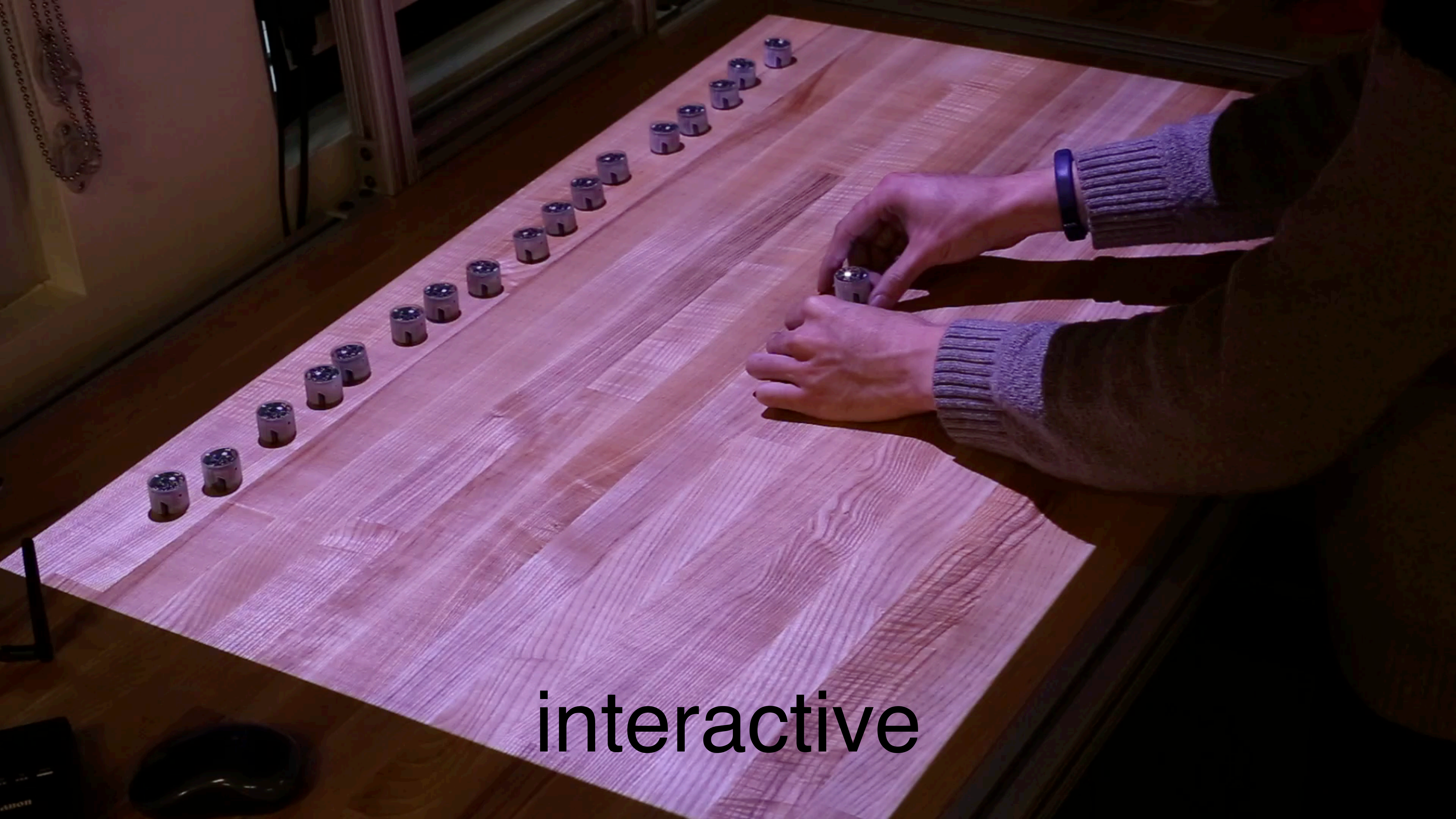
# Swarm User Interfaces





**dynamic**





interactive





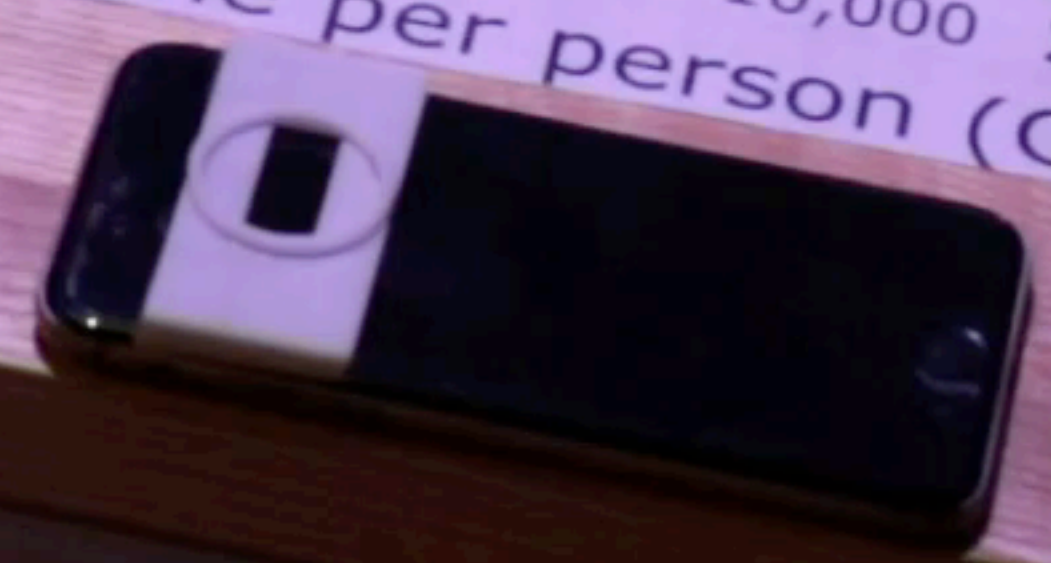
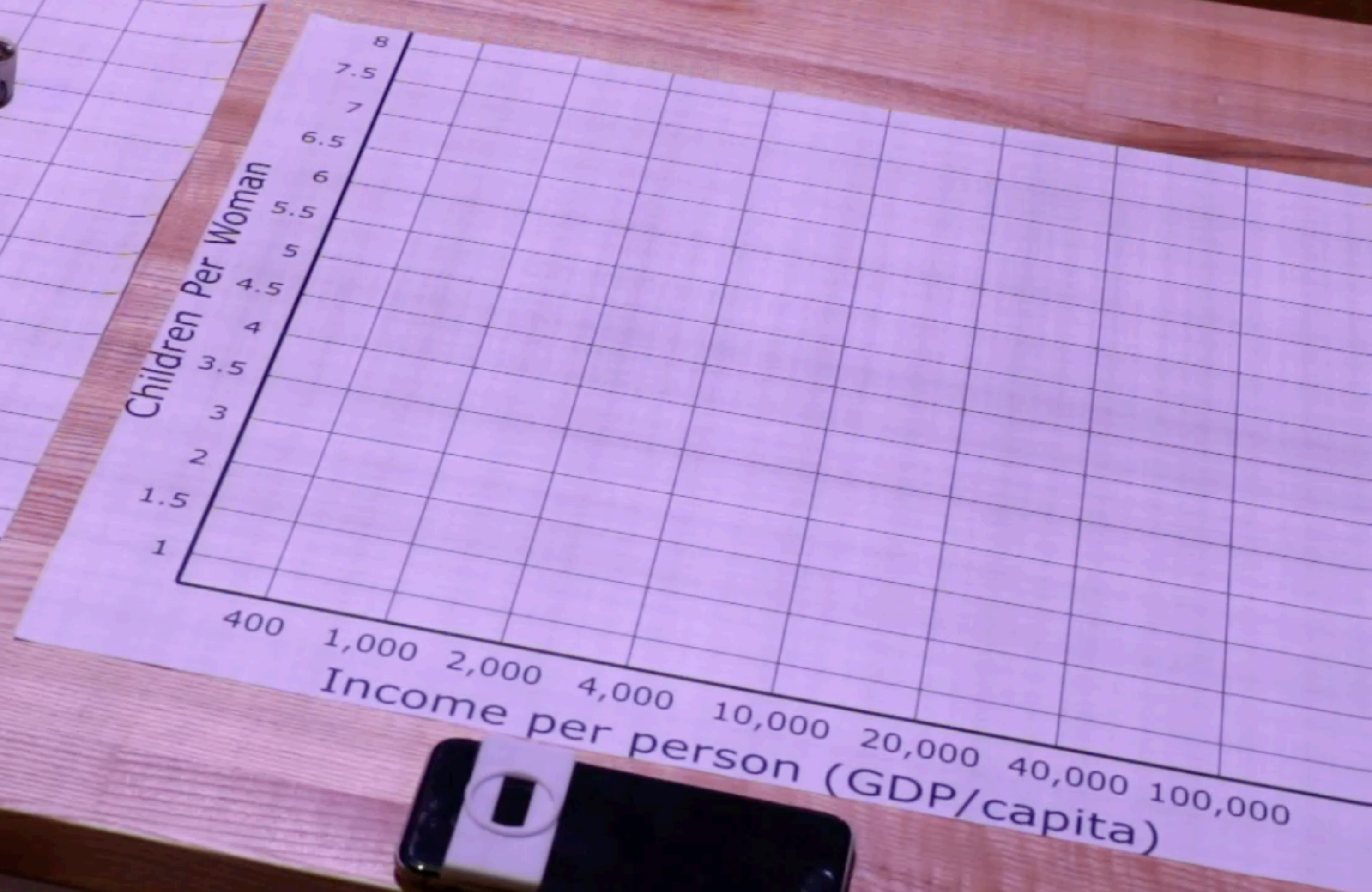
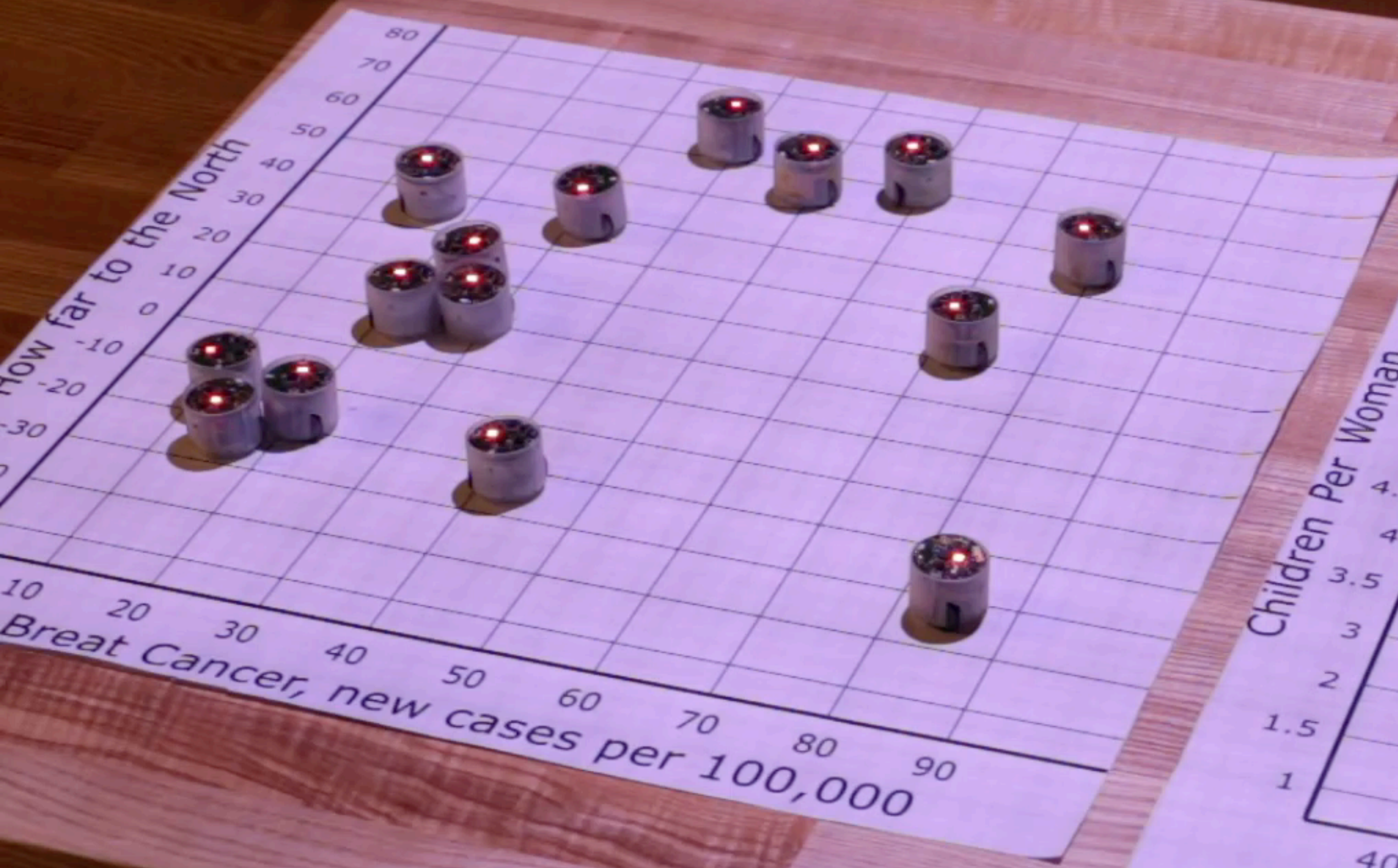
many



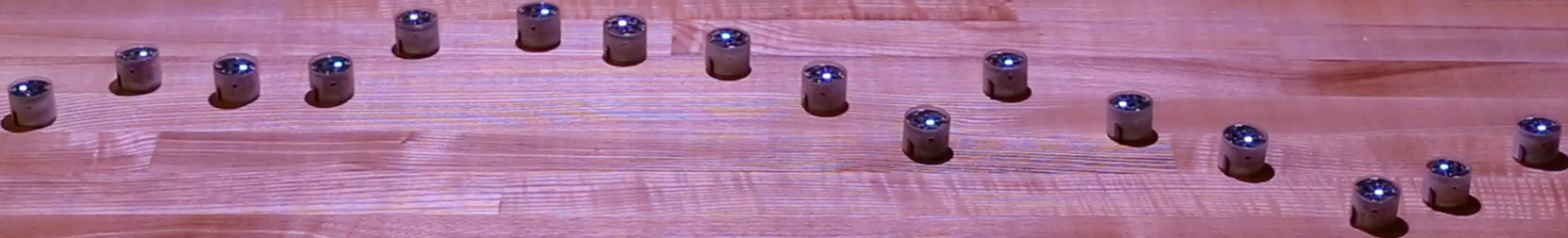
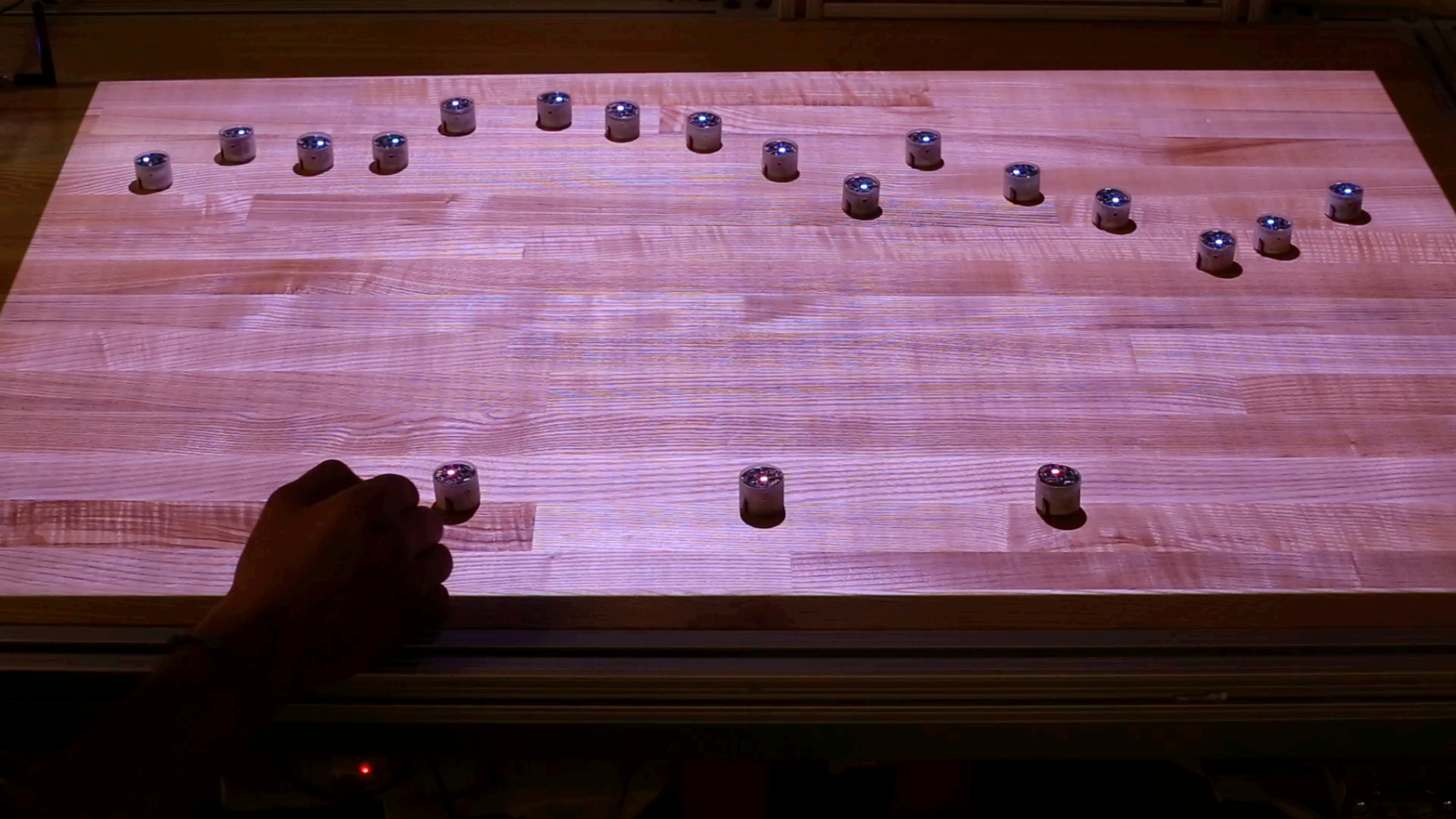
zooids

















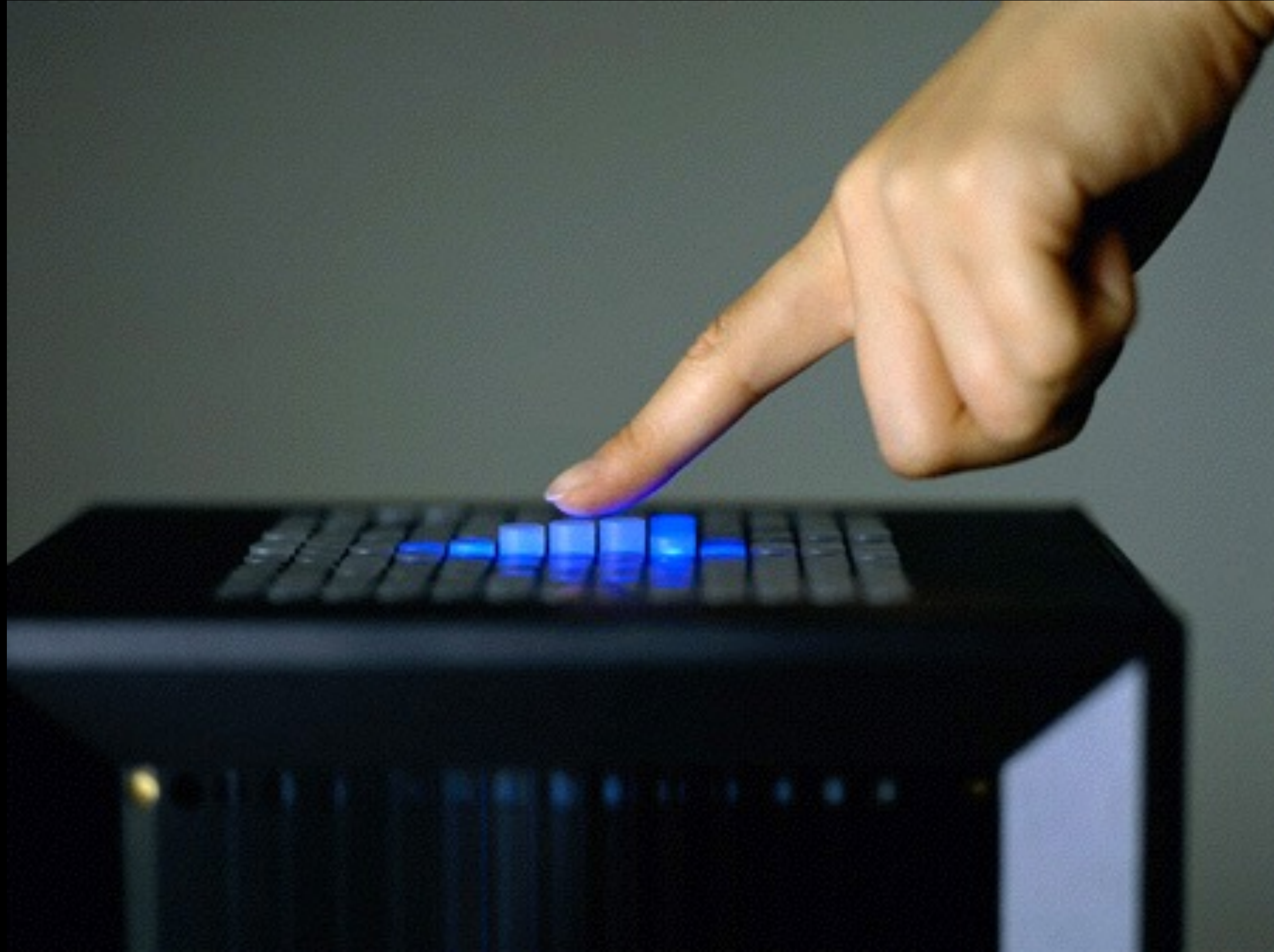
# Contributions

- Defining Swarm UIs,
- Illustrating scenarios,
- General design principles and challenges,
- The first open-source platform for Swarm UIs

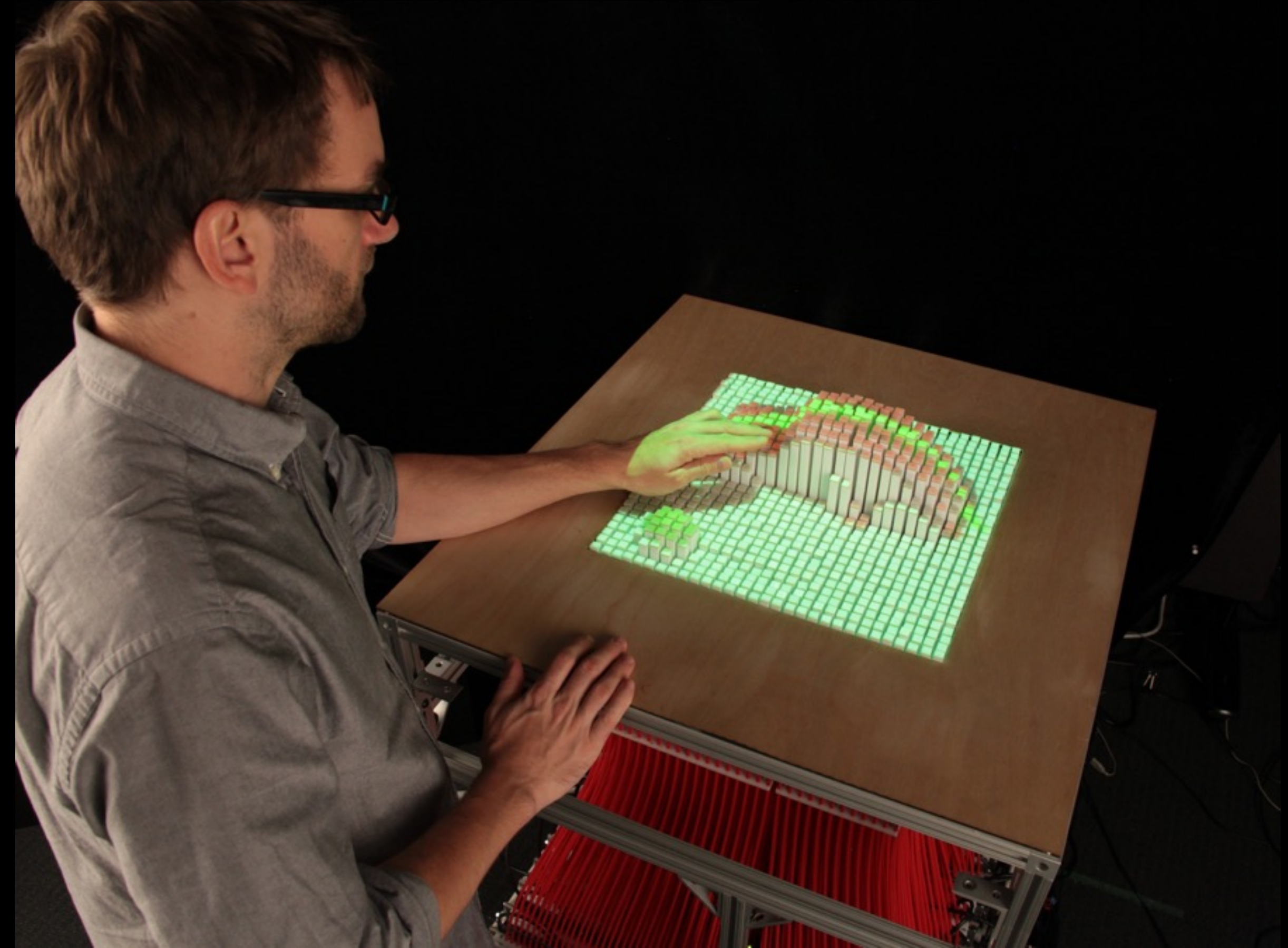


**Background**



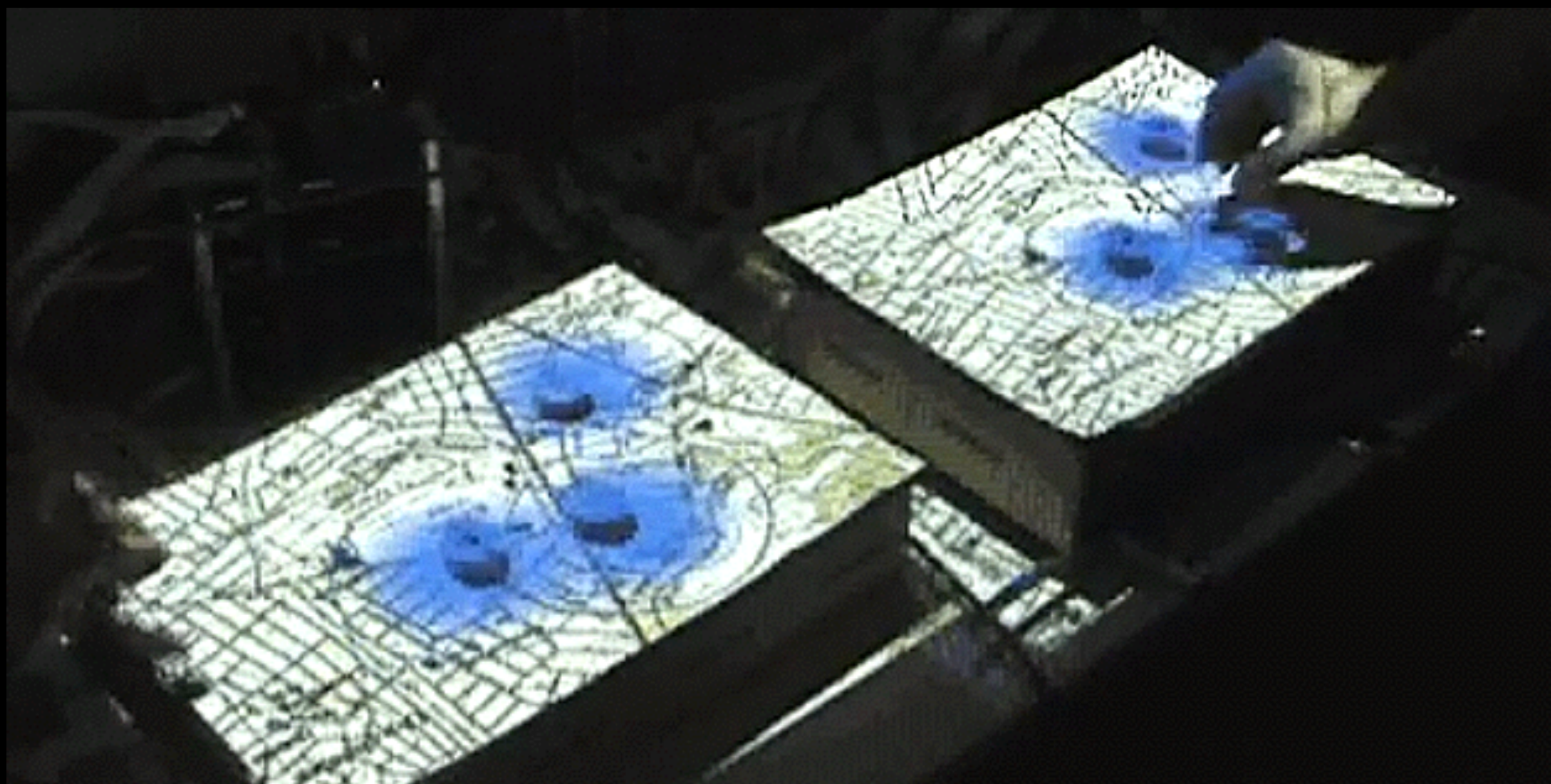


Lumen, Poupyrev et al., 2004

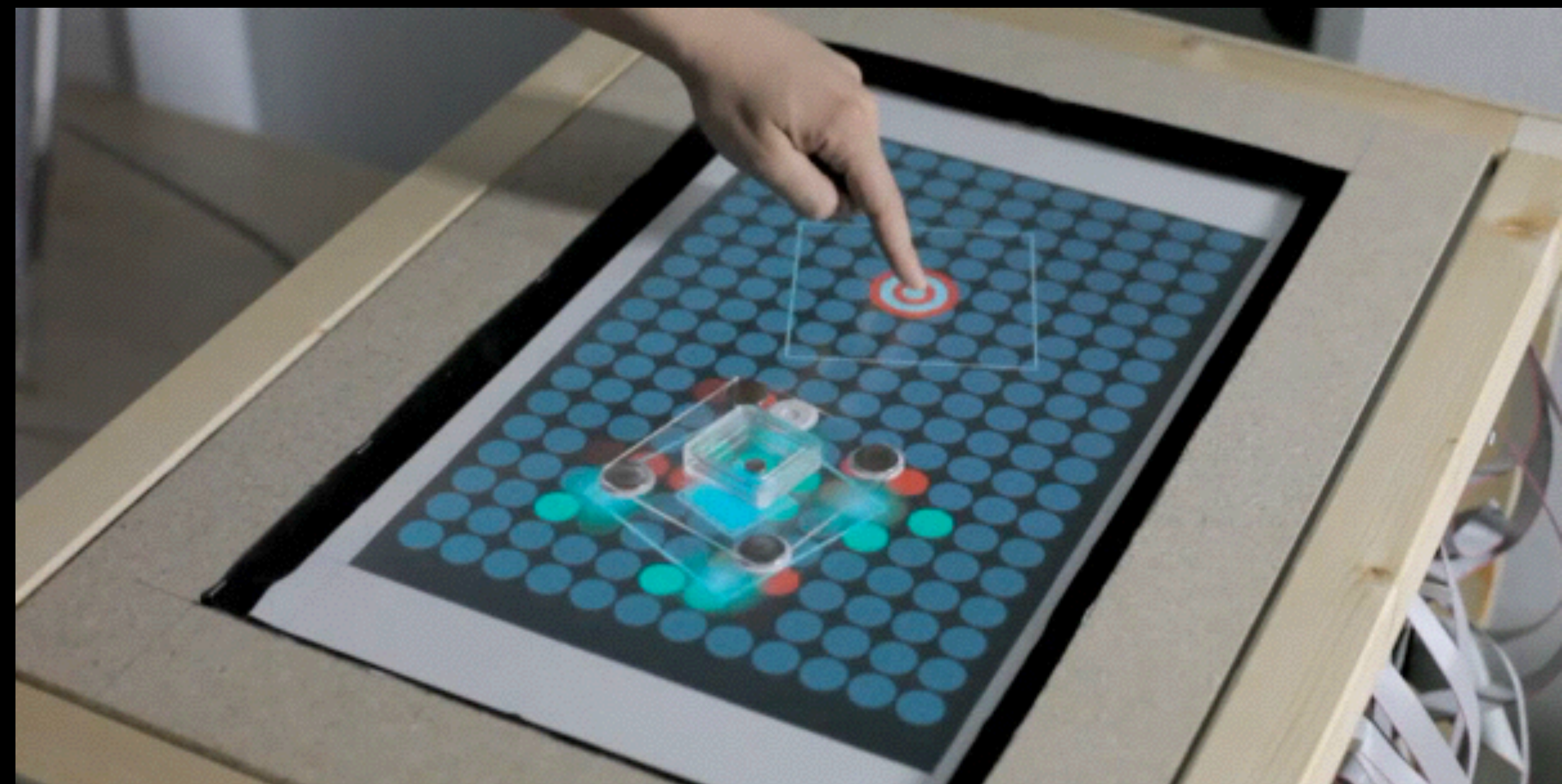


inFORM, Follmer et al., 2013





Actuated Workbench, Pangaro et al., 2002

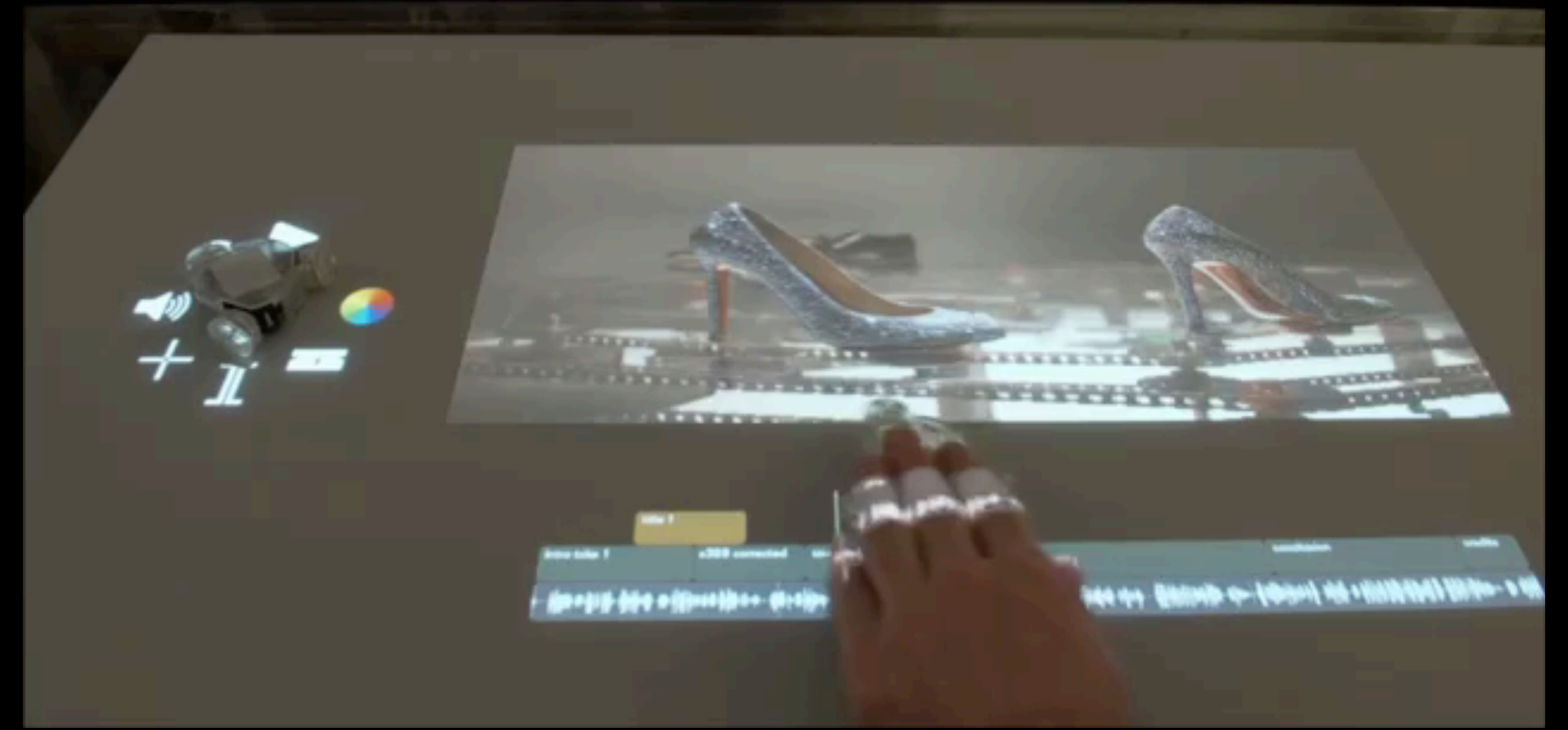


Madgets, Weiss et al., 2010





Tangible Bots, Pedersen et al., 2011

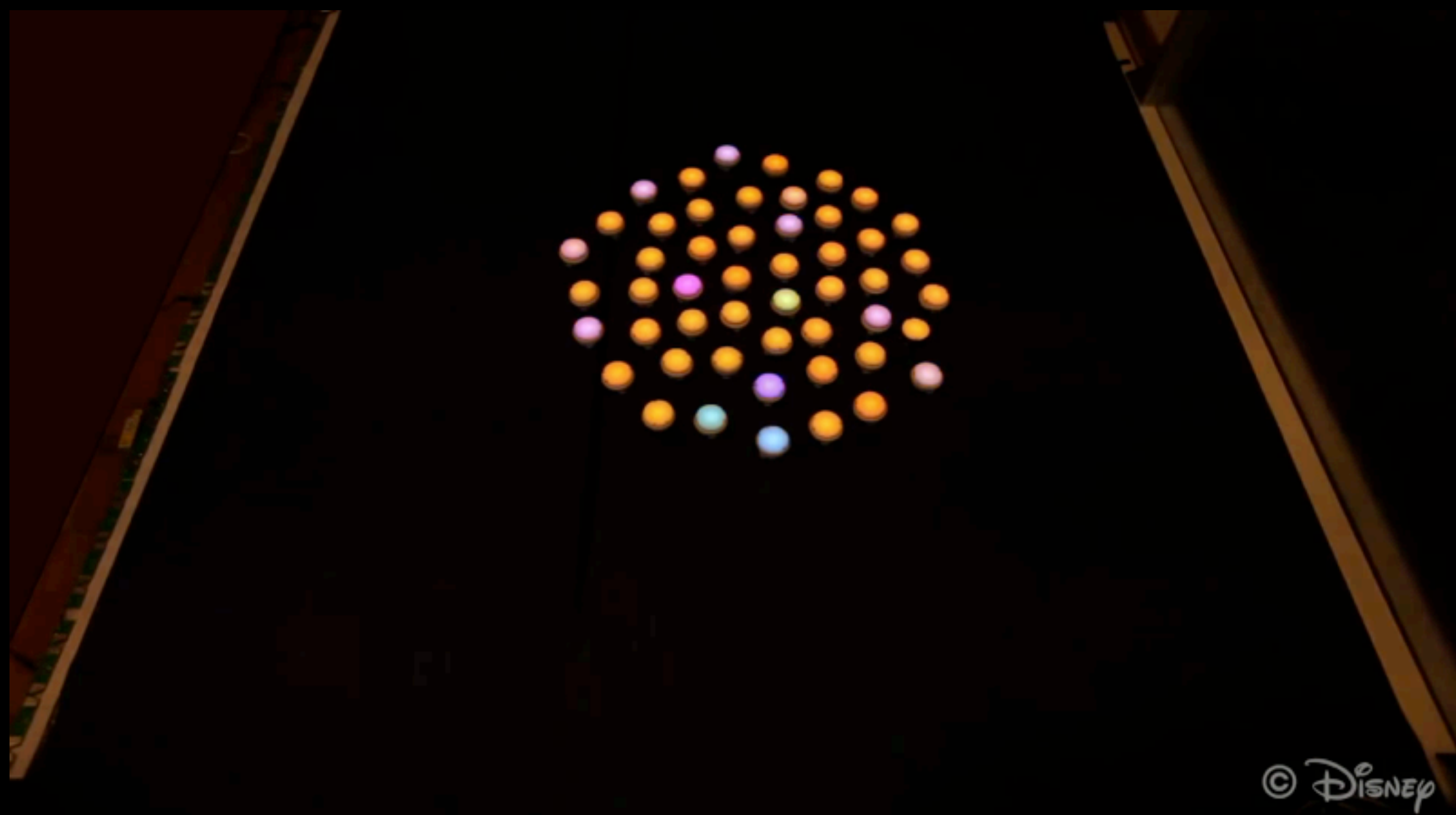


Thumbles, Patten Studio, 2014

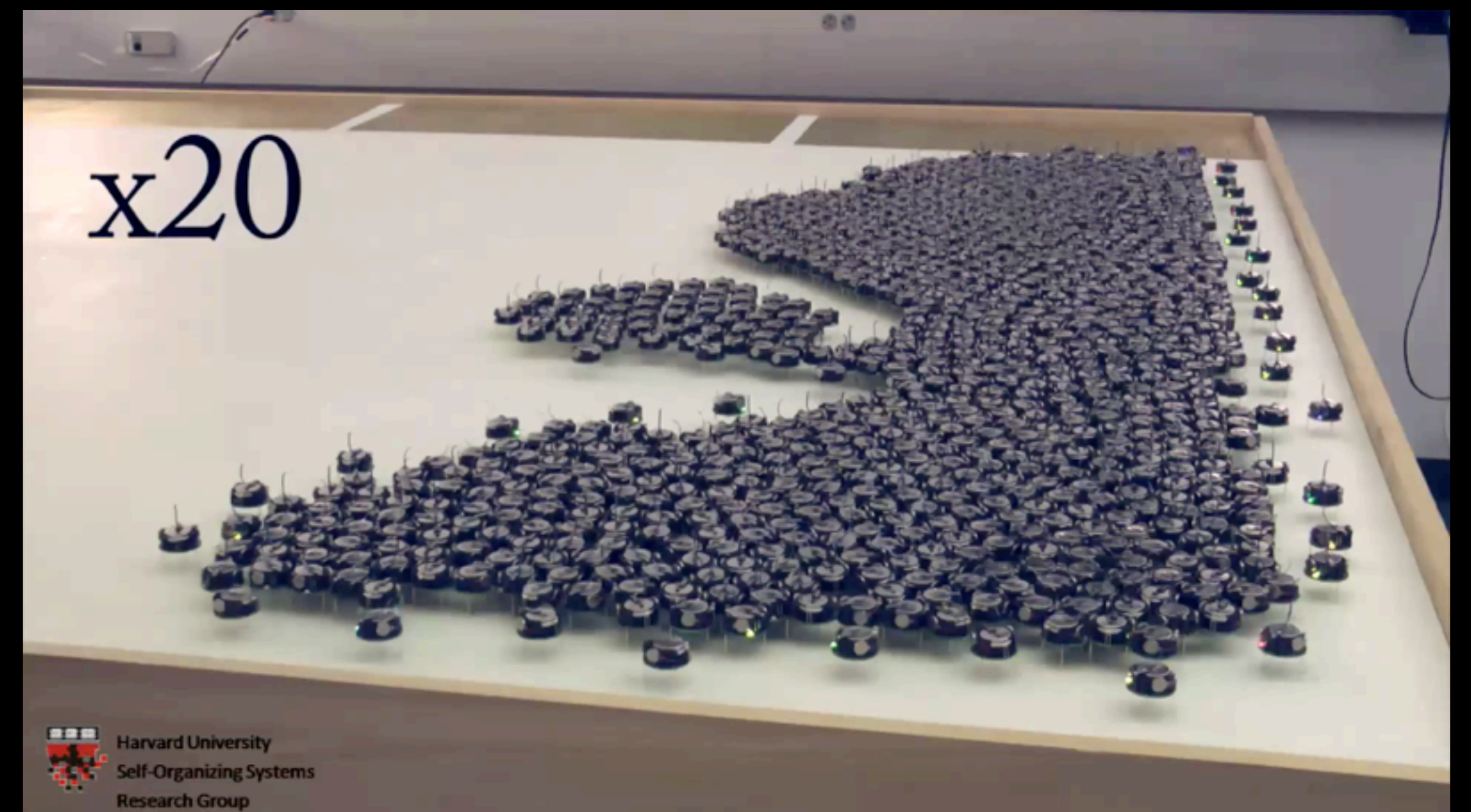


Bitdrones, Gomes et al., 2016





DisplaySwarm, Alonso-Mora et al., 2011



Kilobots, Rubenstein et al., 2014



Drone100, Futurelab, 2016

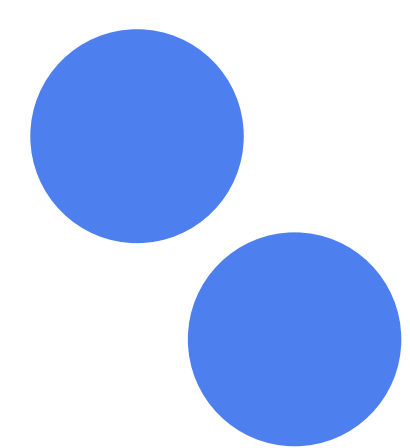
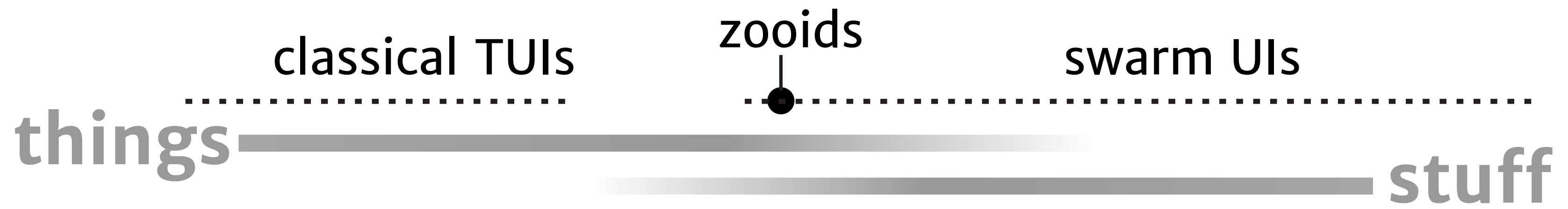


**Swarm User Interfaces** *are human-computer interfaces made of independent self-propelled elements that move collectively and react to user input.*

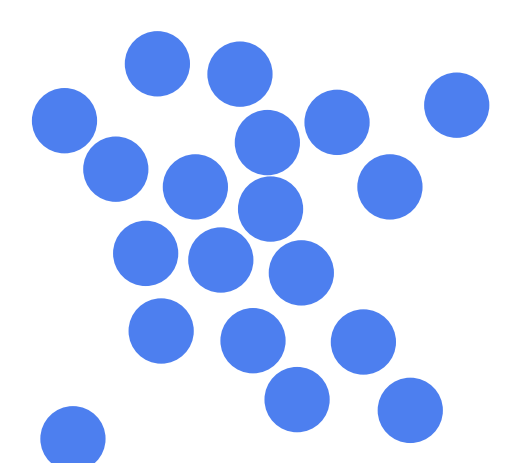
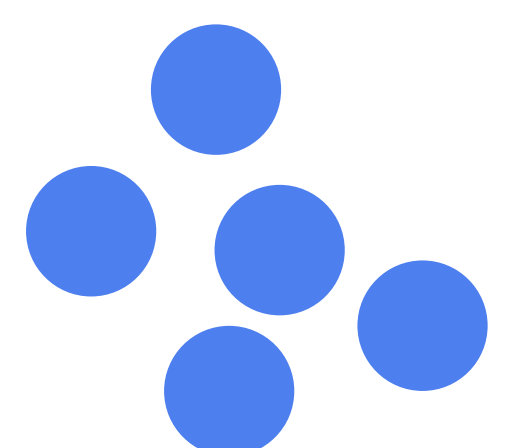


# Design considerations

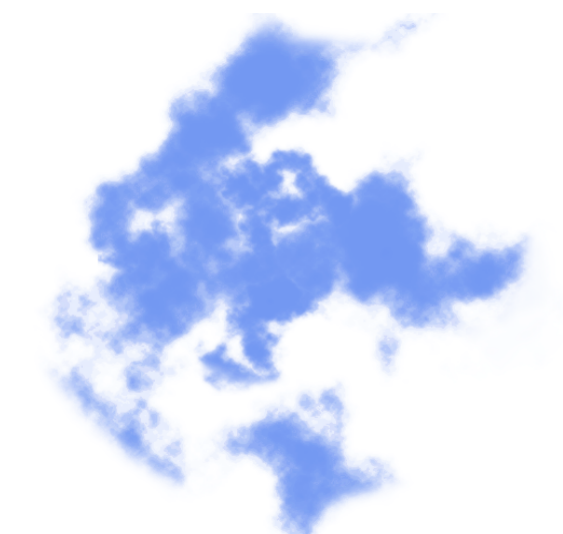
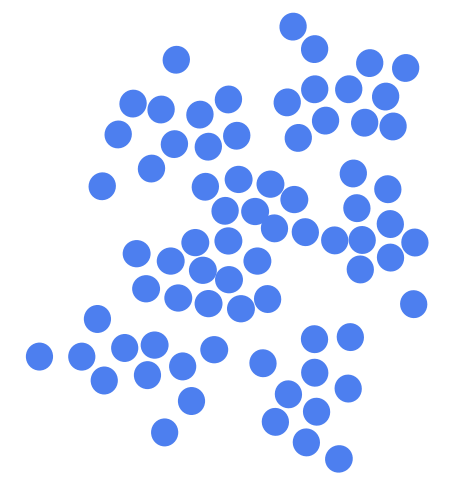




objects



particles



atoms



Display

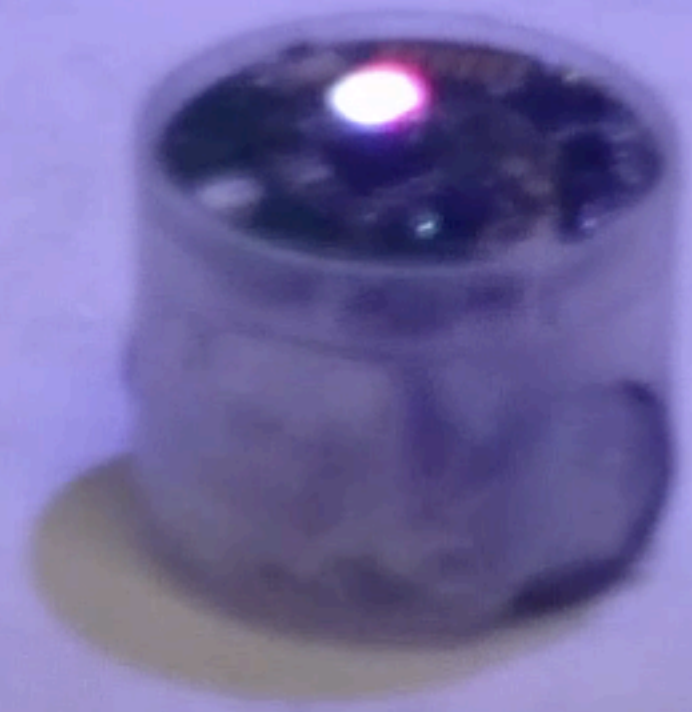


# Color

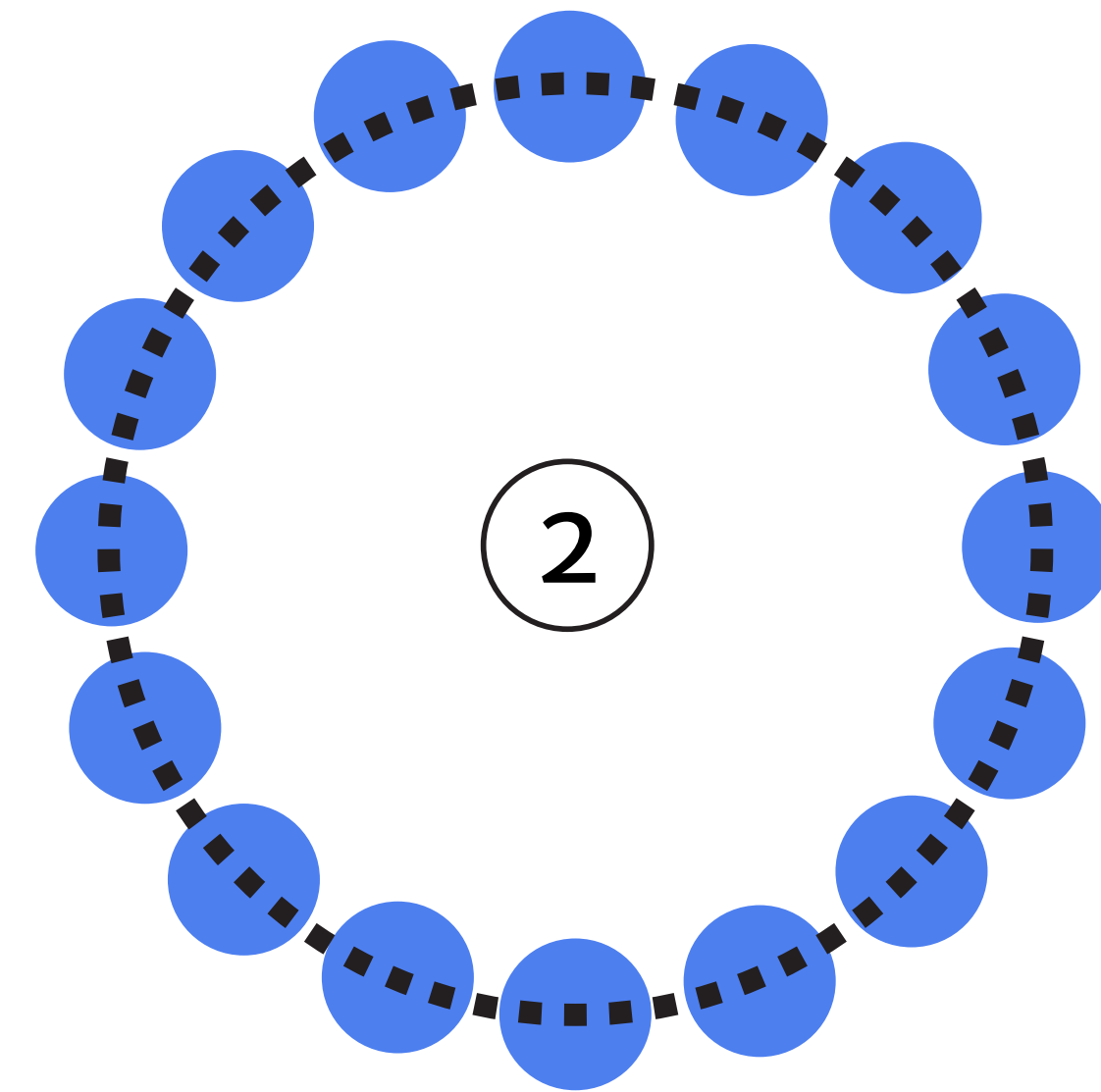
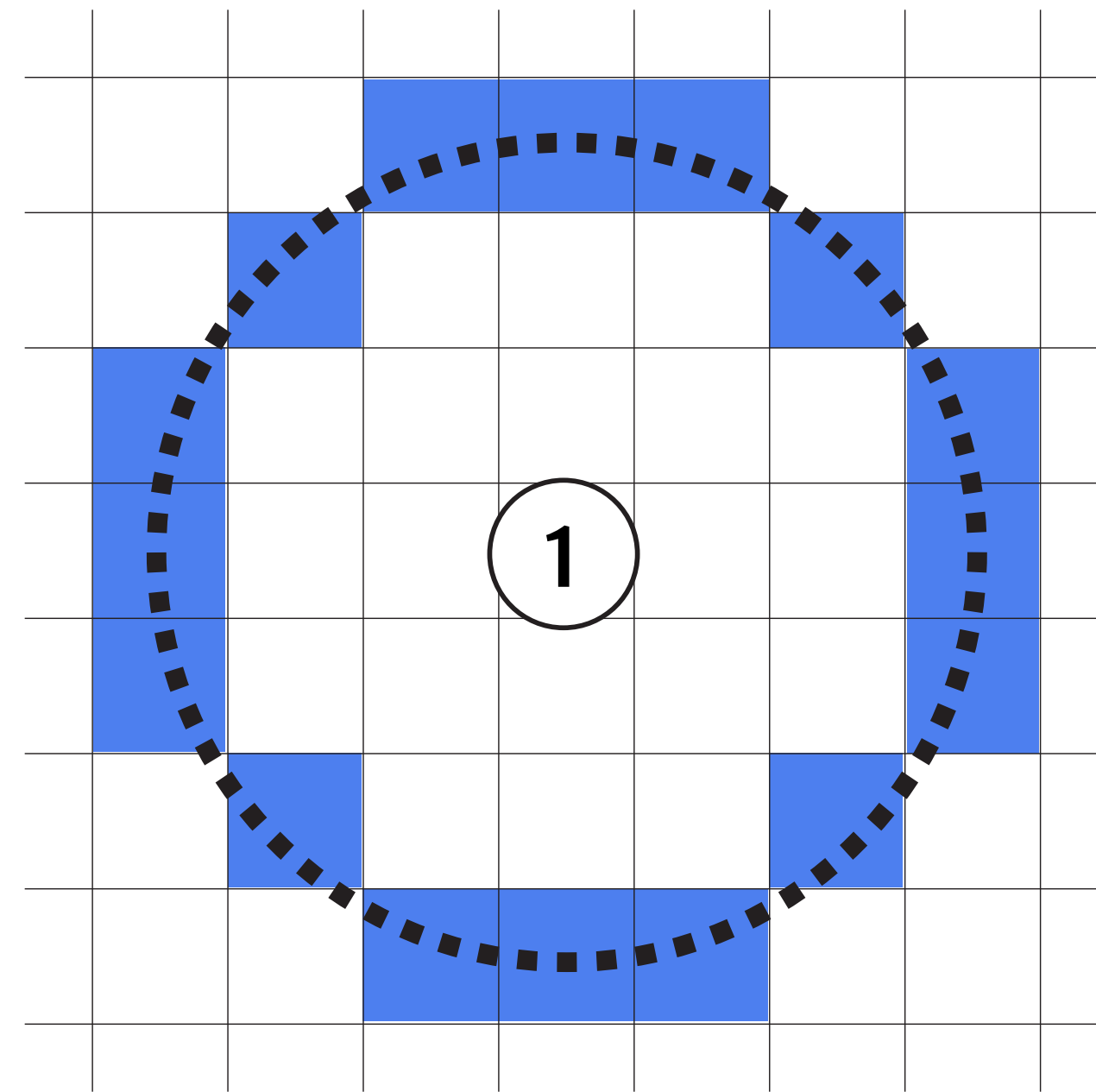




# Motion











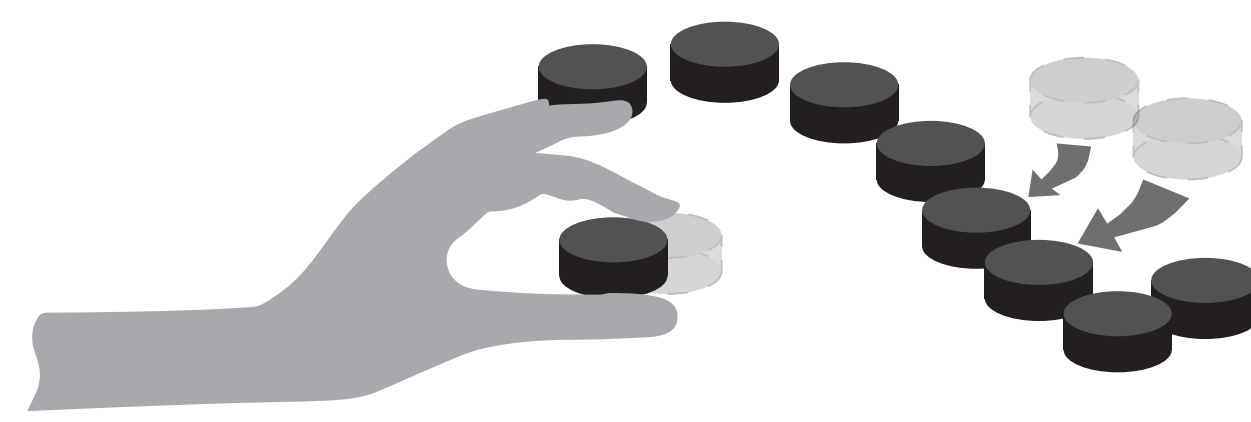


# Interaction

using Capacitive Touch Sensing and Position Sensing



one to one

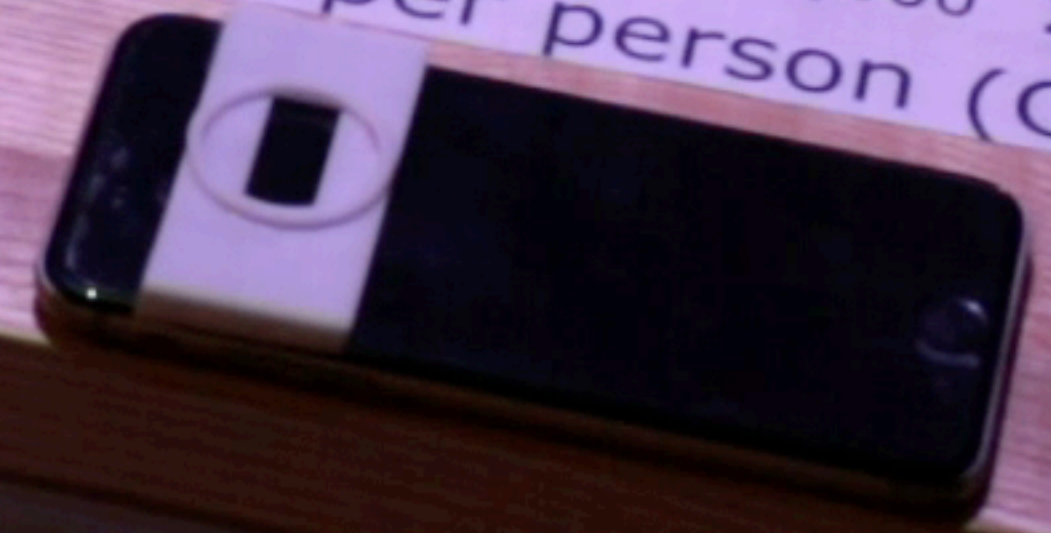
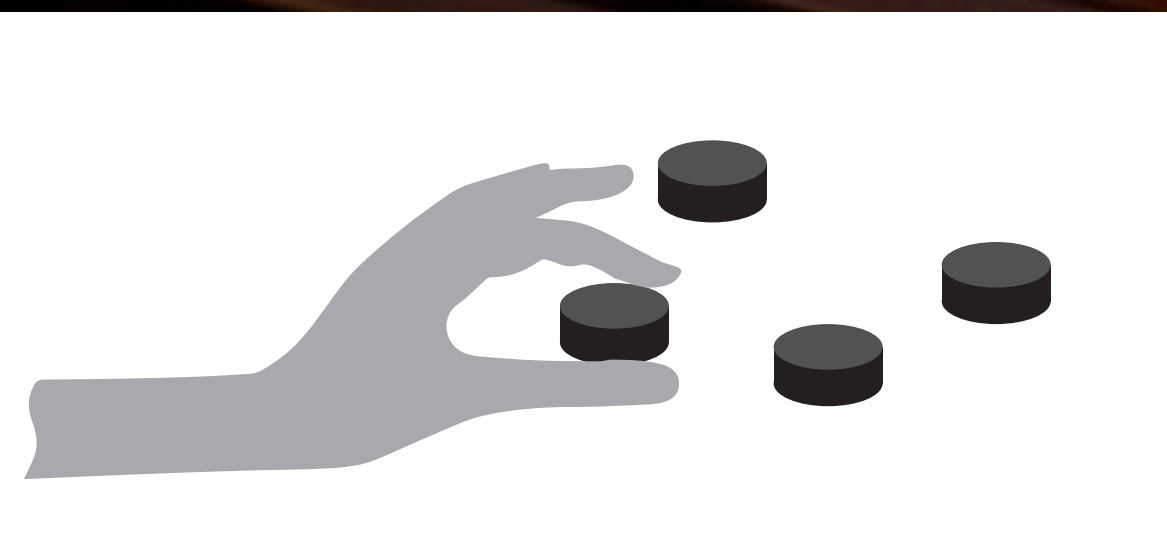
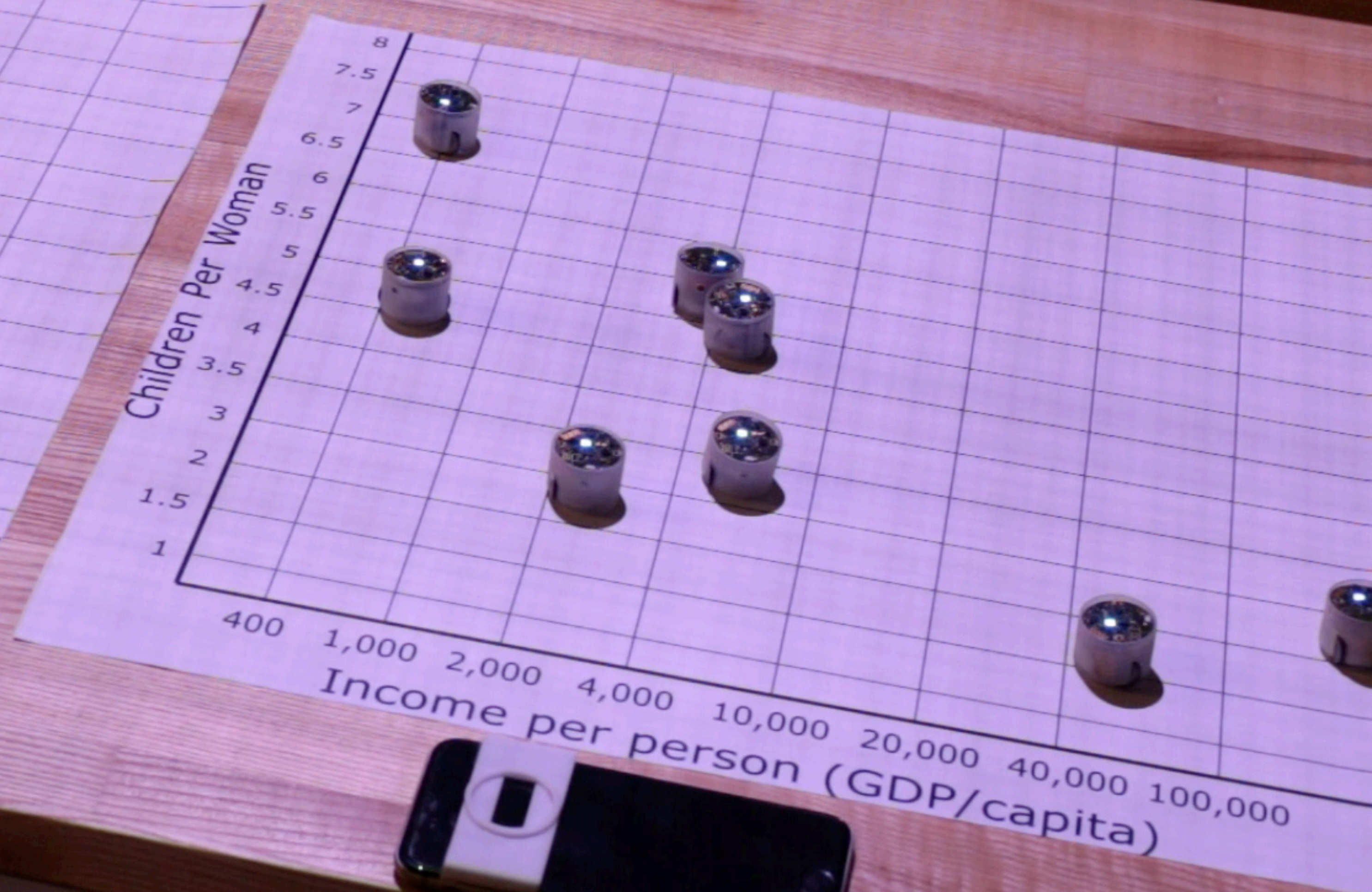
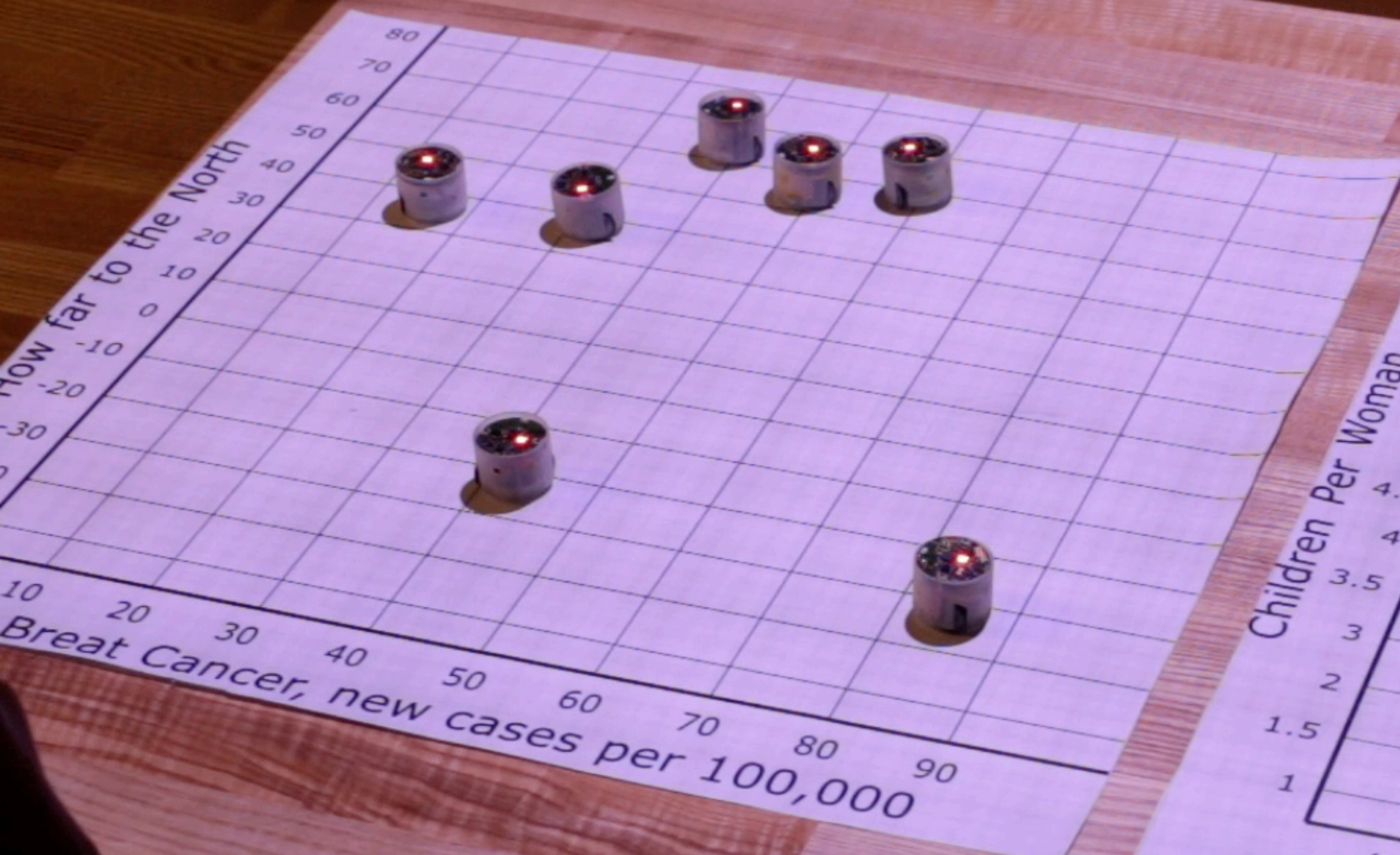


one to many

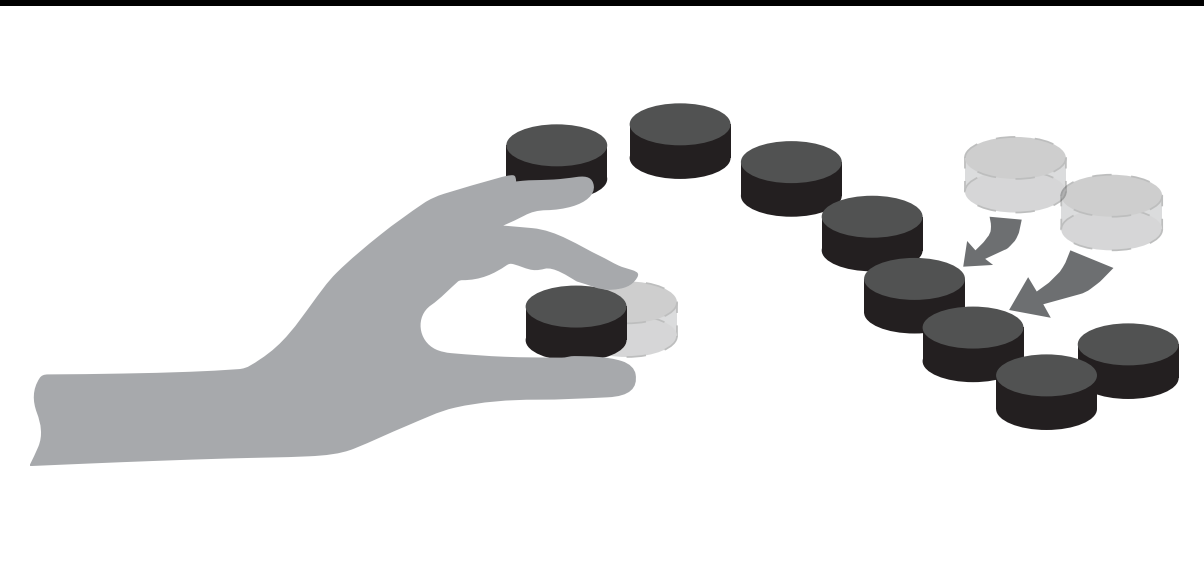


Groups





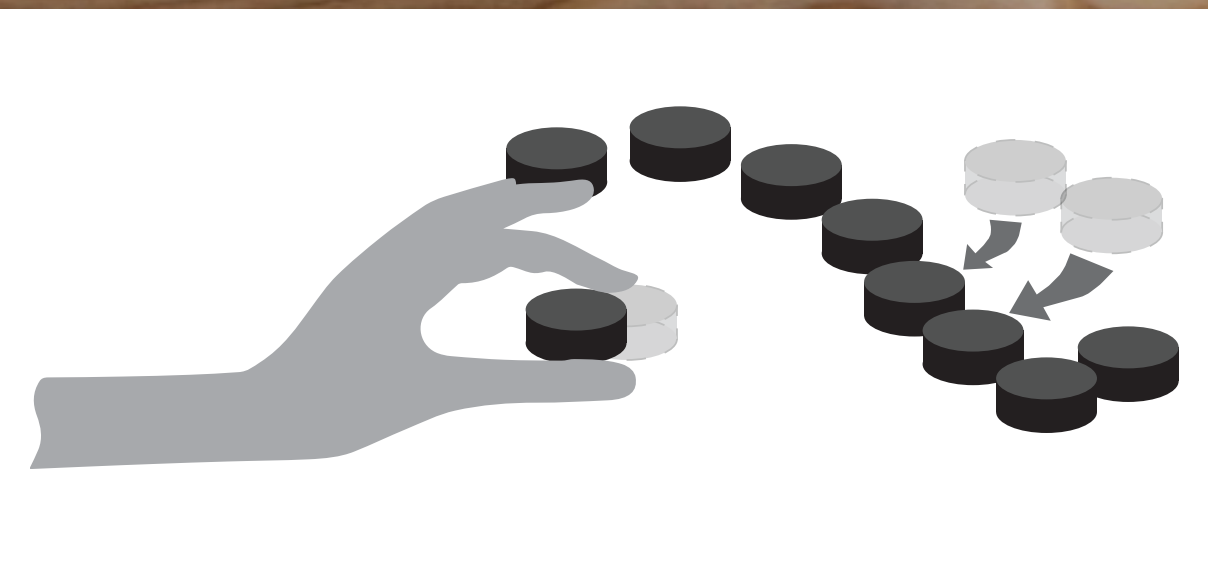
















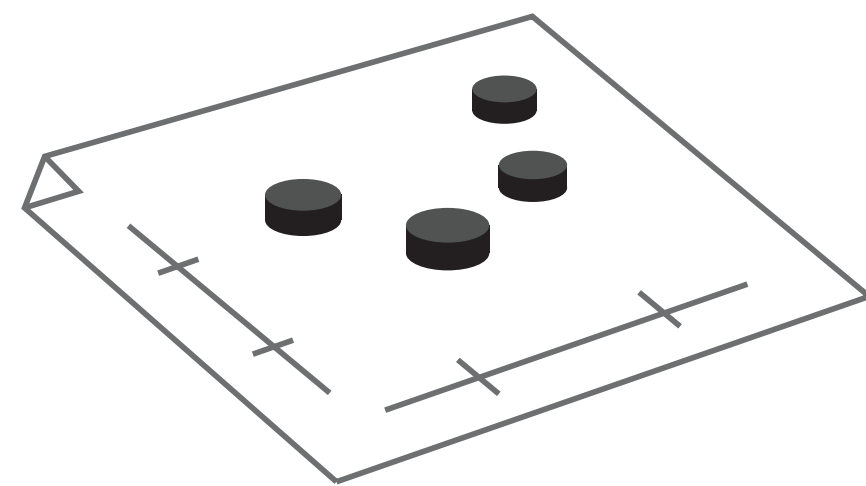


# UI Primitives

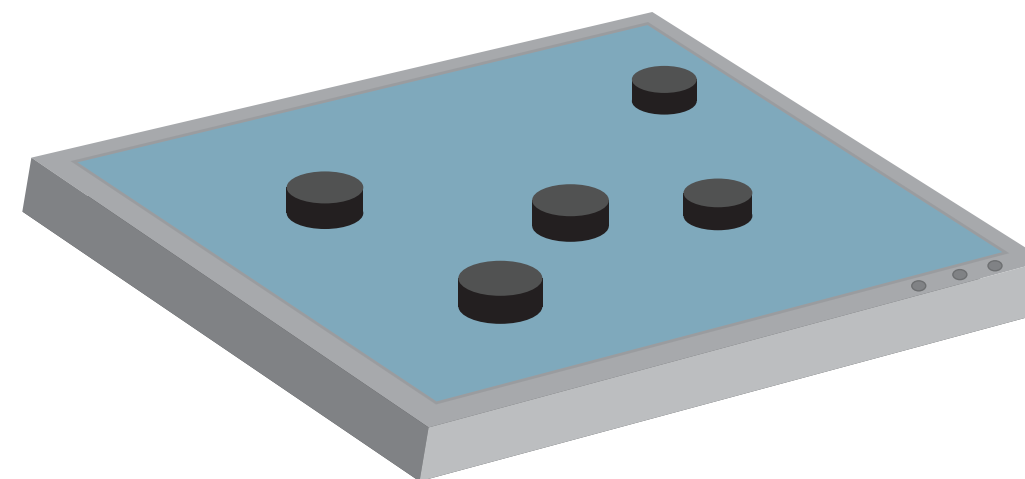




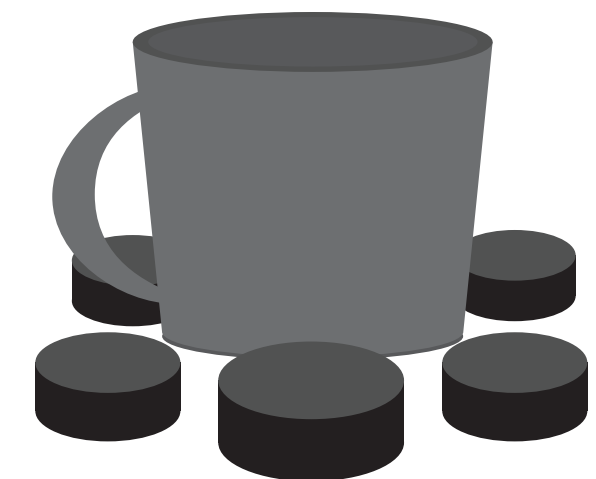
# Display context



Paper Templates

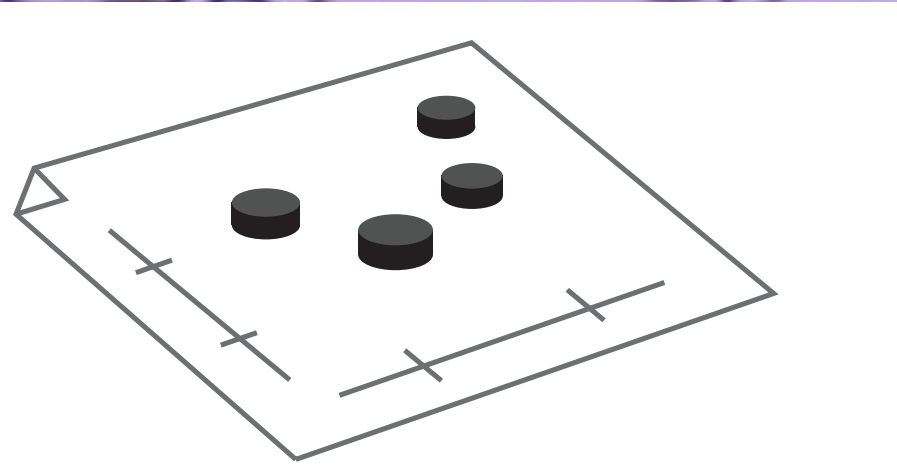
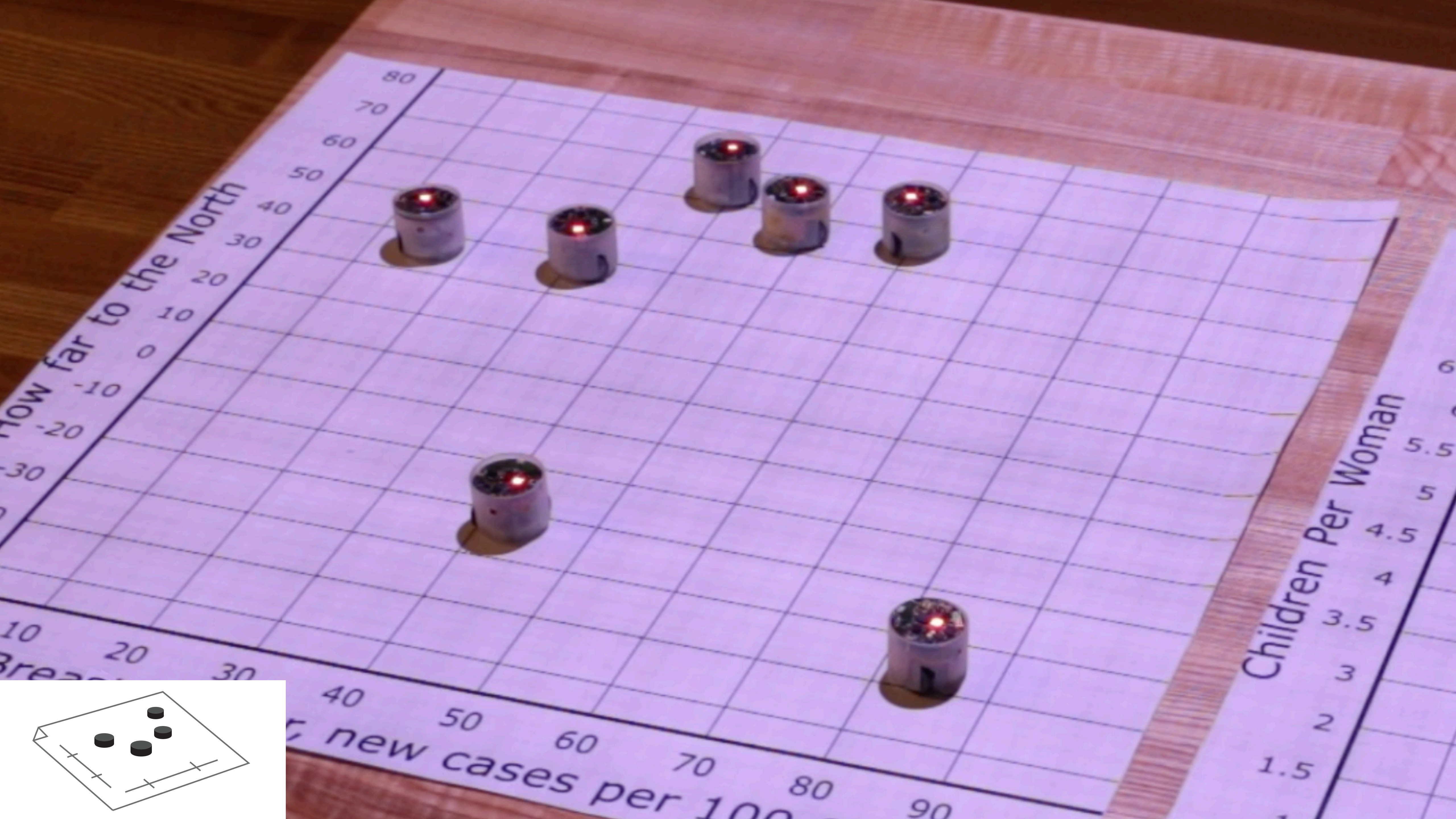


On screen

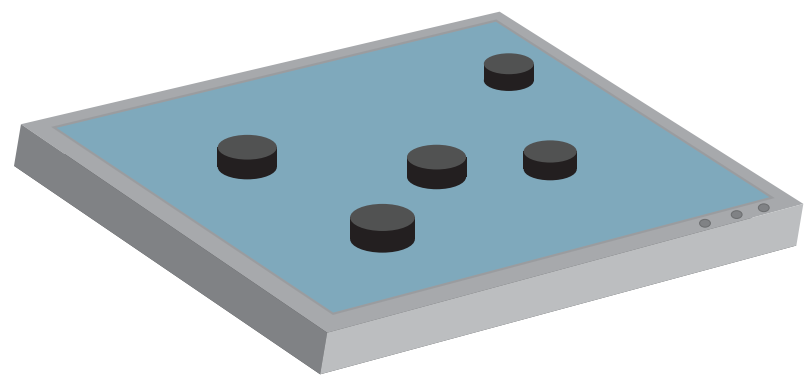
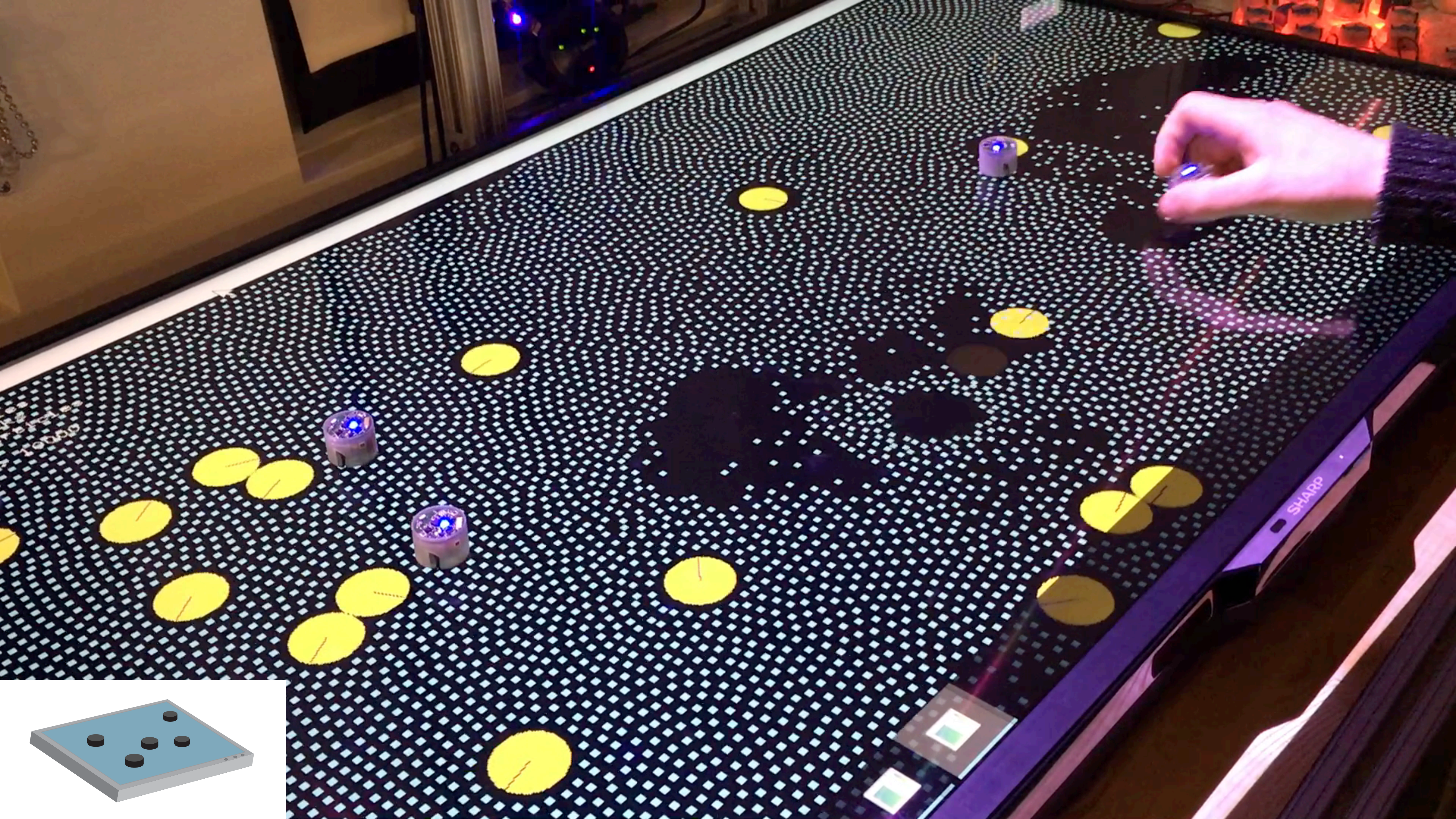


In the wild











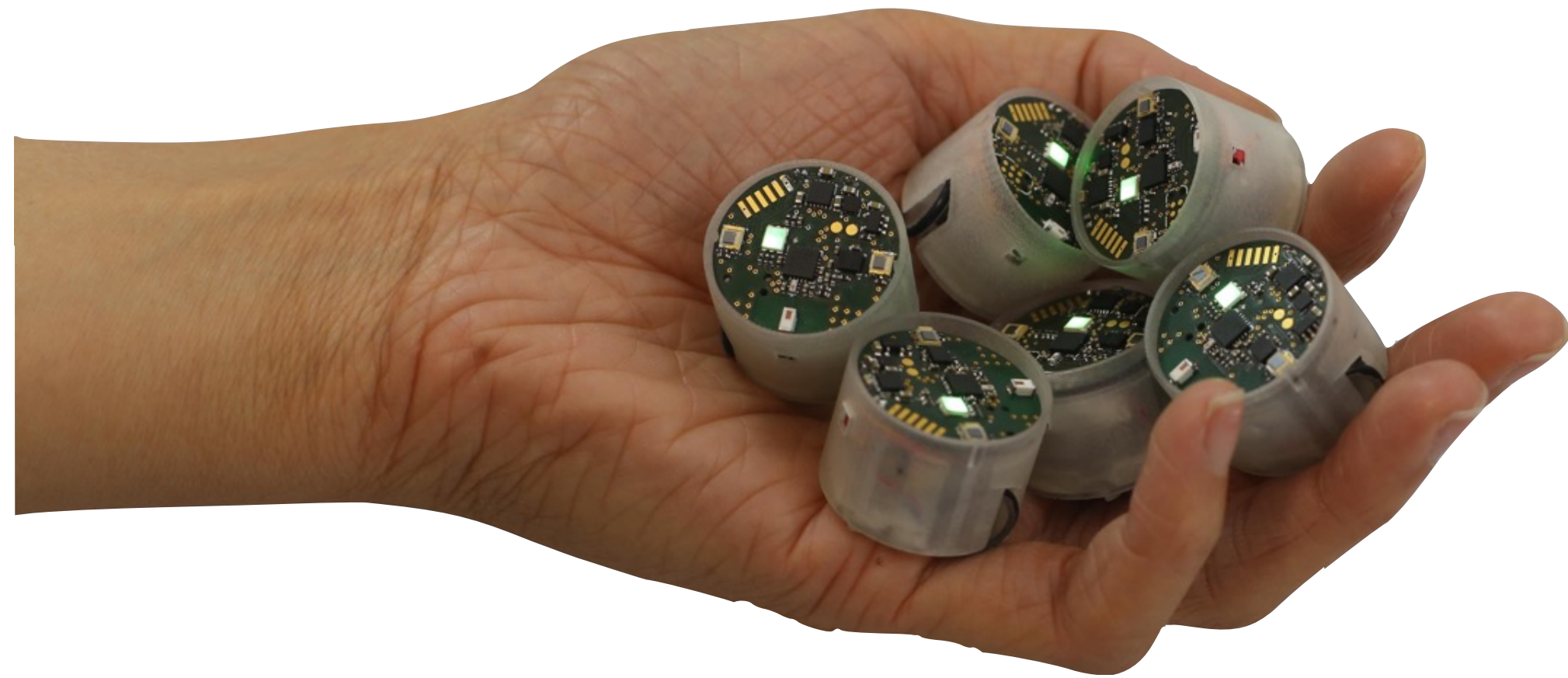
# Audio Notifications





# Implementation

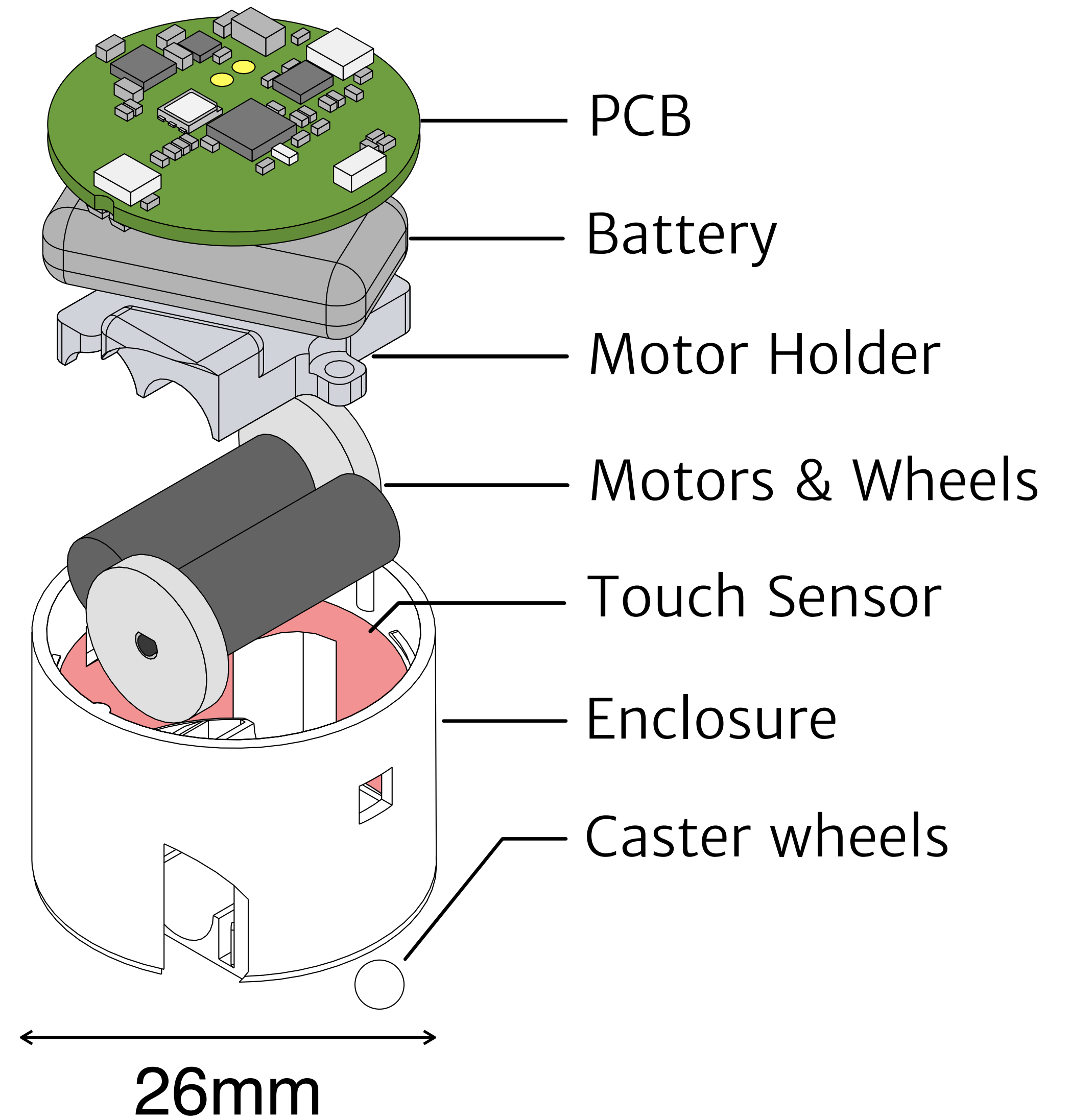




\$60 each  
in quantities of 200

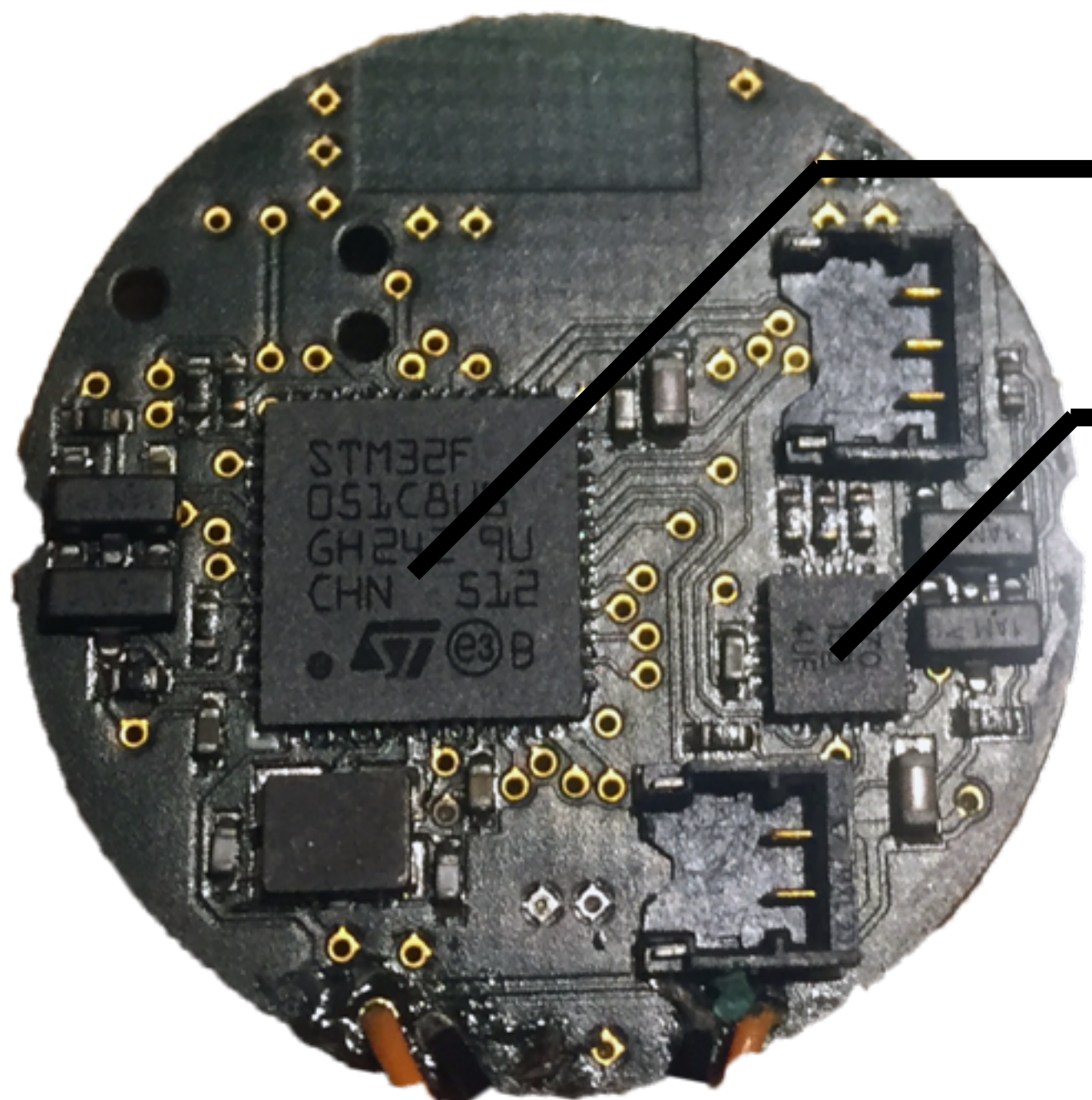
Battery Life 1-2hrs

21mm



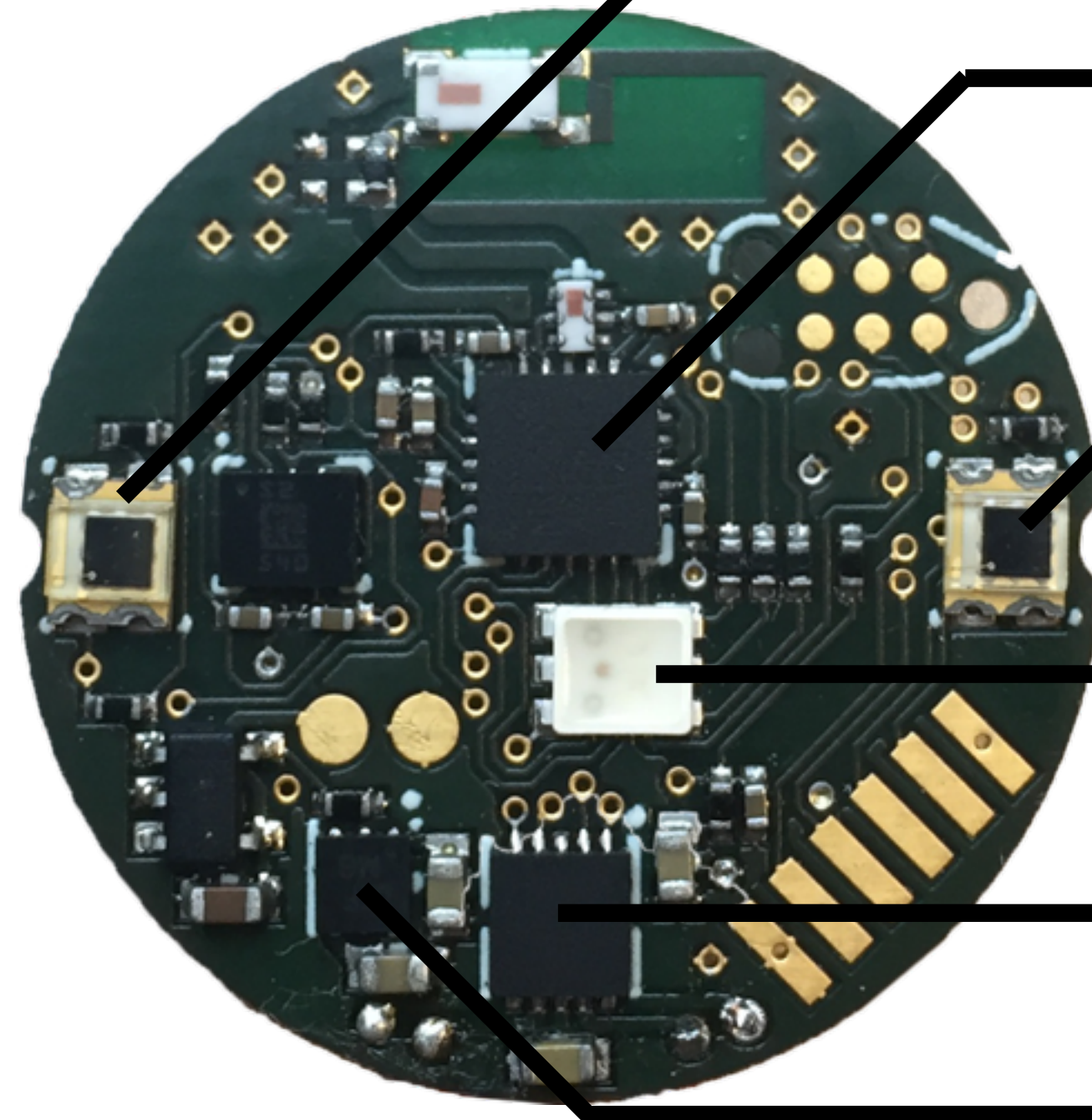


# PCB Close Up



Microcontroller

Touch sensor



Photodiode #1

Radio Module

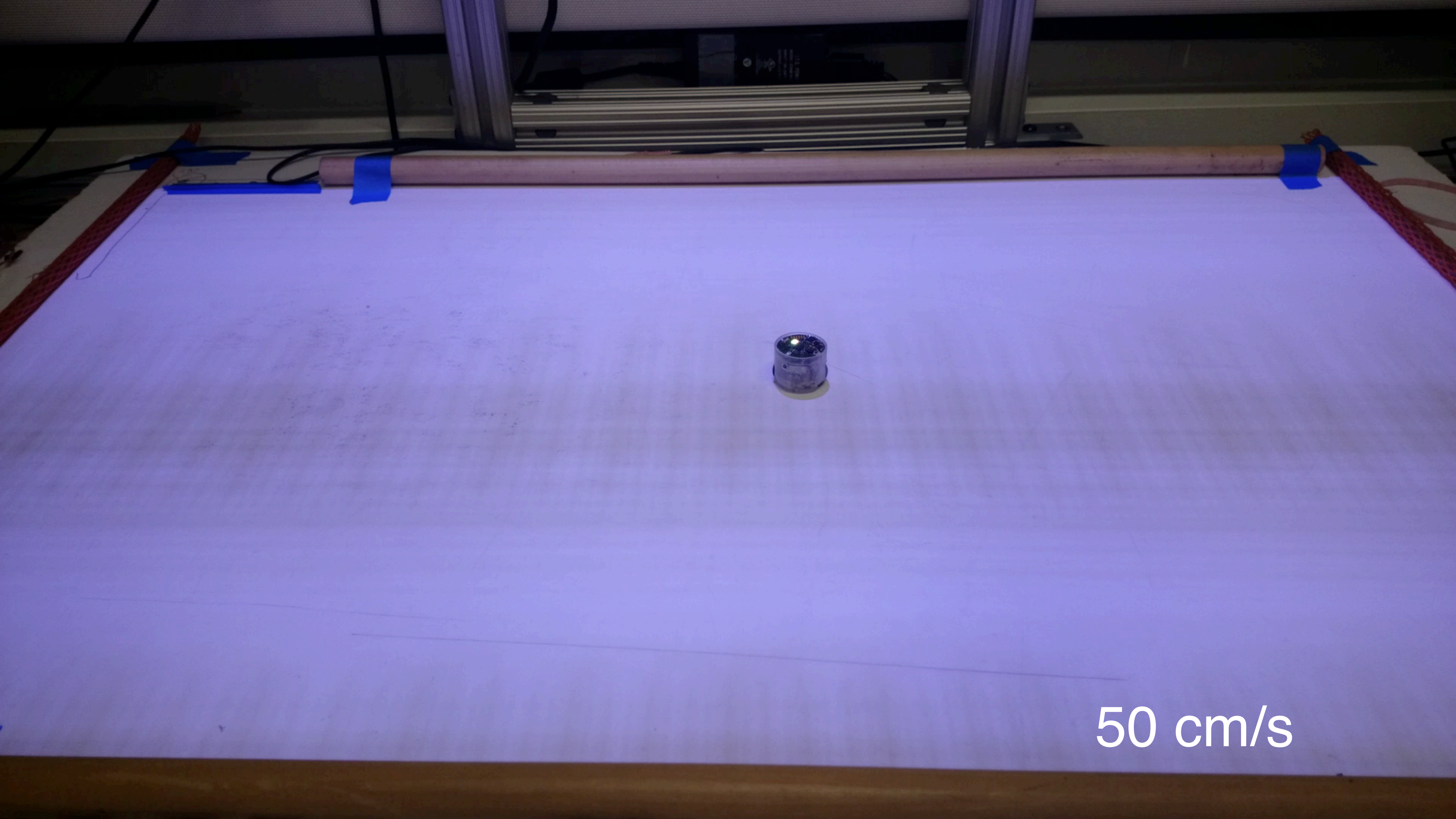
Photodiode #2

RGB LED

Motor controller

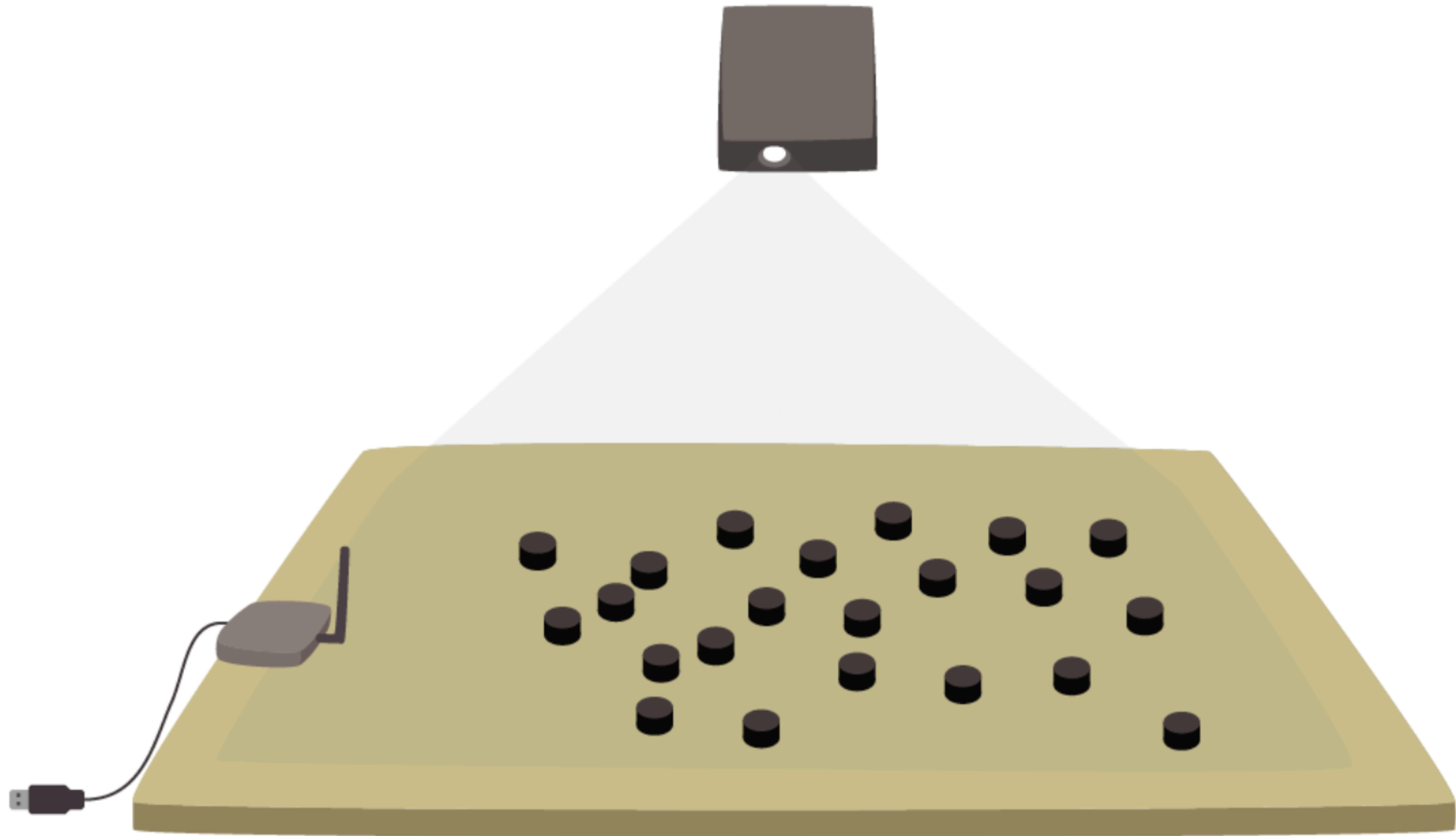
Battery charger





50 cm/s





Automatic Projector Calibration using Embedded Light Sensors, Lee et al., 2004



# Application

API

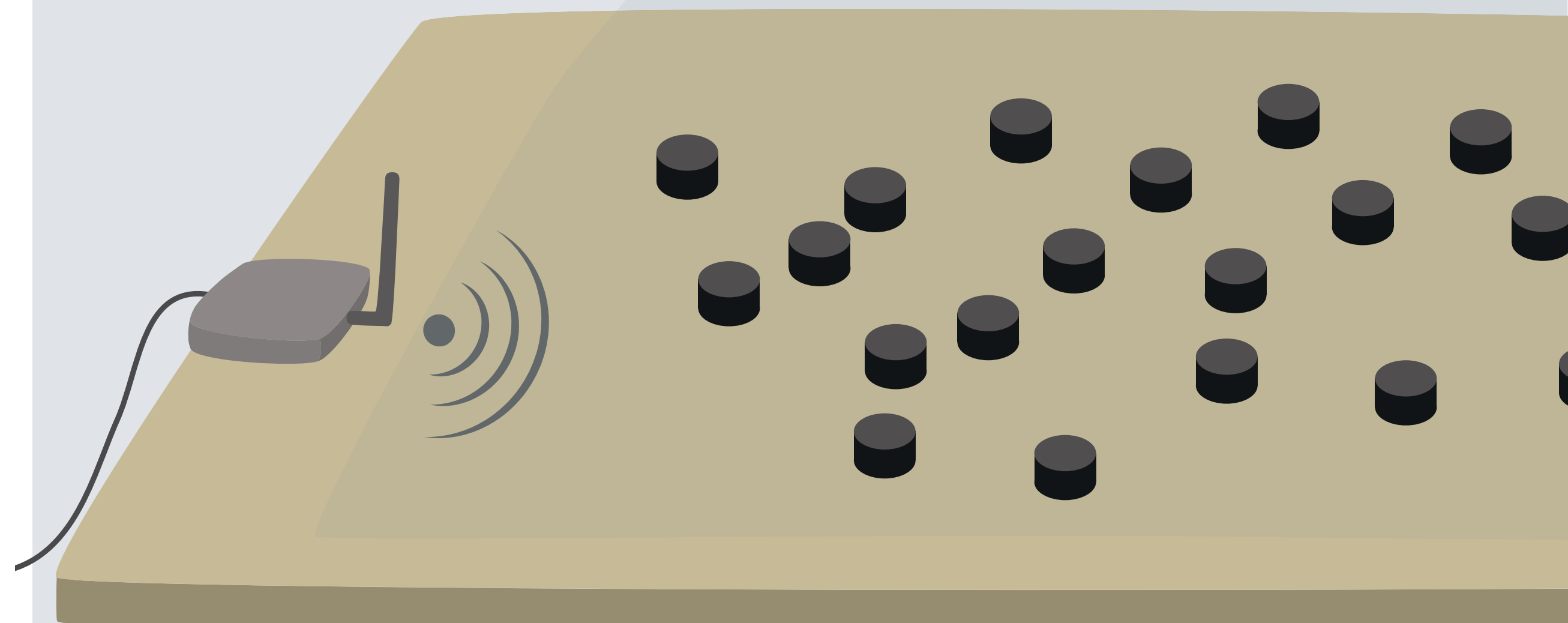
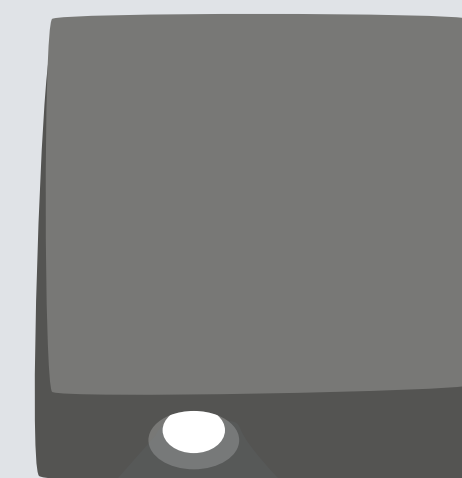
Goal

Goal

Orientation

Color

# Hardware





# Application

API

Goal

Goal

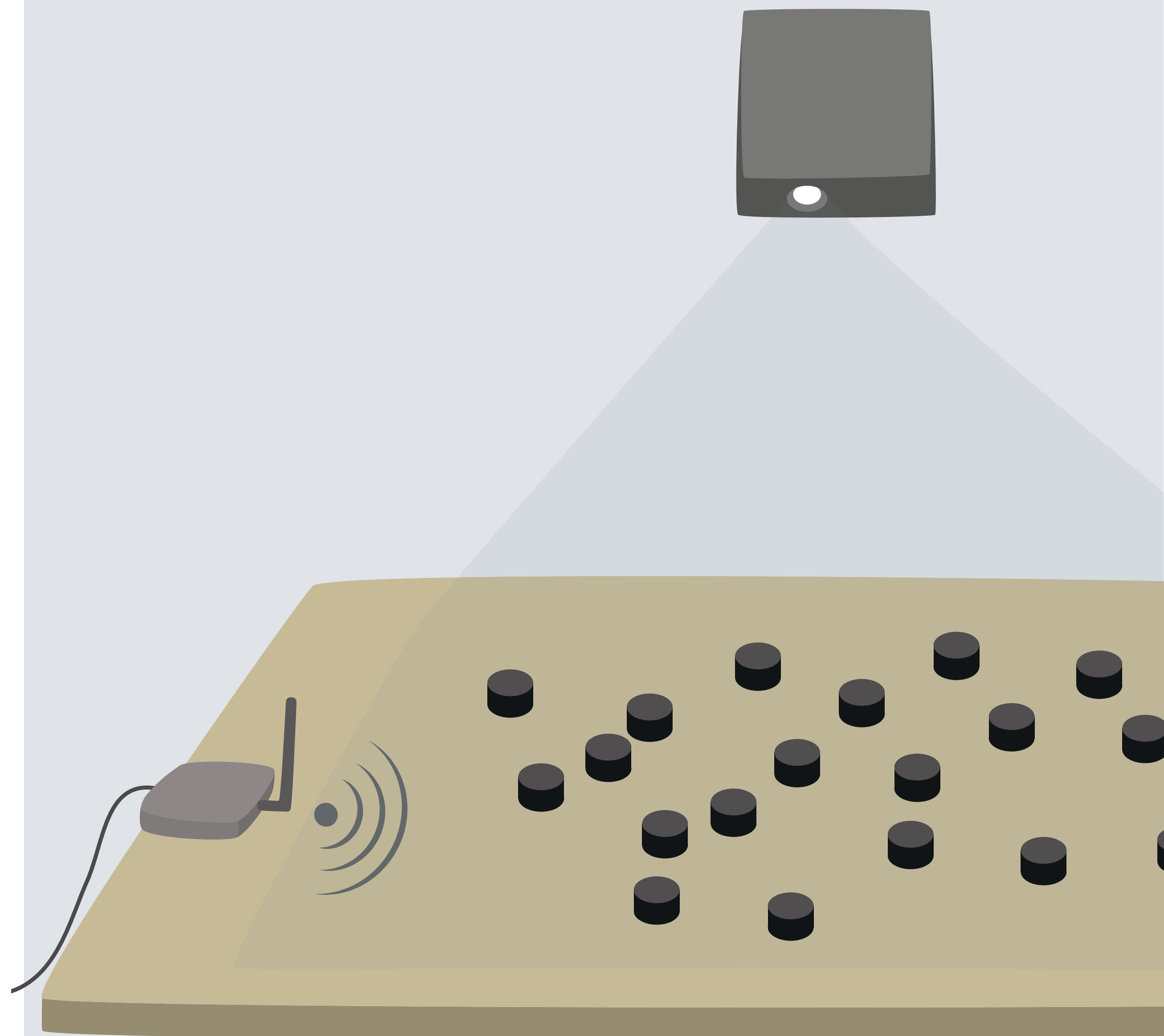
Orientation

Color

# Simulation

Path  
Planning  
Steps

# Hardware





# Application

API

Goal

Goal

Orientation

Color

# Simulation

Path  
Planning  
Steps

# Server

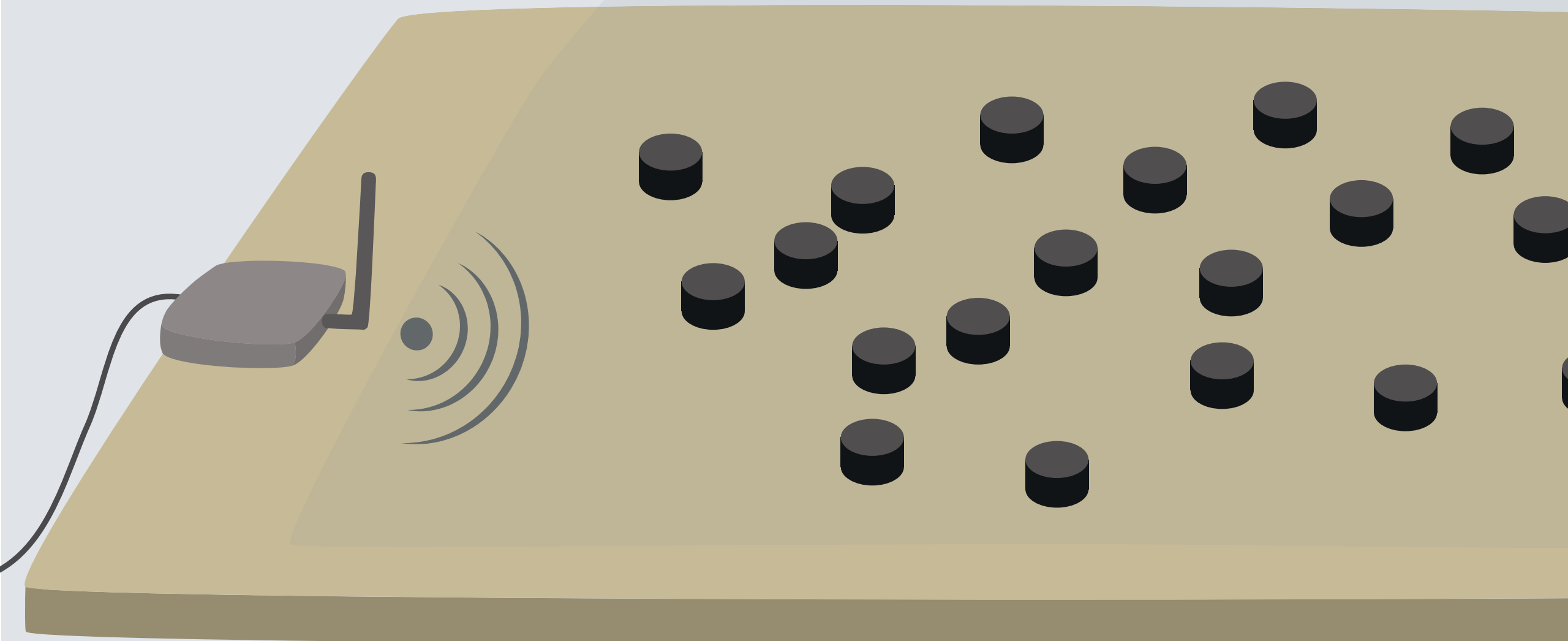
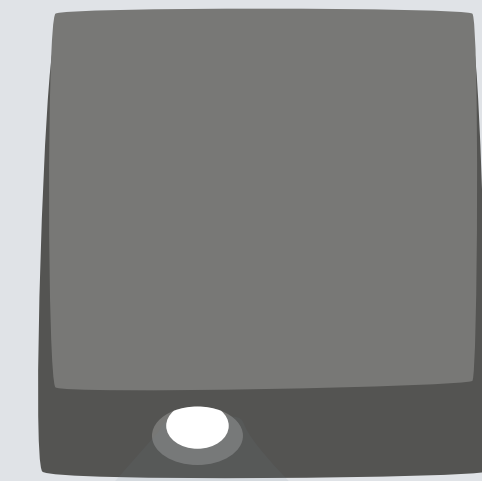
Robots

Position

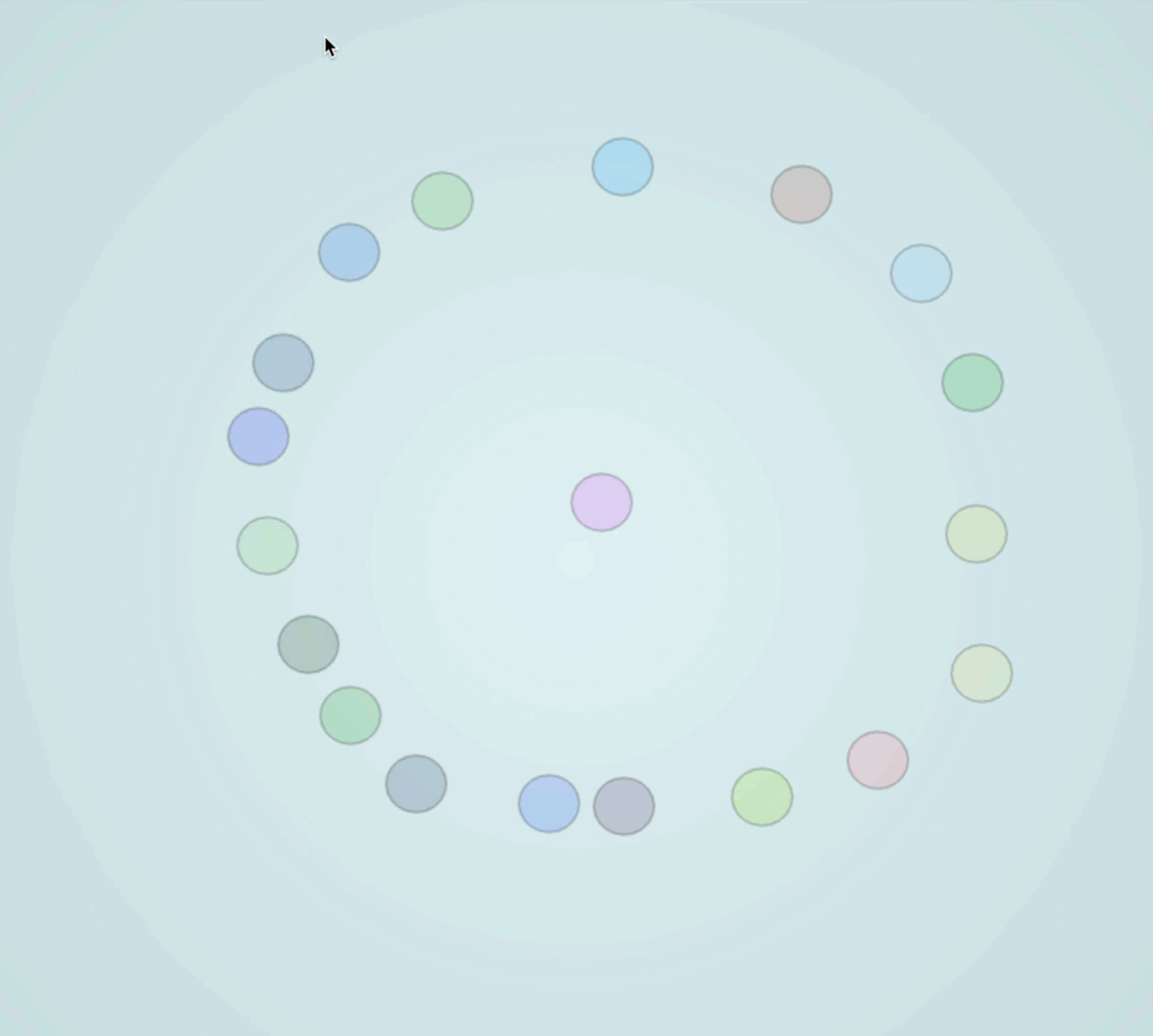
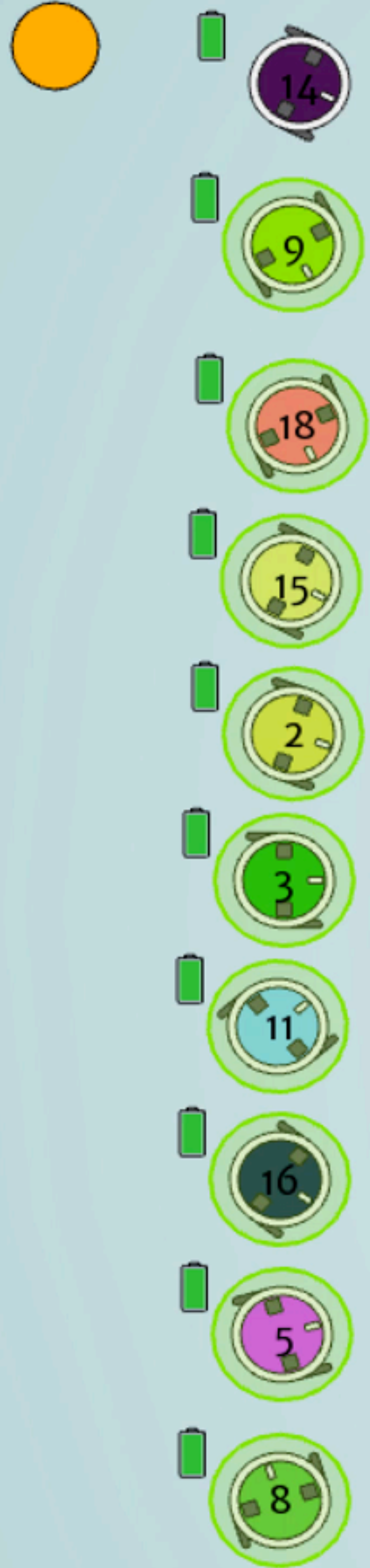
Orientation

Touch

# Hardware



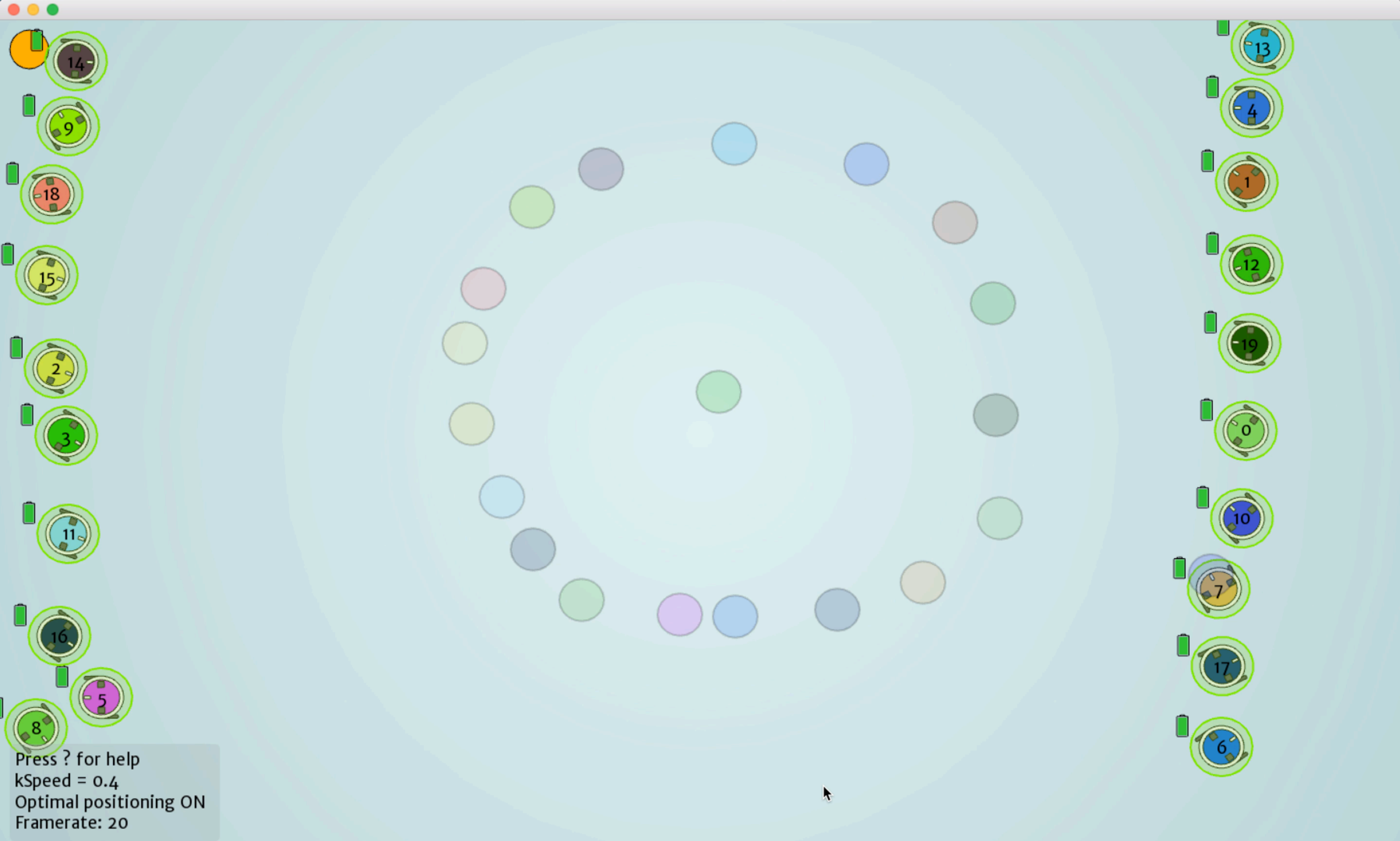




Press ? for help  
kSpeed = 0.4  
Optimal positioning OFF  
Framerate: 21

The hybrid reciprocal velocity obstacle, Snape et al., 2011

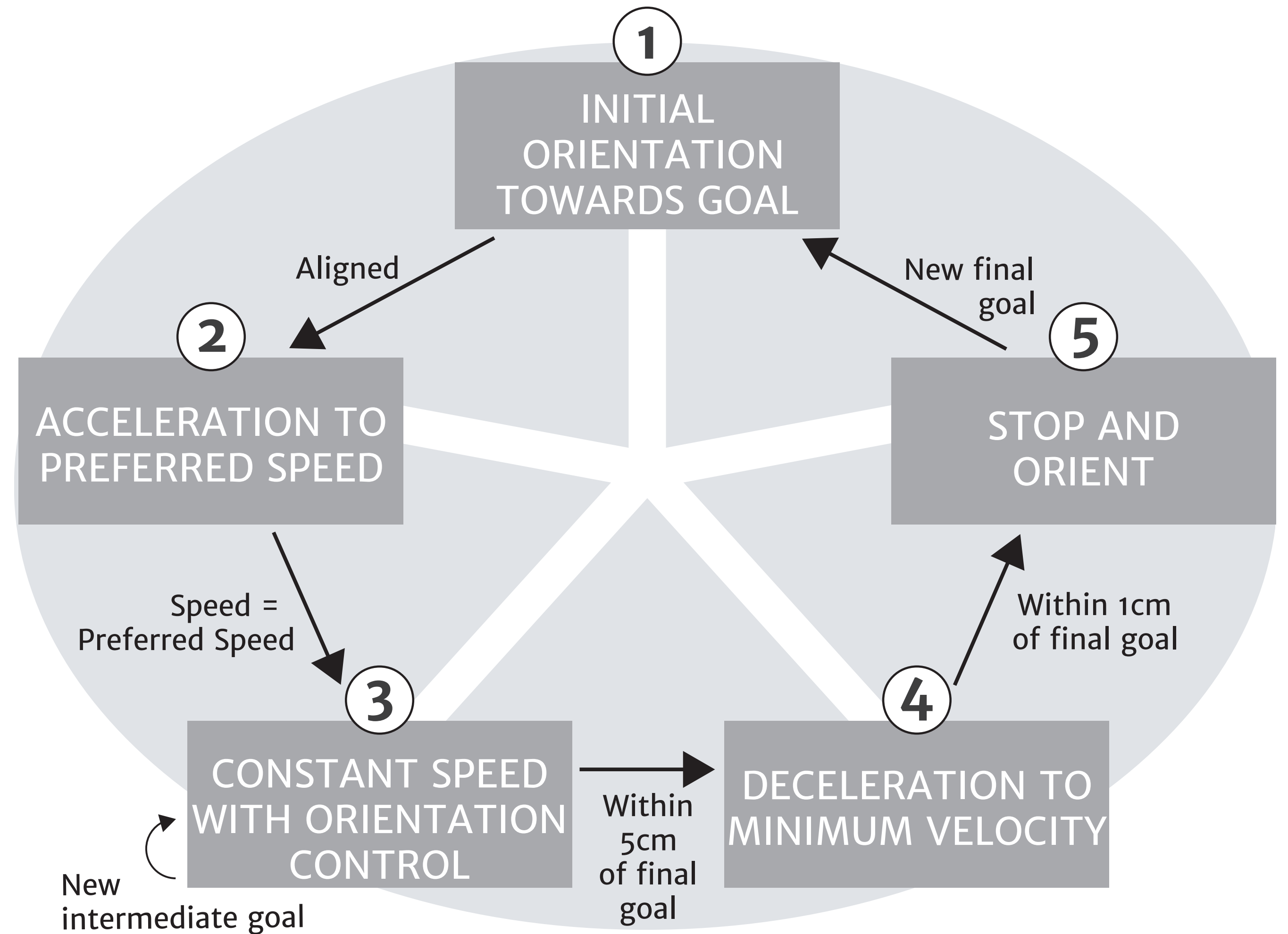
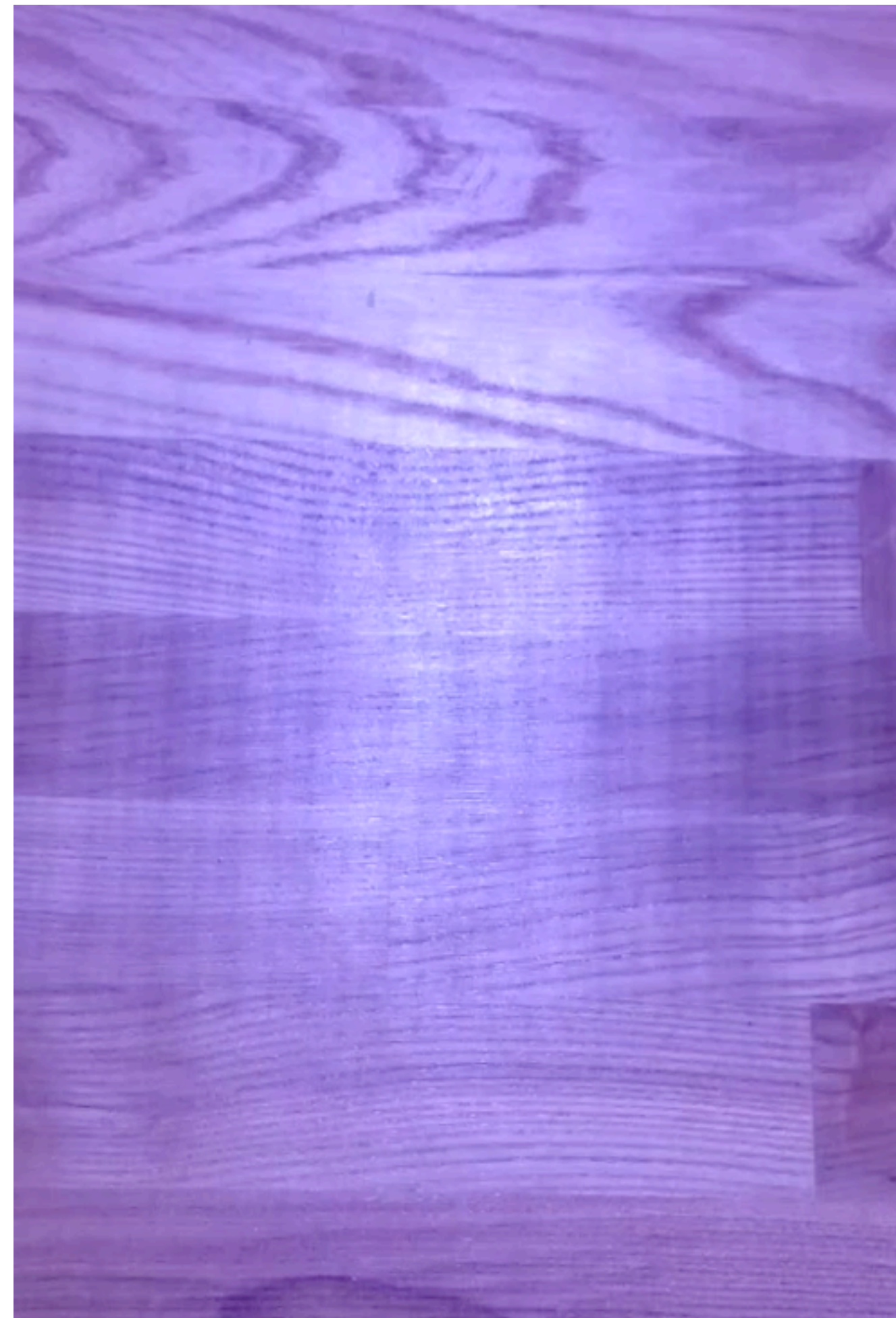




Press ? for help  
kSpeed = 0.4  
Optimal positioning ON  
Framerate: 20



# Local Closed Loop PID Control





# Applications



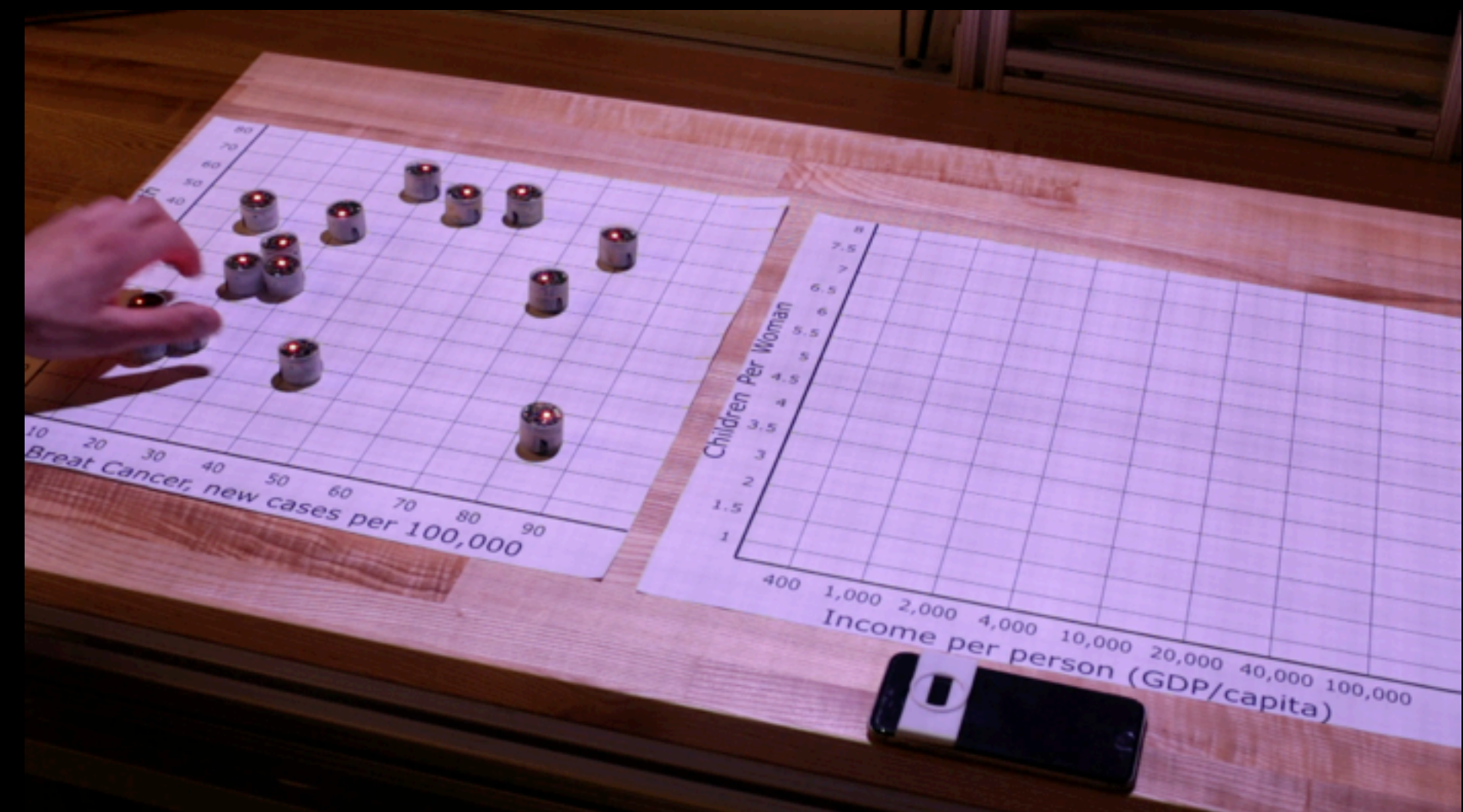
Bezier curves



Shape drawing



Ubiquitous interfaces



Information Visualization



# Limitations

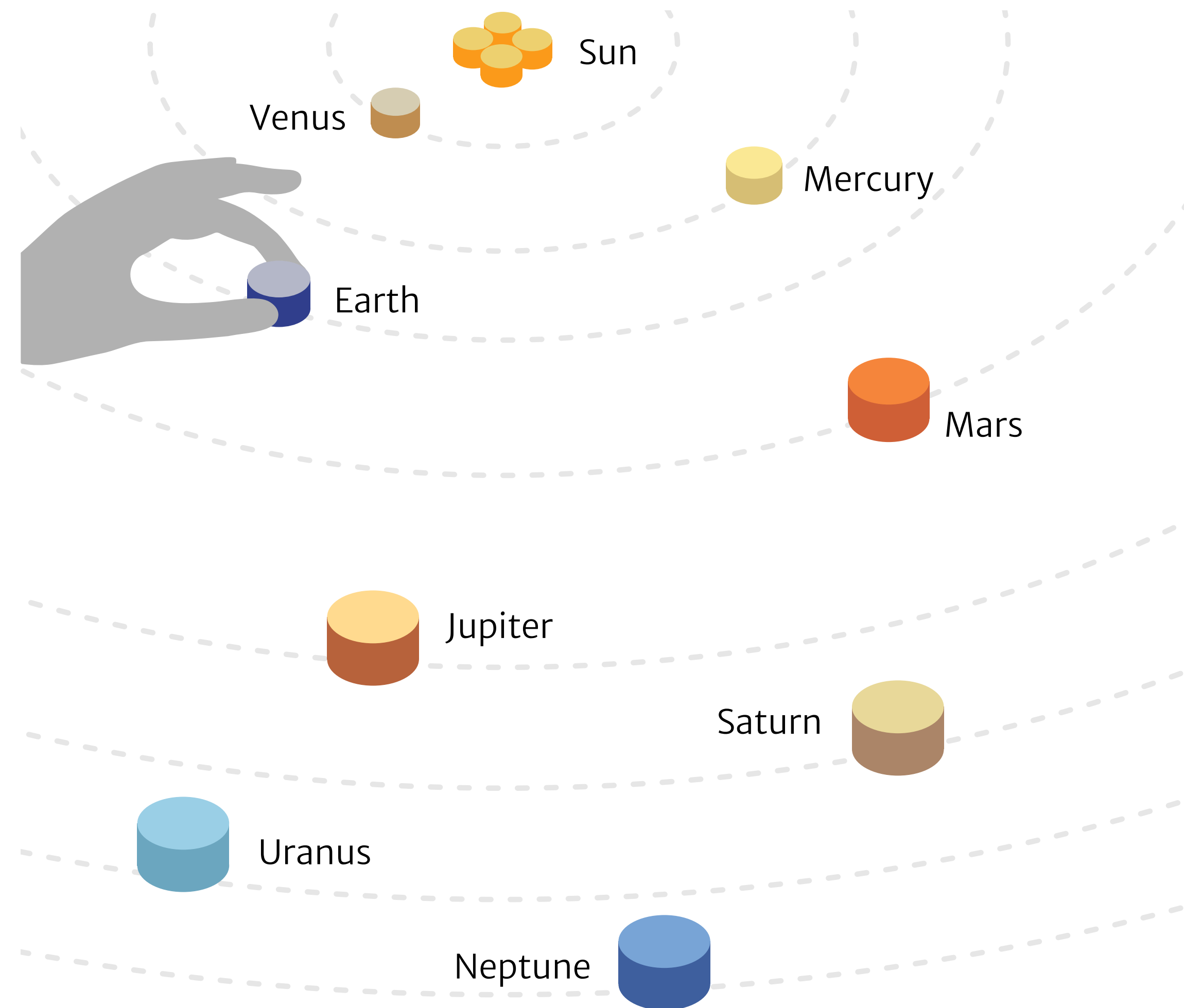
- Tracking system limiting interaction area
- Lack of omni-directional drive train
- Resolution
- Scalability
- Power supply - challenge as size decreases



**Future work**

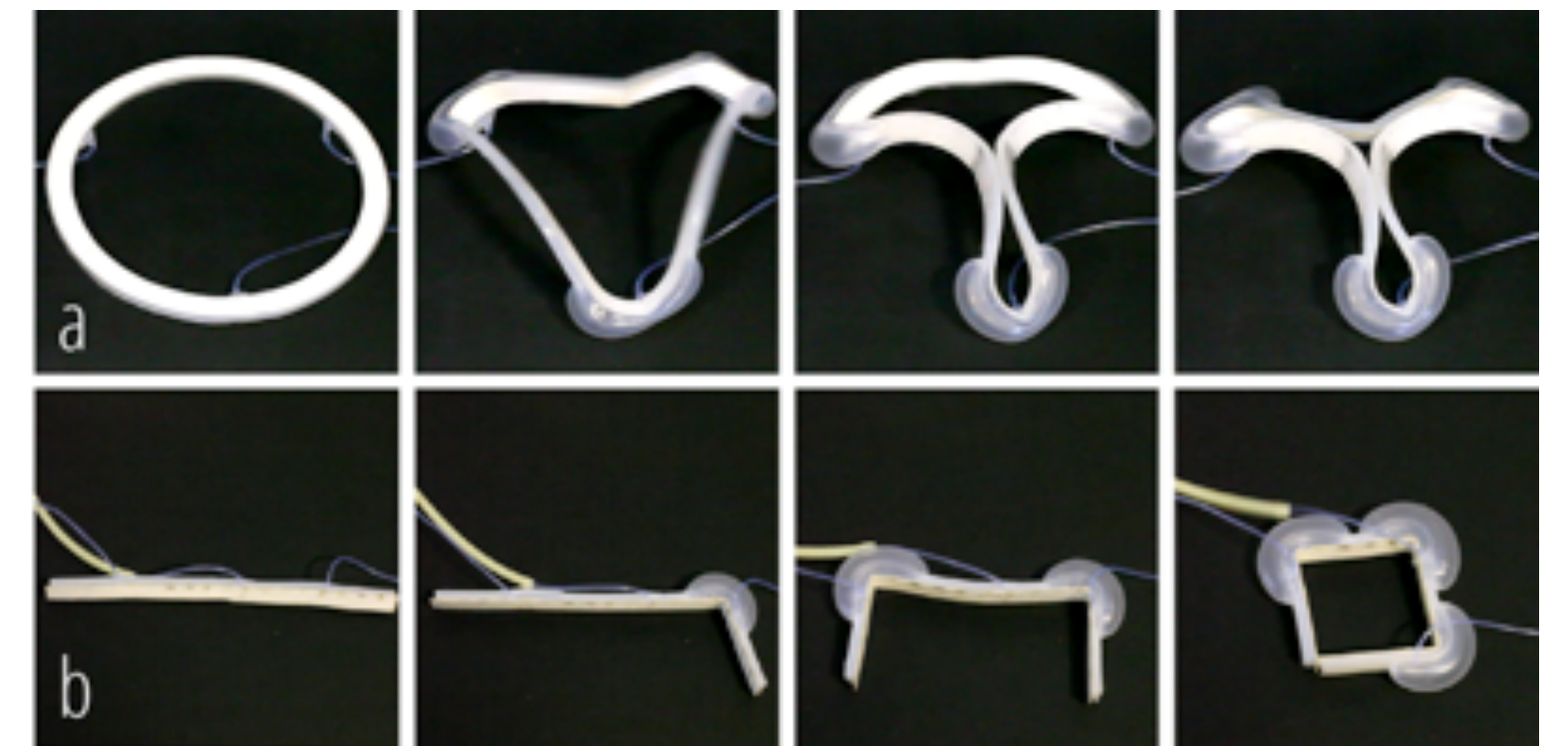
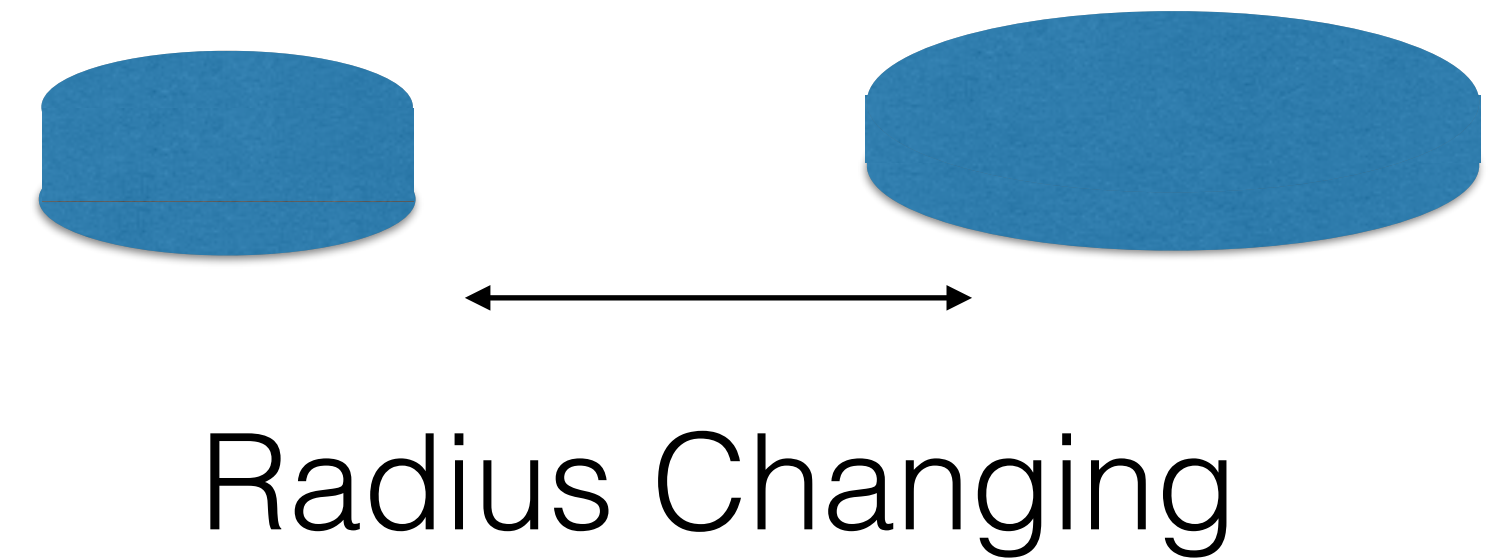


# Applications in education and for the visually impaired





# Shape-changing Zooids

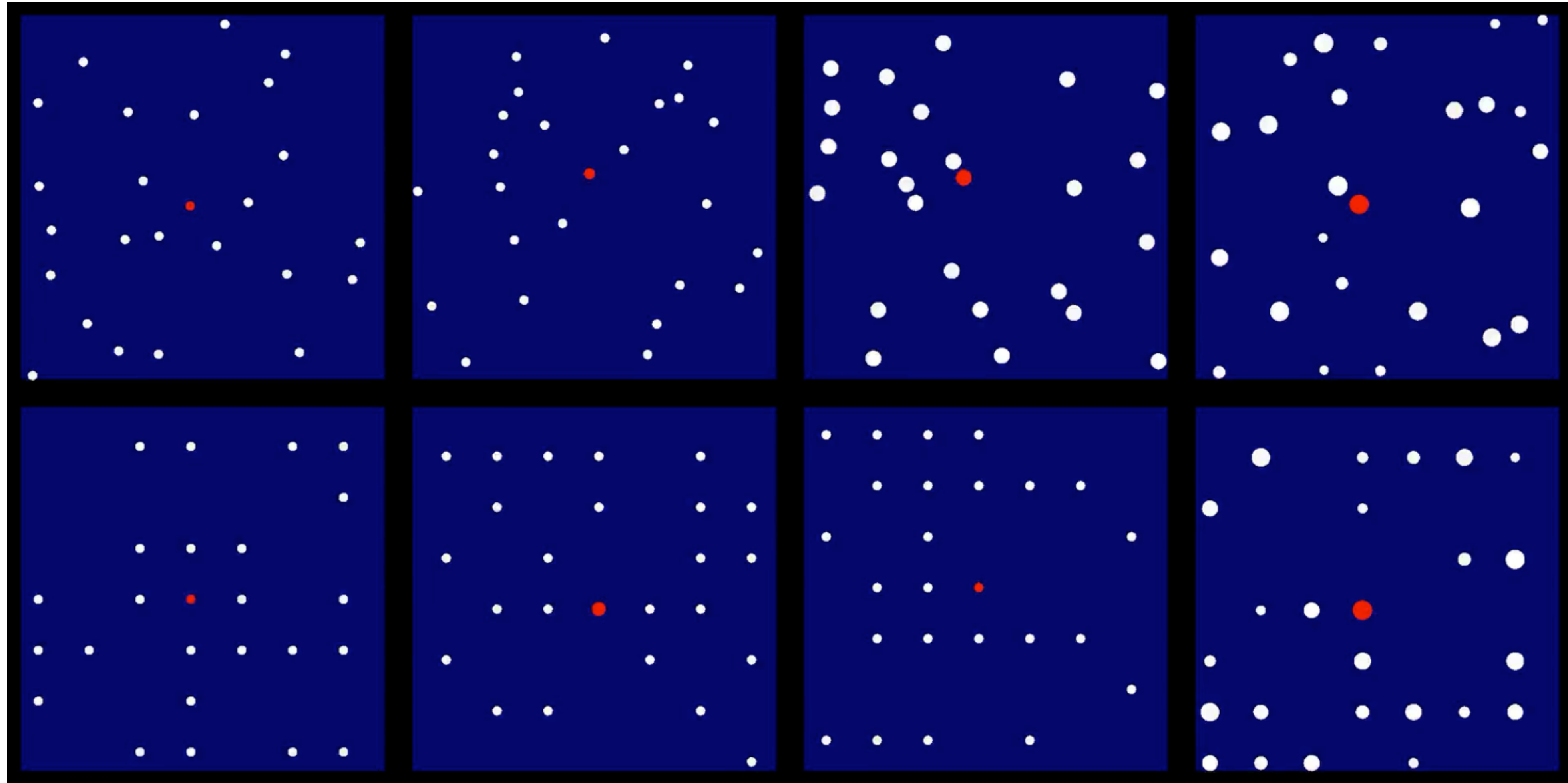


Yao et al 2013

Shape Primitives



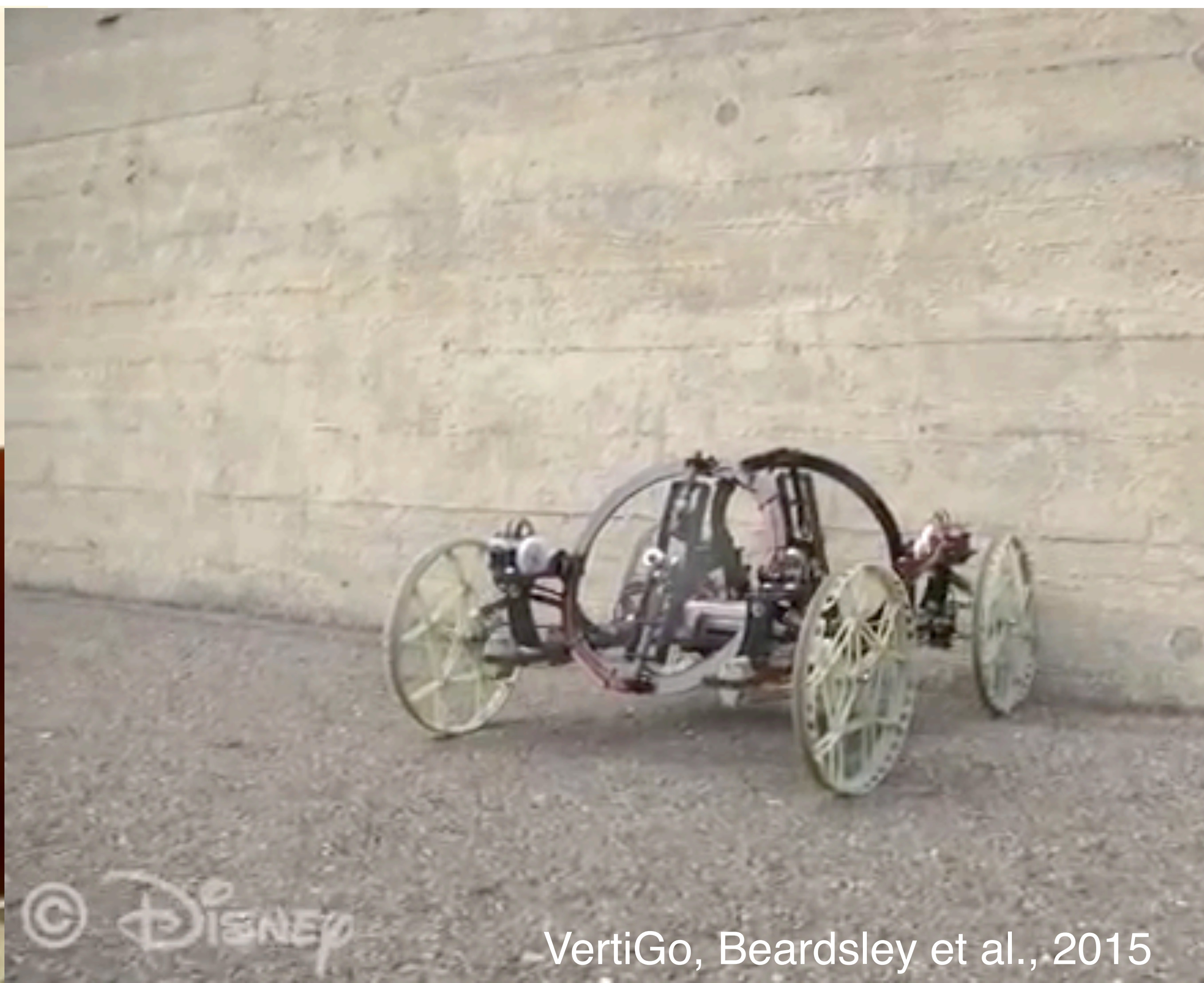
# Understanding Physical Information Display and Animacy





# Climbing on Surfaces for Ubiquitous Display

SRI Electrostatic Adhesion

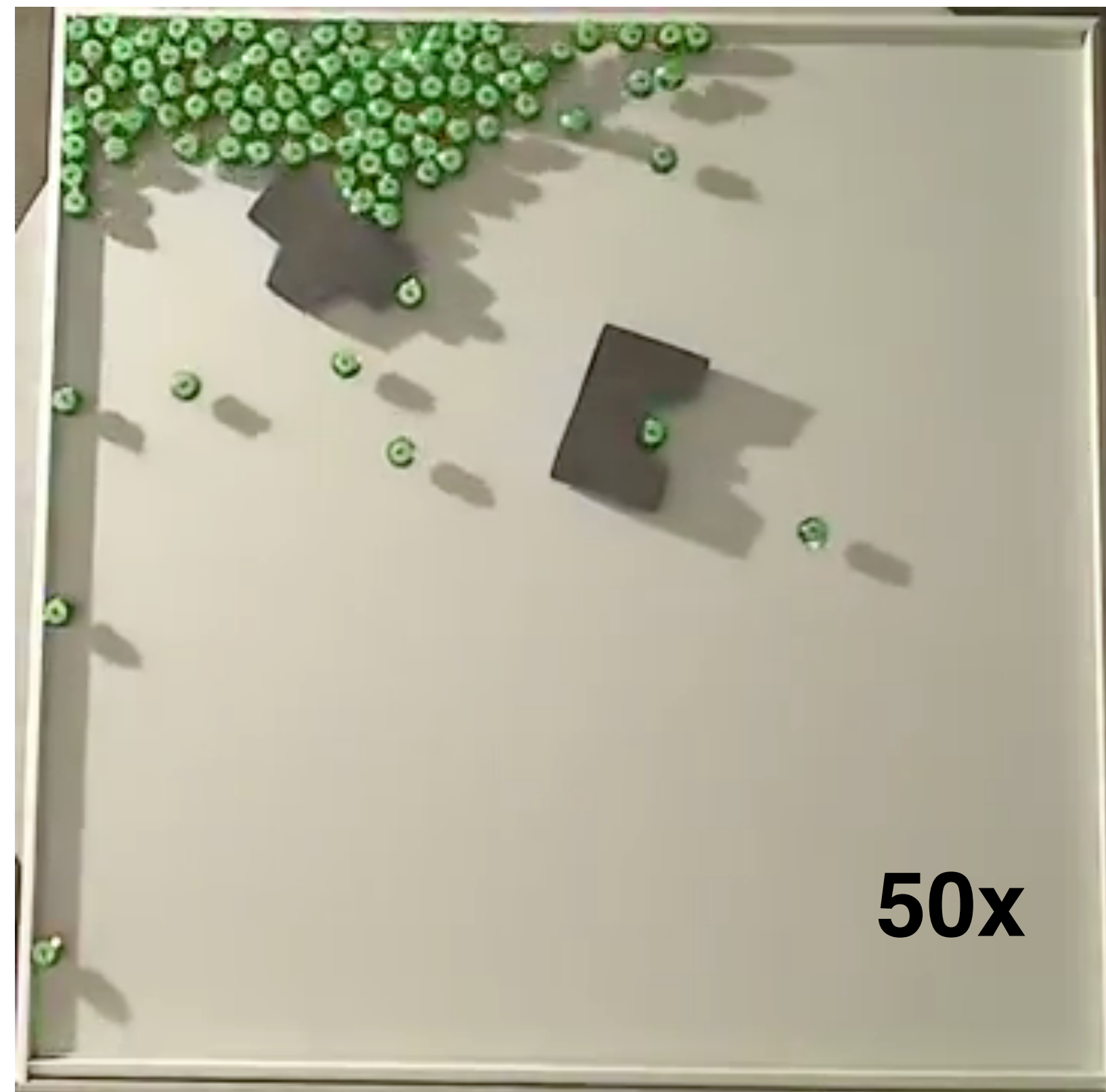


© Disney

VertiGo, Beardsley et al., 2015



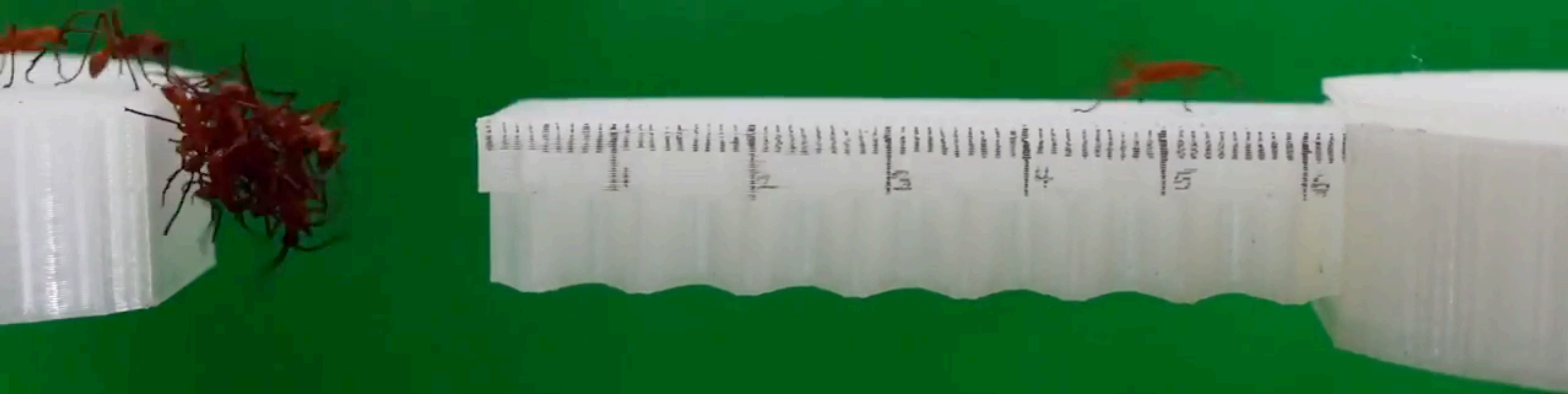
# Manipulating Passive Objects for Interaction



Massive Manipulation. IROS 2013.



# Assembled 3D Interfaces 10x





From Ubiquitous Computing  
to  
Ubiquitous Robotics











# Ubiquitous Robotic Interfaces

**Body**

**Devices**

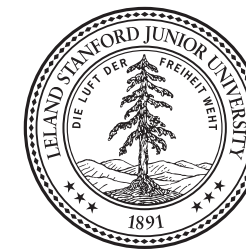
**Furniture**

**Architecture**



Scale





Fork it on GitHub!

<https://github.com/ShapeLab/SwarmUI>

