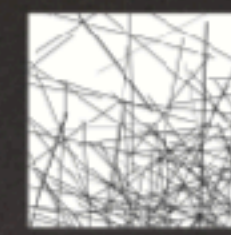
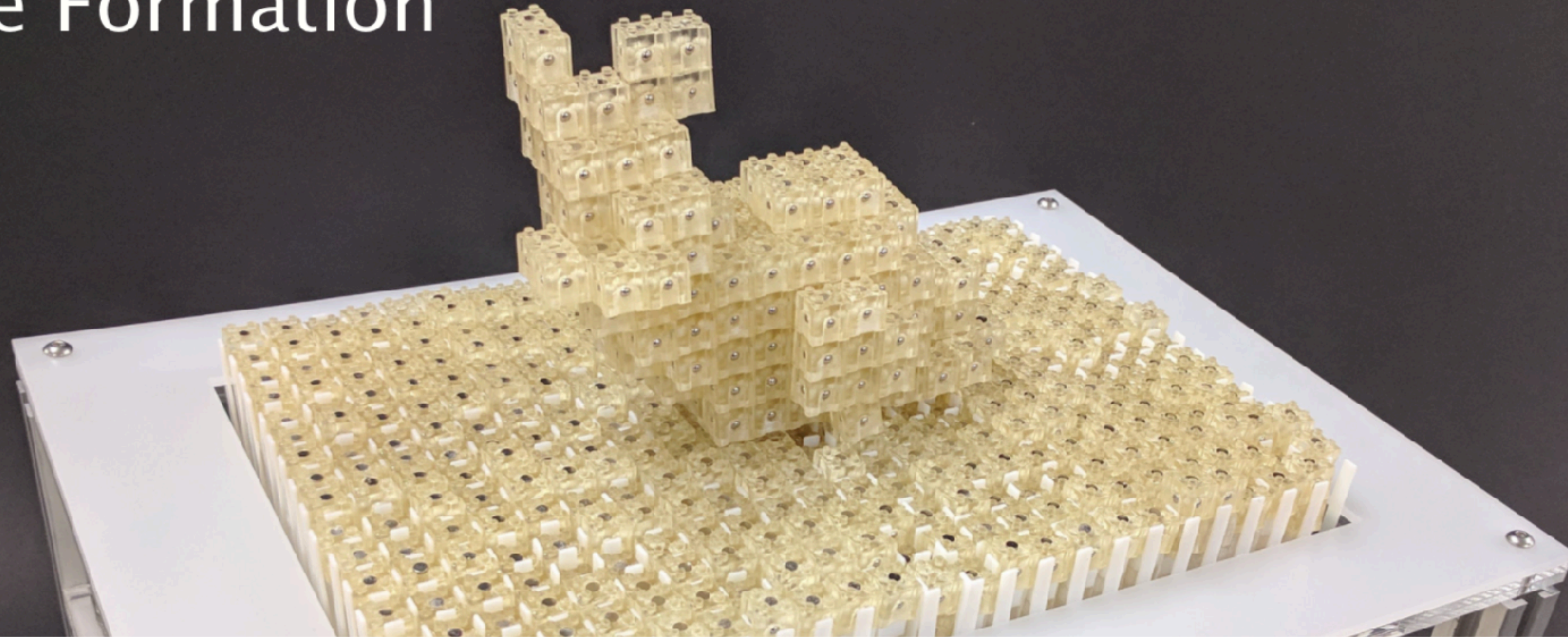


# Dynablock

## Dynamic 3D Printing for Instant and Reconstructable Shape Formation



ERATO川原万有情報網プロジェクト  
ERATO Kawahara Universal Information Network Project



**Ryo Suzuki<sup>1</sup>, Junichi Yamaoka<sup>2</sup>, Daniel Leithinger<sup>1</sup>, Tom Yeh<sup>1</sup>, Mark D. Gross<sup>1</sup>,  
Yoshihiro Kawahara<sup>2</sup>, Yasuaki Kakehi<sup>2</sup>**

University of Colorado Boulder<sup>1</sup>, University of Tokyo<sup>2</sup>



University of Colorado  
Boulder



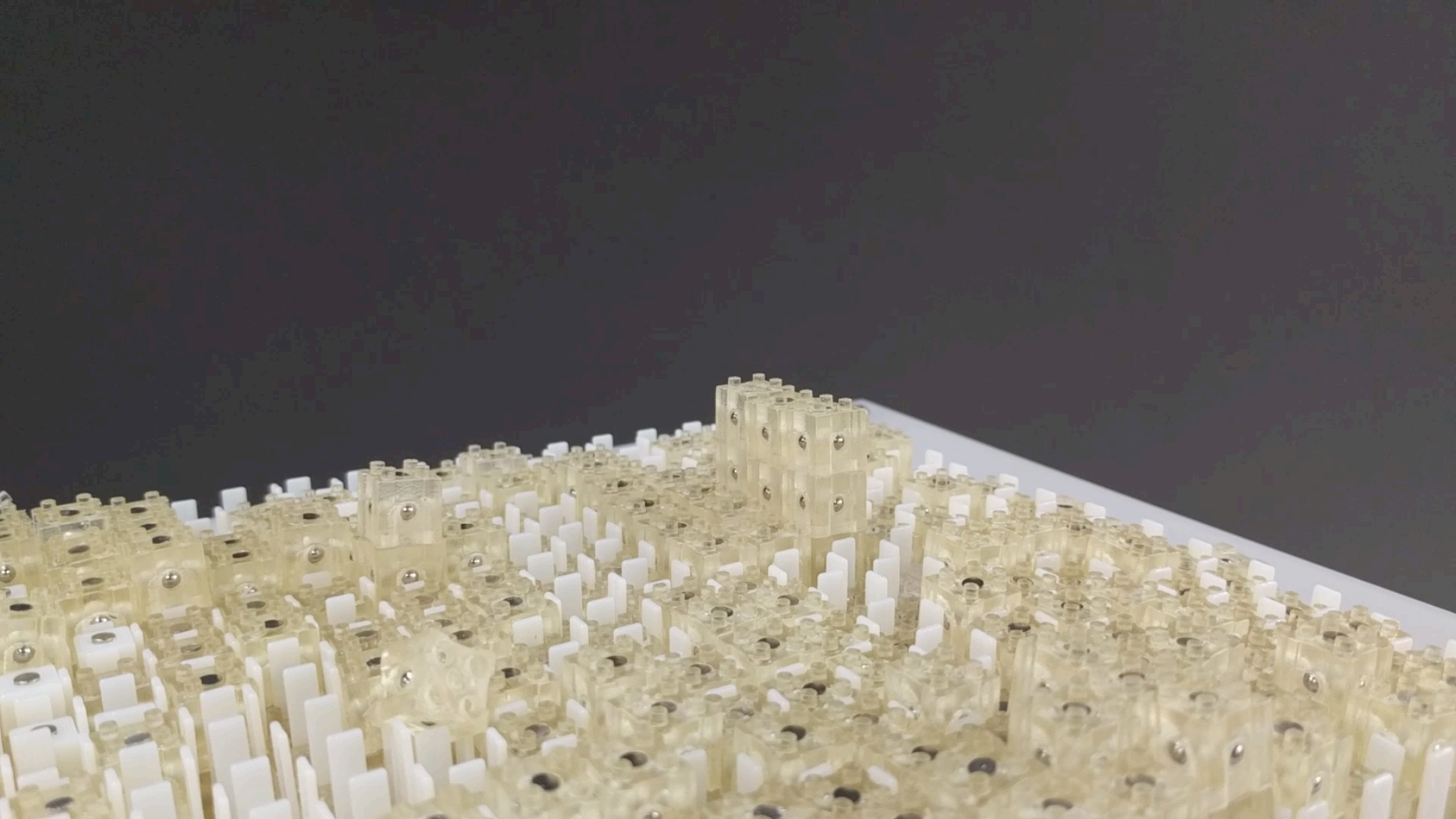
THE UNIVERSITY  
OF TOKYO

What if 3D printers could print  
a physical object **in seconds**?

What if the object could be  
disassembled and **reconstructed**  
as a new object like clay?



3D printer as  
**an Interactive medium,**  
not a fabrication device



1. Summary

## 2. Related Work

3. Dynamic 3D Printing: Design Architecture

4. Dynablock: System and Implementation

5. Limitations and Future Work



*“The **Ultimate Display** would, of course, be a room within which the computer can control the existence of matter.”*

*“The Ultimate Display” by Ivan Sutherland, 1965*

# PERFECT RED PERFECT SPHERE

A close-up photograph of a hand holding a small, perfectly round red sphere. The hand is in grayscale, and the sphere is a vibrant red. A white line points from the text 'PERFECT SPHERE' to the sphere.

*“Radical Atoms is our vision of human interactions with **dynamic physical materials that can transform their shape.**”*

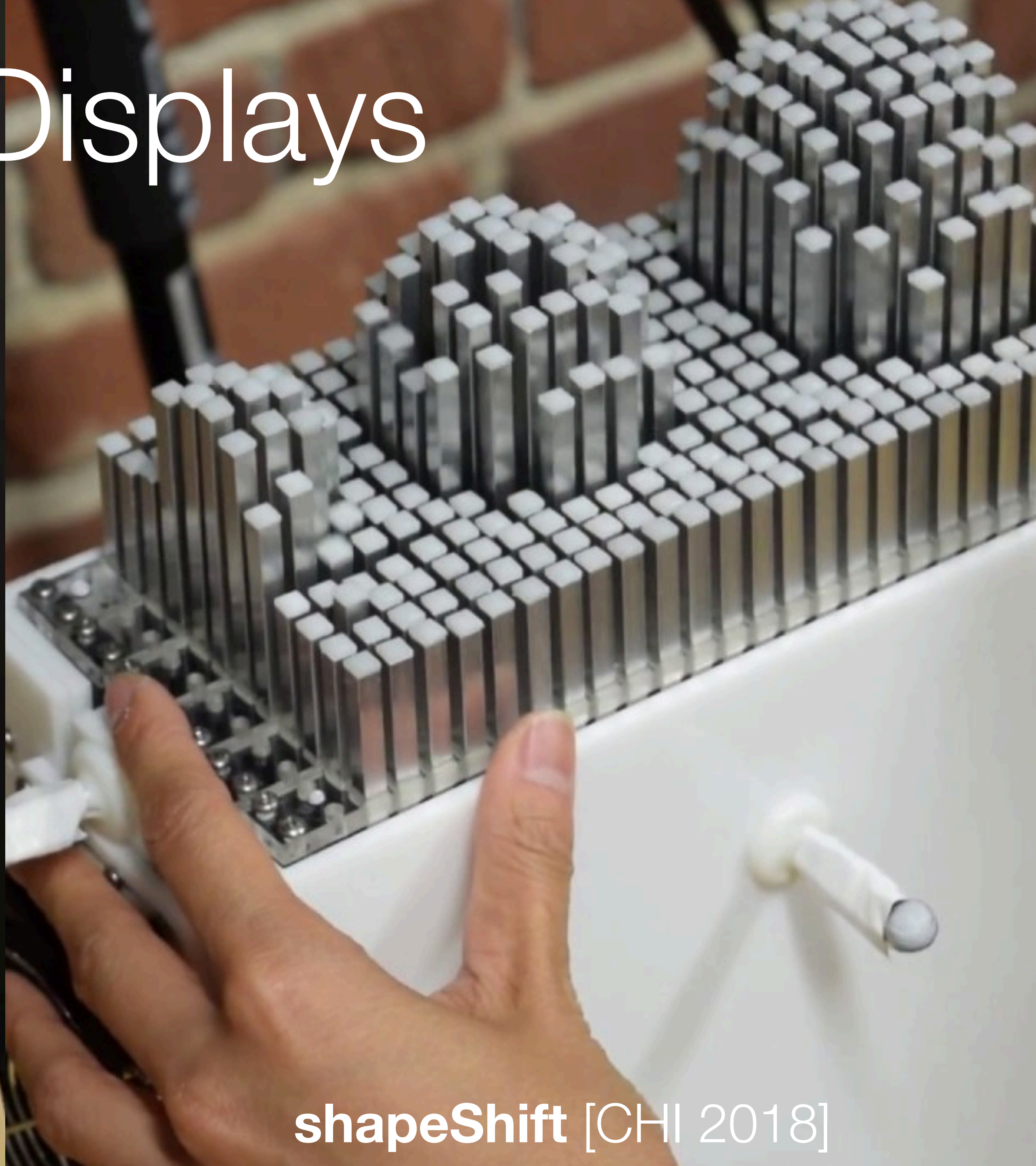
*“Radical Atoms ” by Hiroshi Ishii et al, 2012*



# Shape Displays



**inFORM** [UIST 2013]



**shapeShift** [CHI 2018]

# Shape Displays

**Only 2.5D shape + Not graspable**

inFORM [UIST 2013]

shapeShift [CHI 2018]

# Constructive Assembly



**Kinetic Blocks** [UIST 2015]

# Constructive Assembly

**Limited block size + resolution**

# Self-Reconfigurable Modular Robots



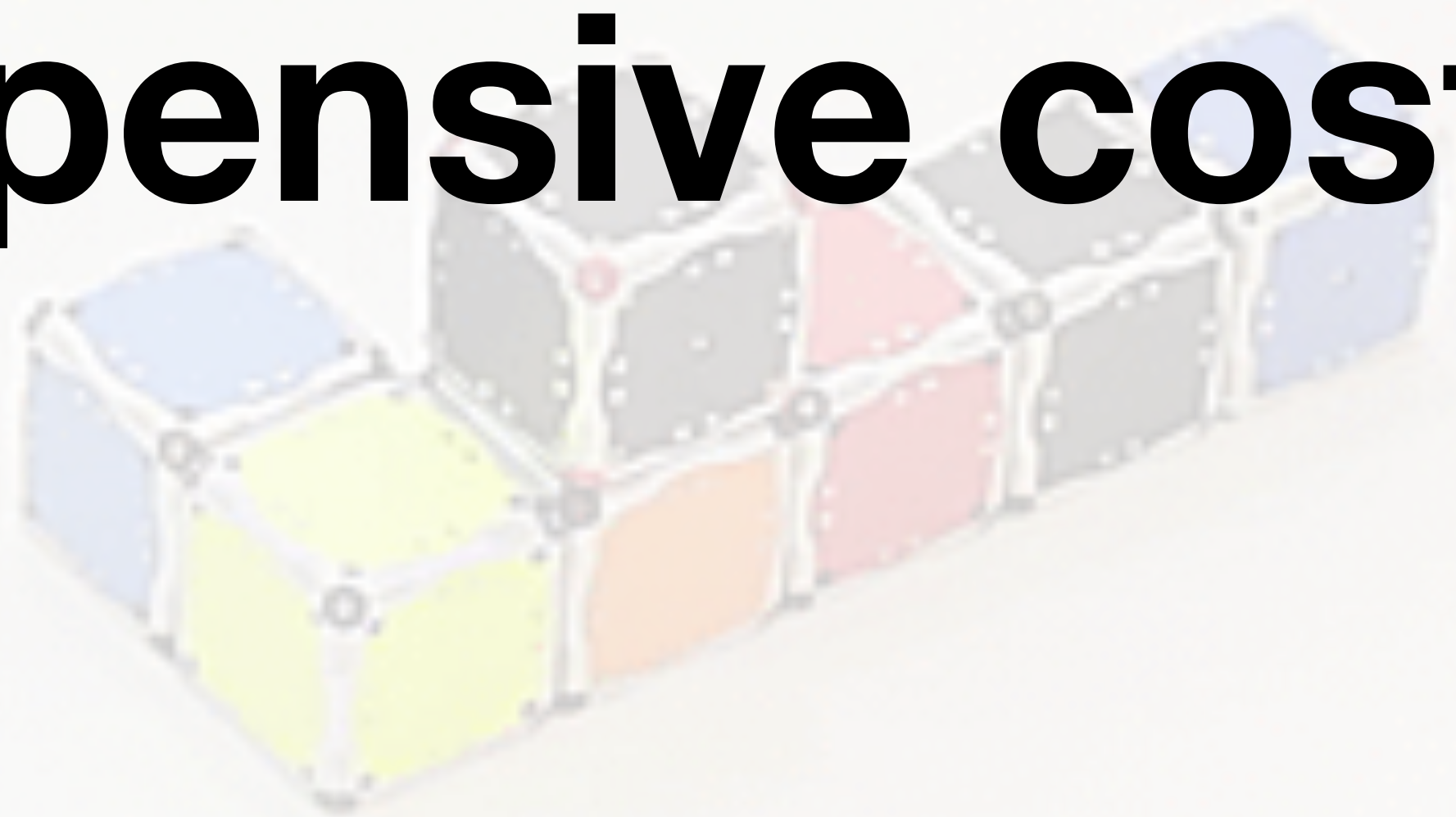
**M-Blocks** [IROS 2013]



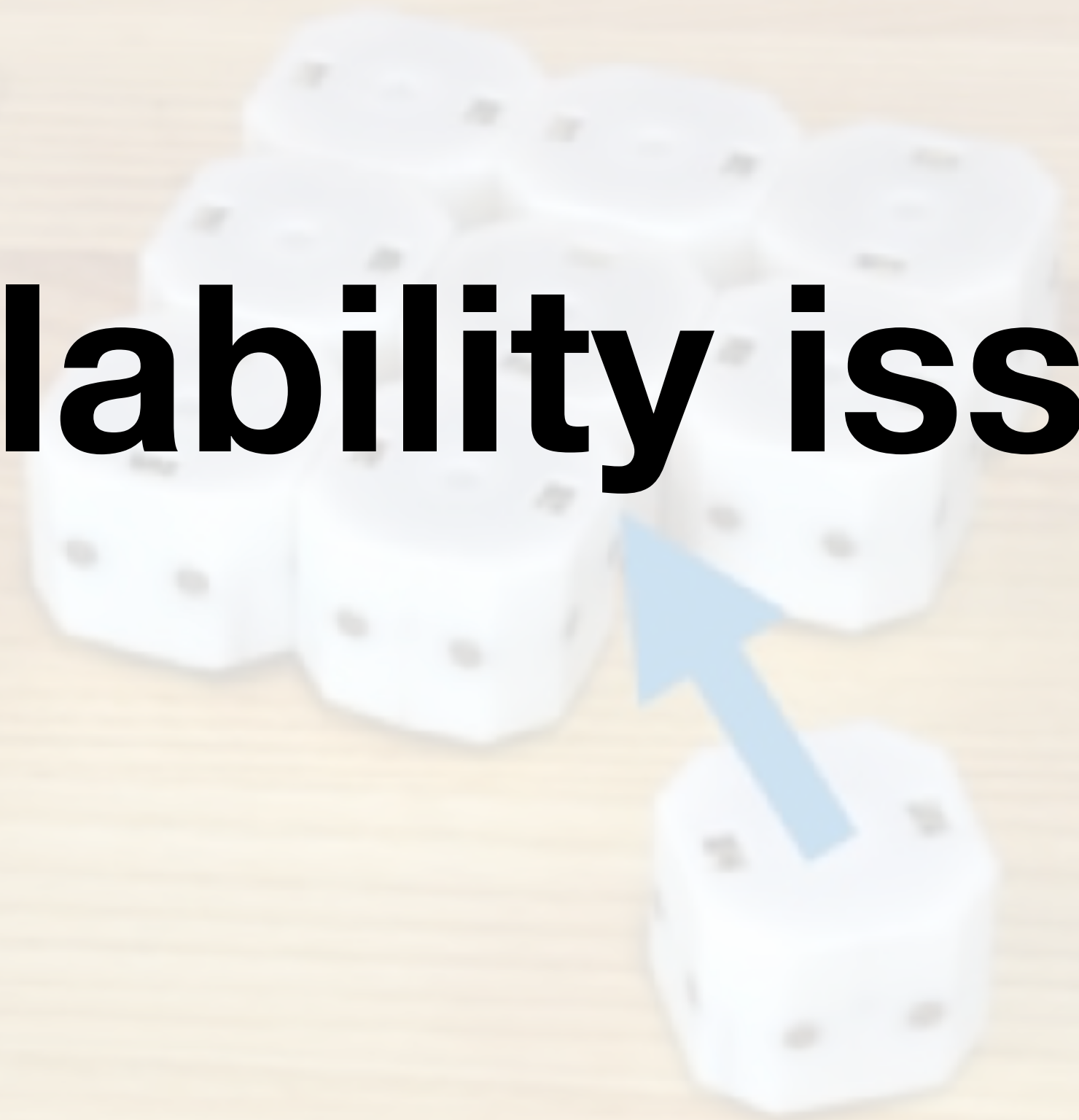
**Robotic Assembly** [ISS 2017]

# Self-Reconfigurable Modular Robots

**Expensive cost / Scalability issue**

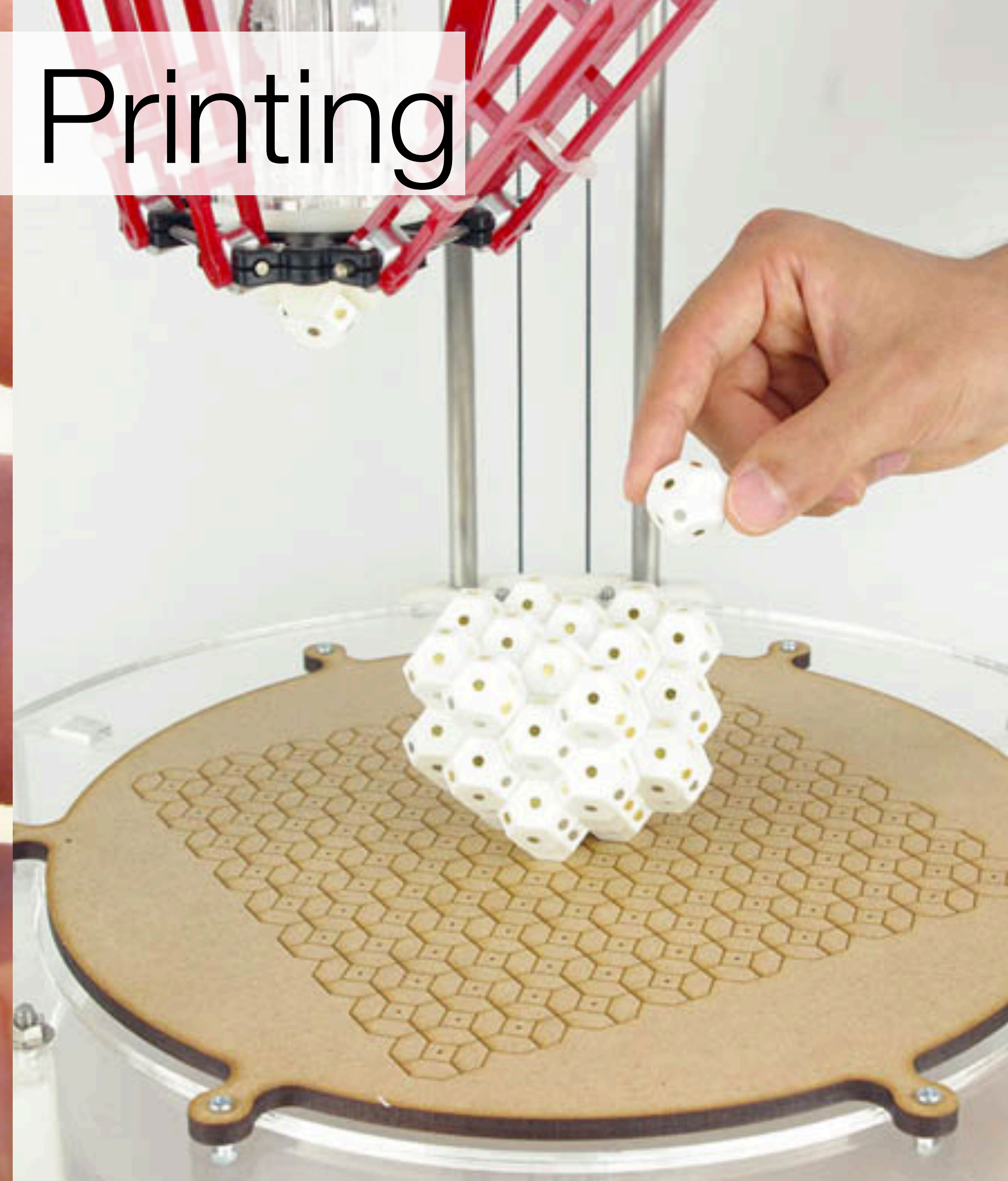


M-Blocks [IROS 2013]



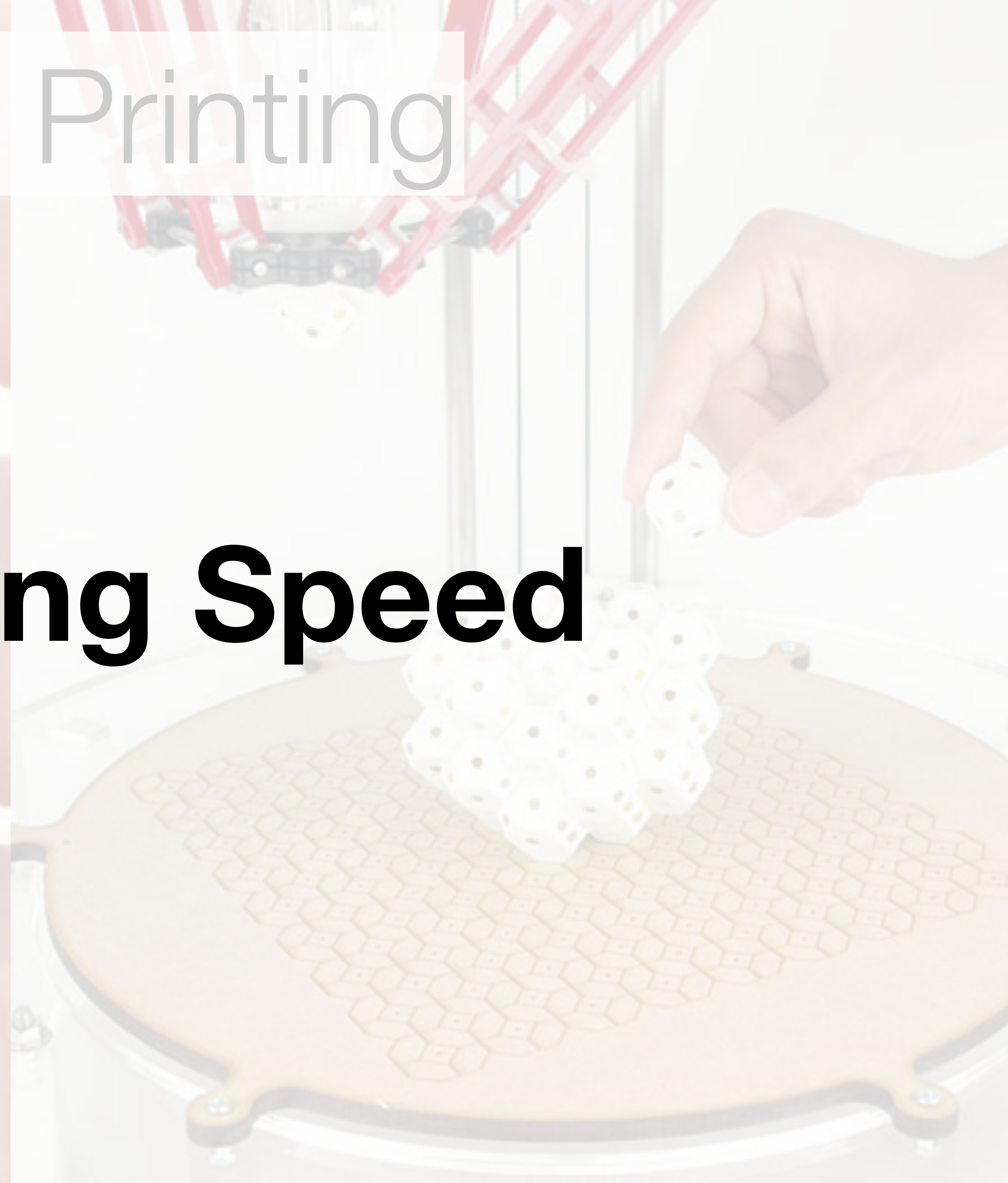
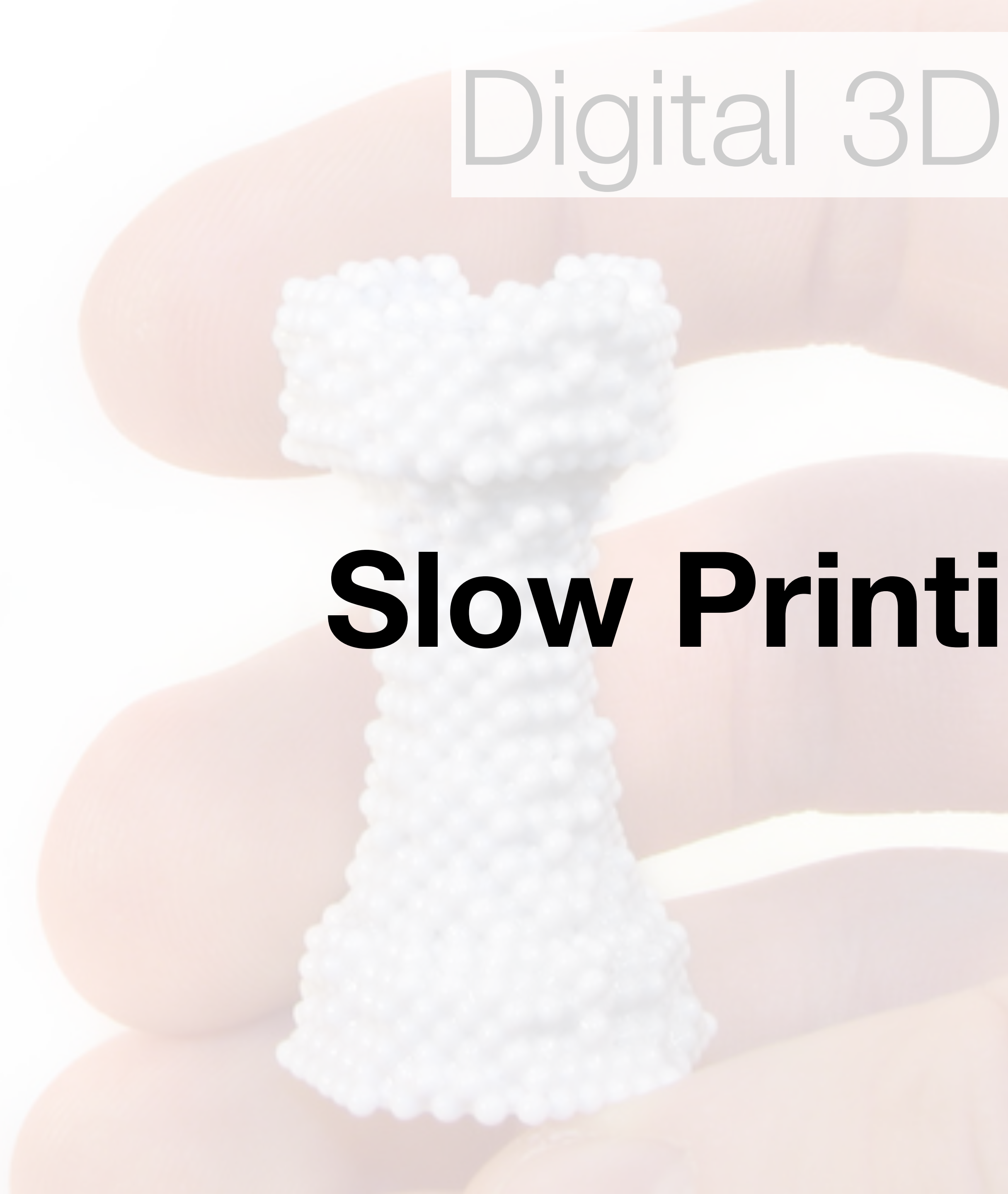
Robotic Assembly [ISS 2017]

# Digital 3D Printing



Digital 3D Printing

**Slow Printing Speed**





1. Summary

2. Related Work

# 3. Dynamic 3D Printing

4. Dynablock: System and Implementation

5. Limitations and Future Work

# Graspable

Object

# Instant

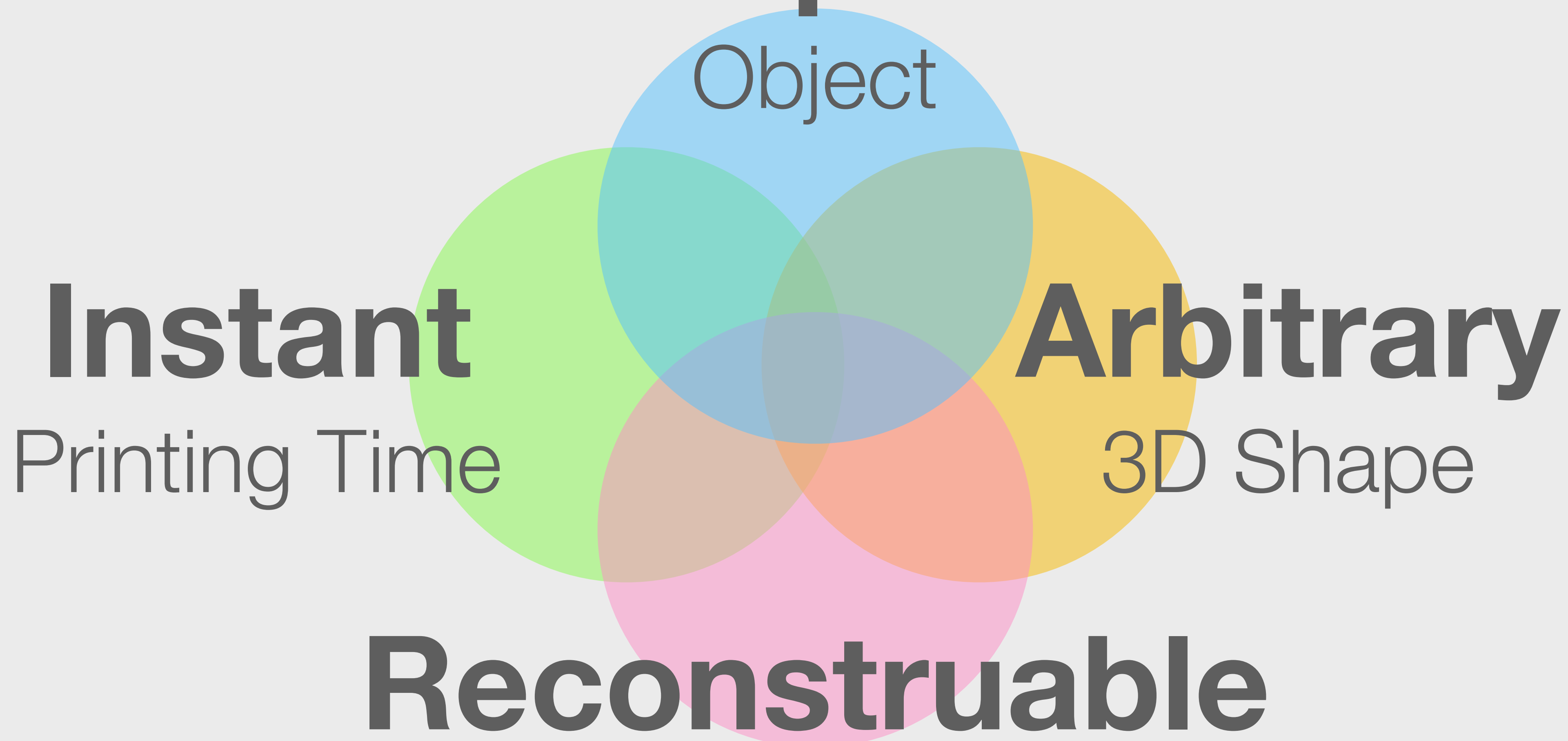
Printing Time

# Arbitrary

3D Shape

# Reconstruable

Materials



**Graspable**

Object

**Instant**

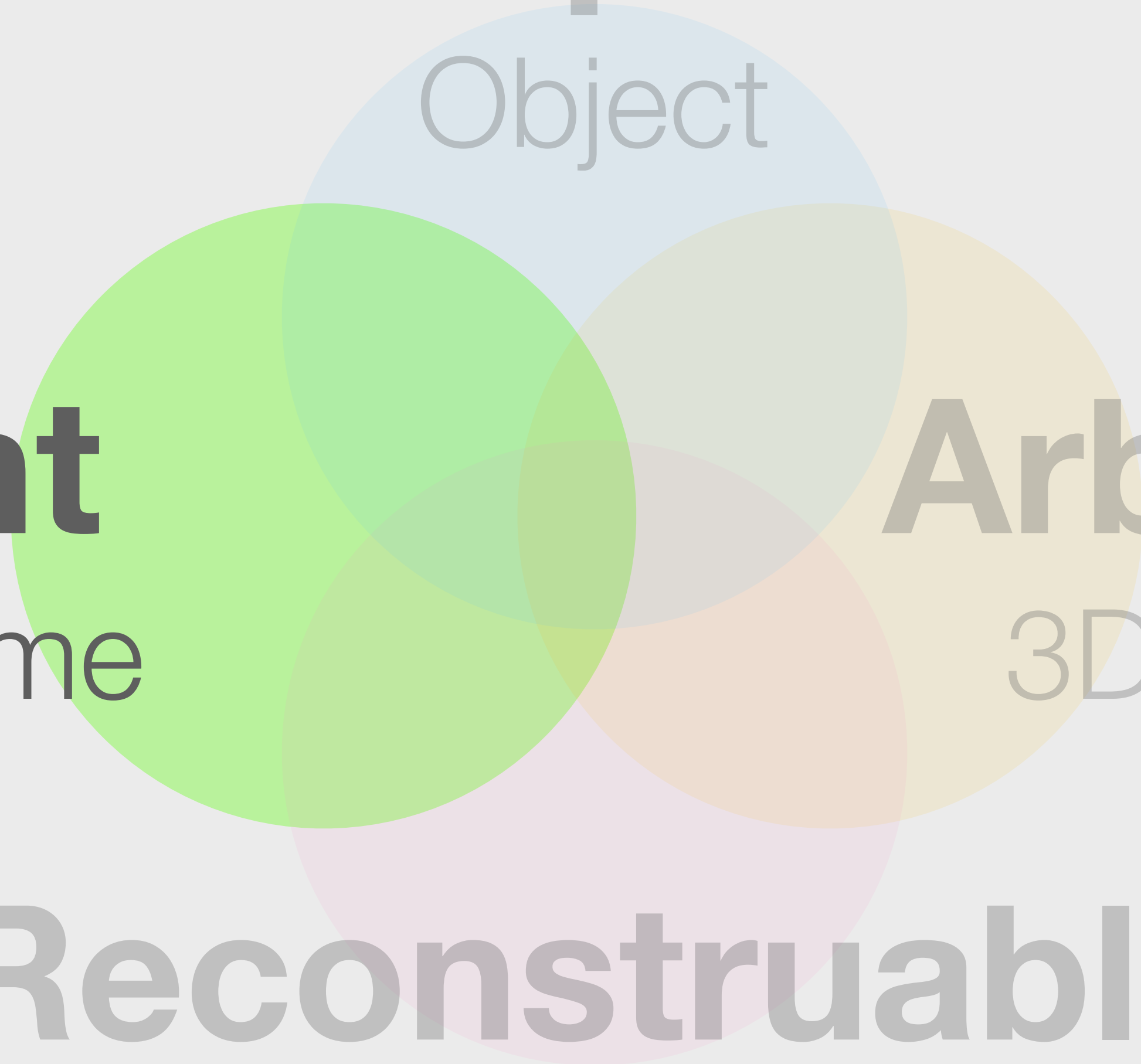
Printing Time

**Arbitrary**

3D Shape

**Reconstruable**

Materials



**Graspable**

Object

**Instant**

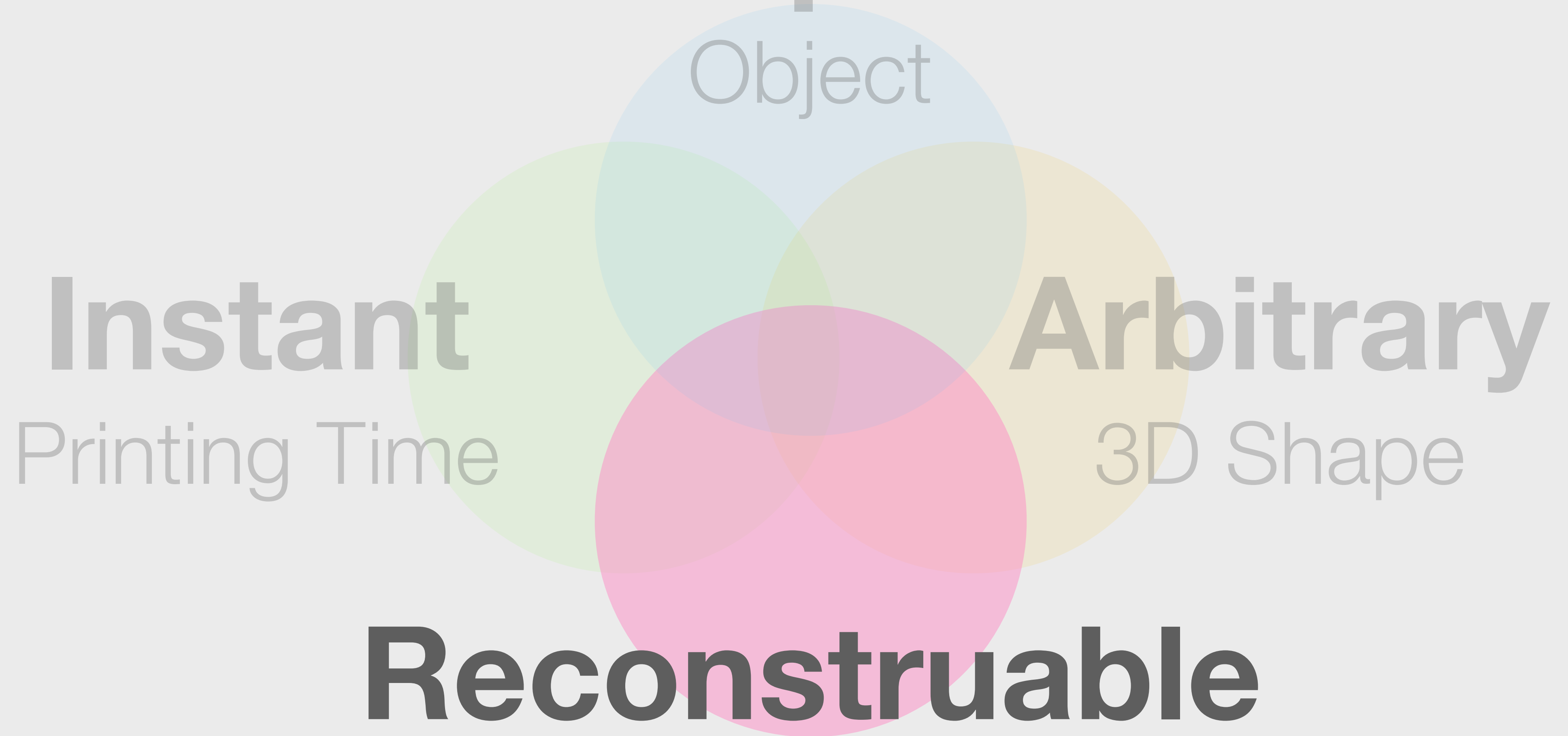
Printing Time

**Arbitrary**

3D Shape

**Reconstruable**

Materials



**Graspable**

Object

**Instant**

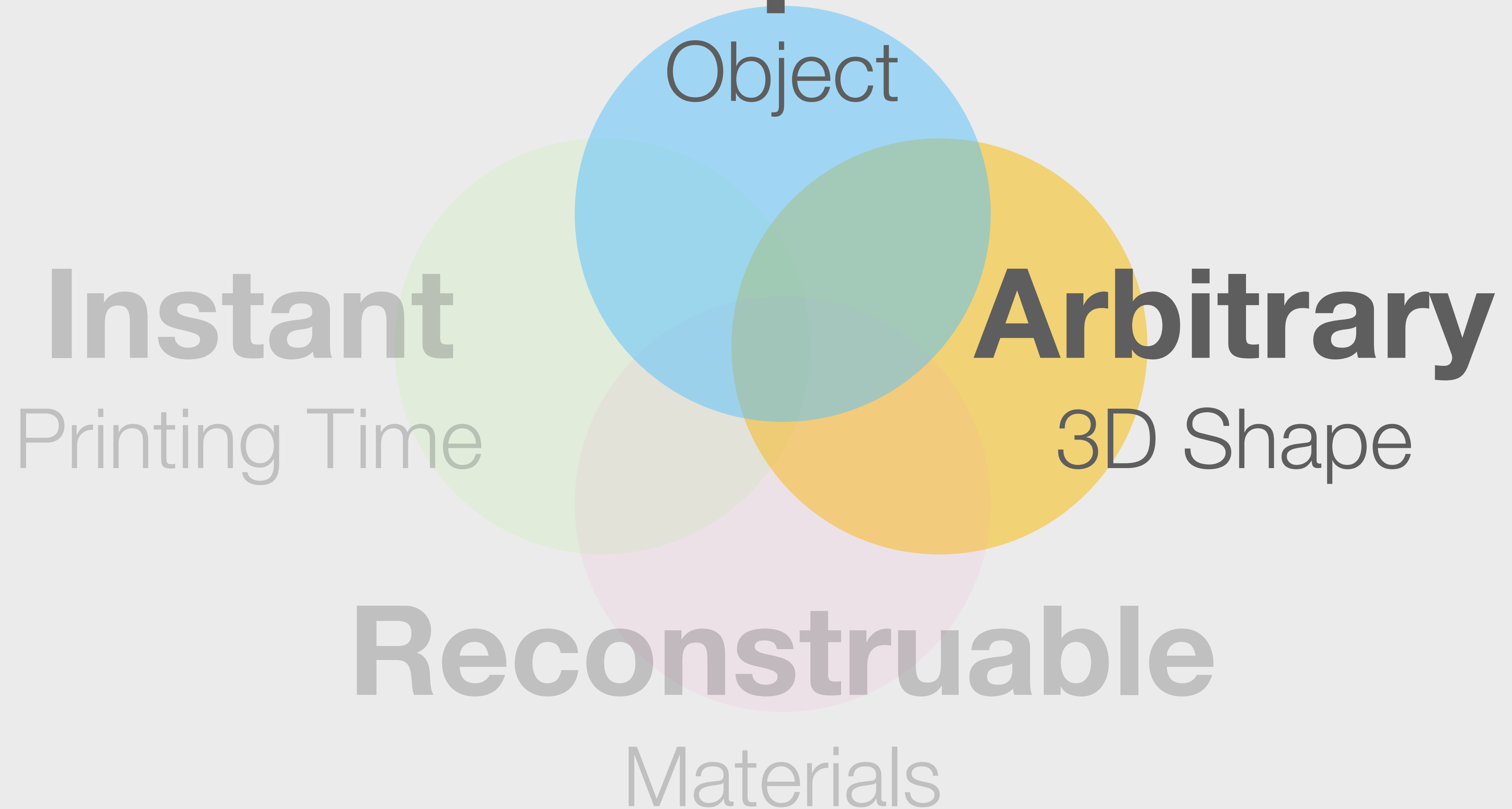
Printing Time

**Arbitrary**

3D Shape

**Reconstruable**

Materials



Graspable

Object

Instant

Arbitrary

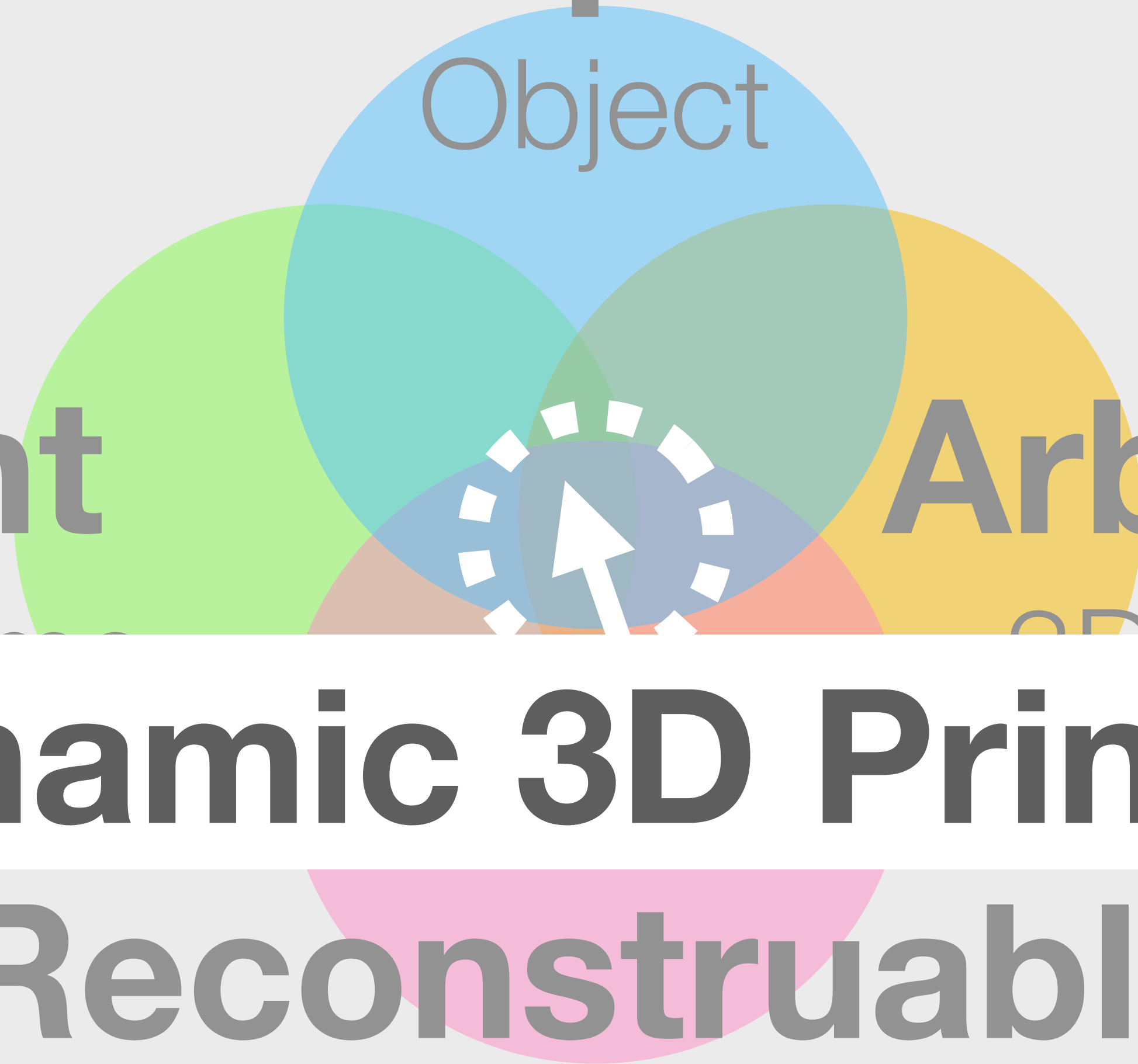
Printing Time

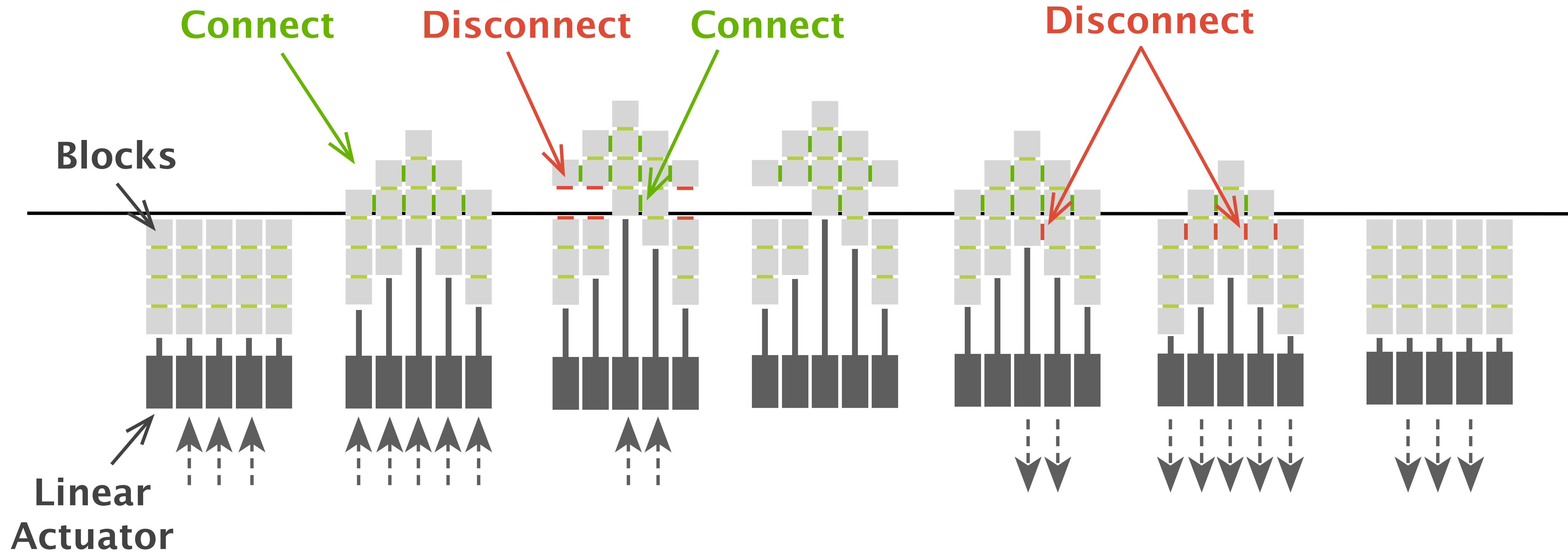
3D Objects

**Dynamic 3D Printing**

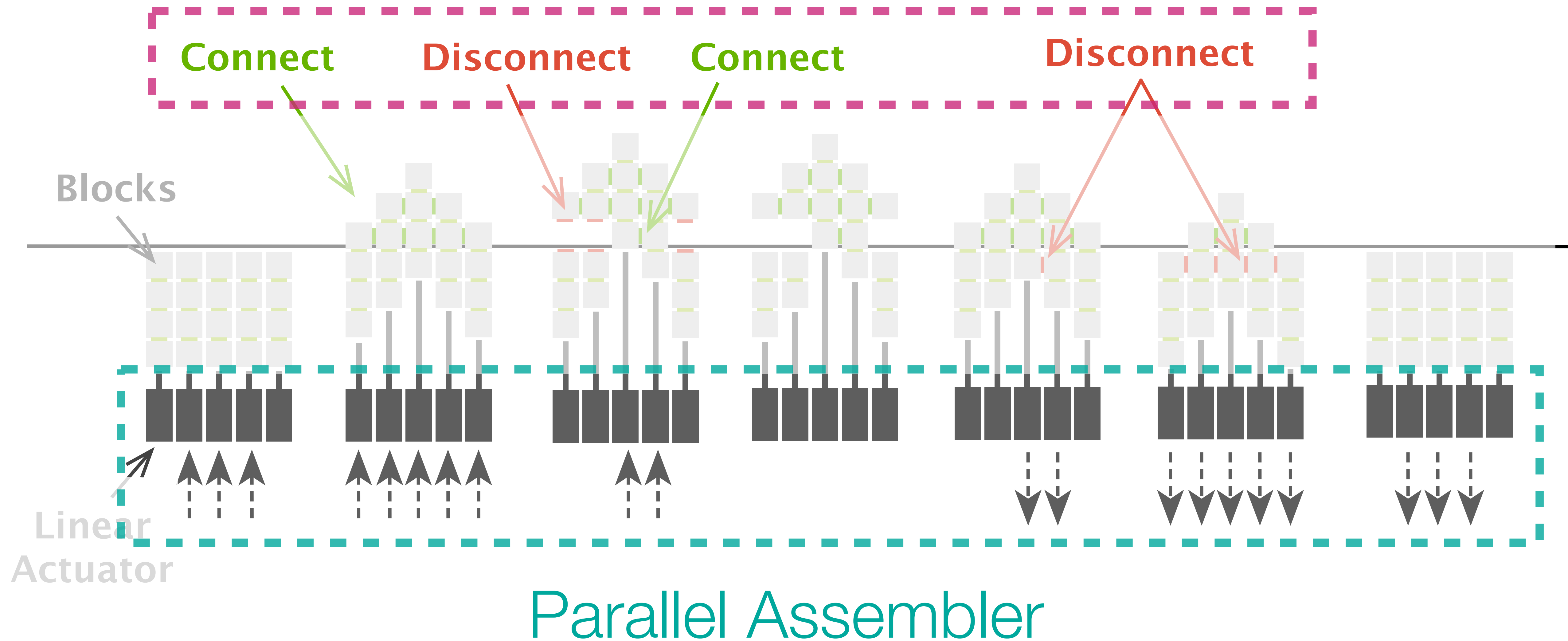
Reconstruable

Materials



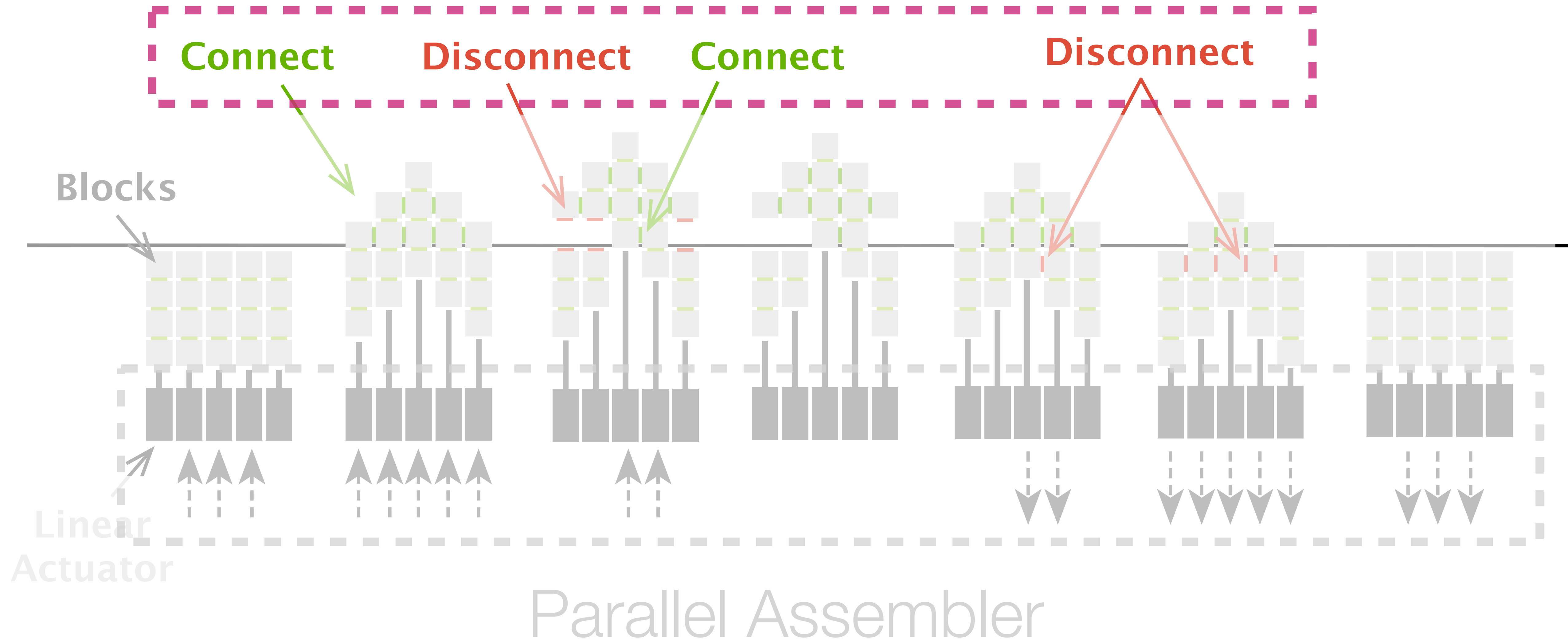


# Switchable Connector





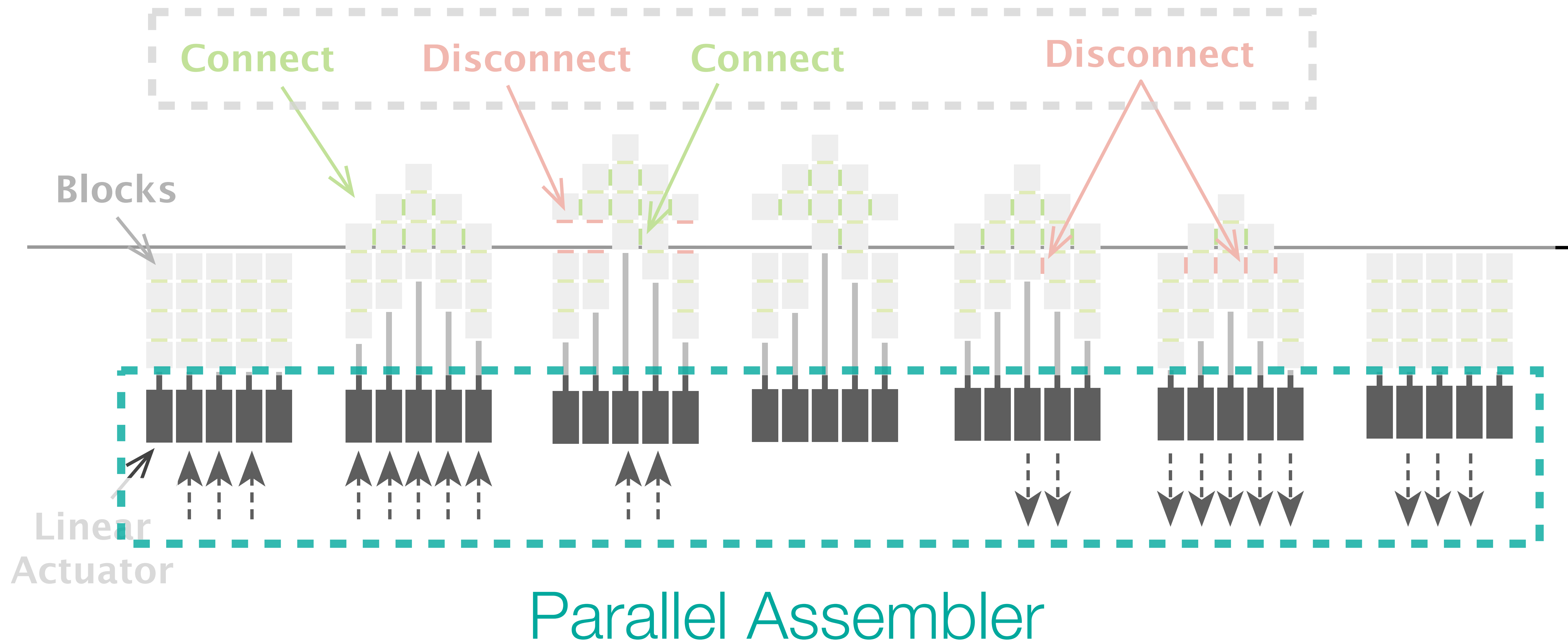
# Switchable Connector



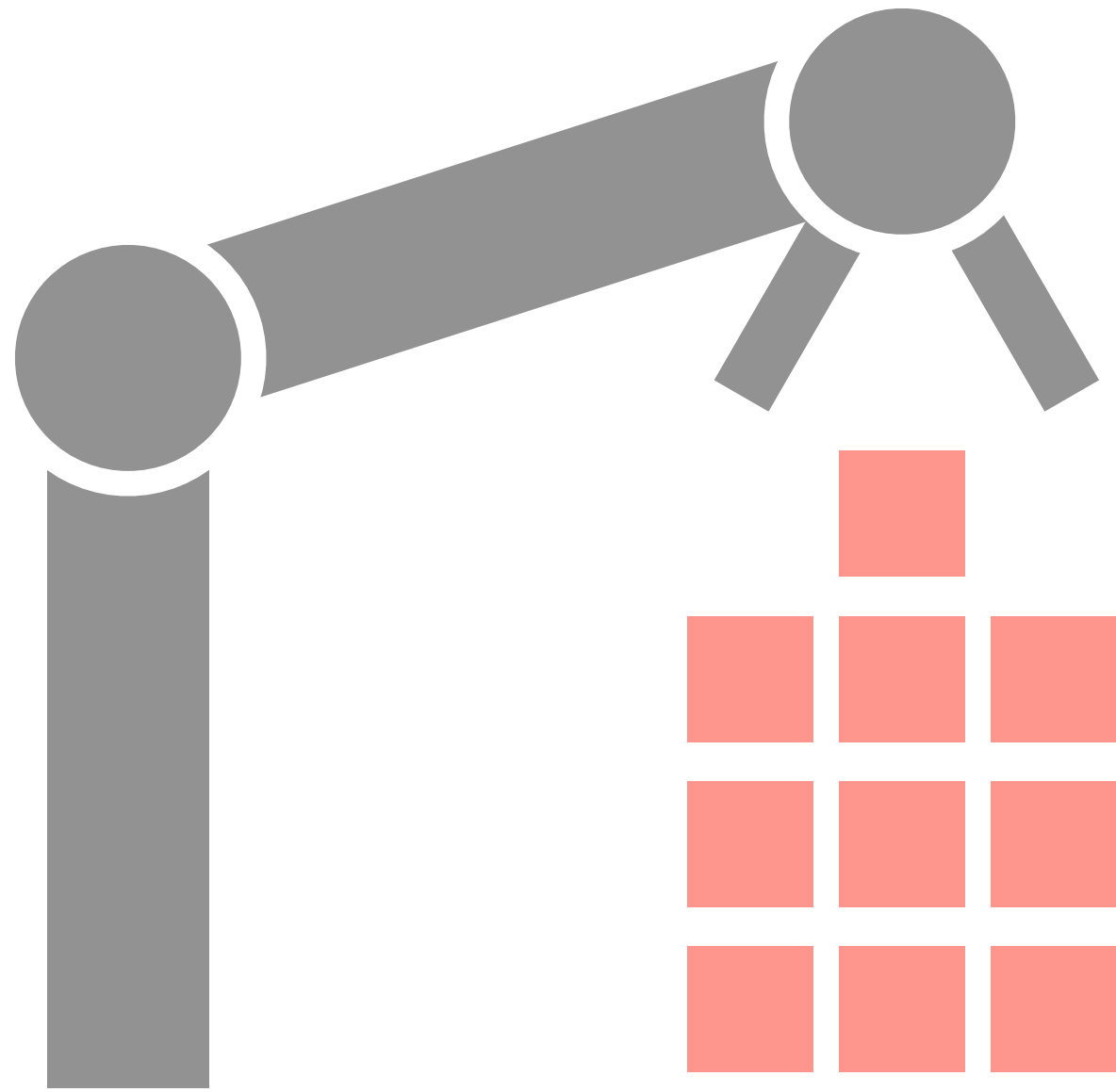
# Switchable Connector

<b>Type</b>	<b>Connection</b>	<b>Disconnection</b>	<b>Time</b>
Mechanical Latching	Push / Rotate	Pull / Rotate	1 - 10s
Permanent Magnet	None	Push / Rotate	0.1 - 1s
Electromagnet	Run Current	Turn off Current	0 - 0.1s
Electrostatic	Apply Voltage	Turn off Voltage	0 - 0.1s
Electro-permanent magnet	Run Pulse Current	Pulse Current	0 - 0.1s
Thermal bonding	Heat and Cool	Heat	1 - 30s
Photochromic bonding	Expose Visible Light	Expose UV Light / Heat	1 - 10s
Dry Adhesion	Surface Contact	Reduce the Contact Area	1 - 10s

# Switchable Connector

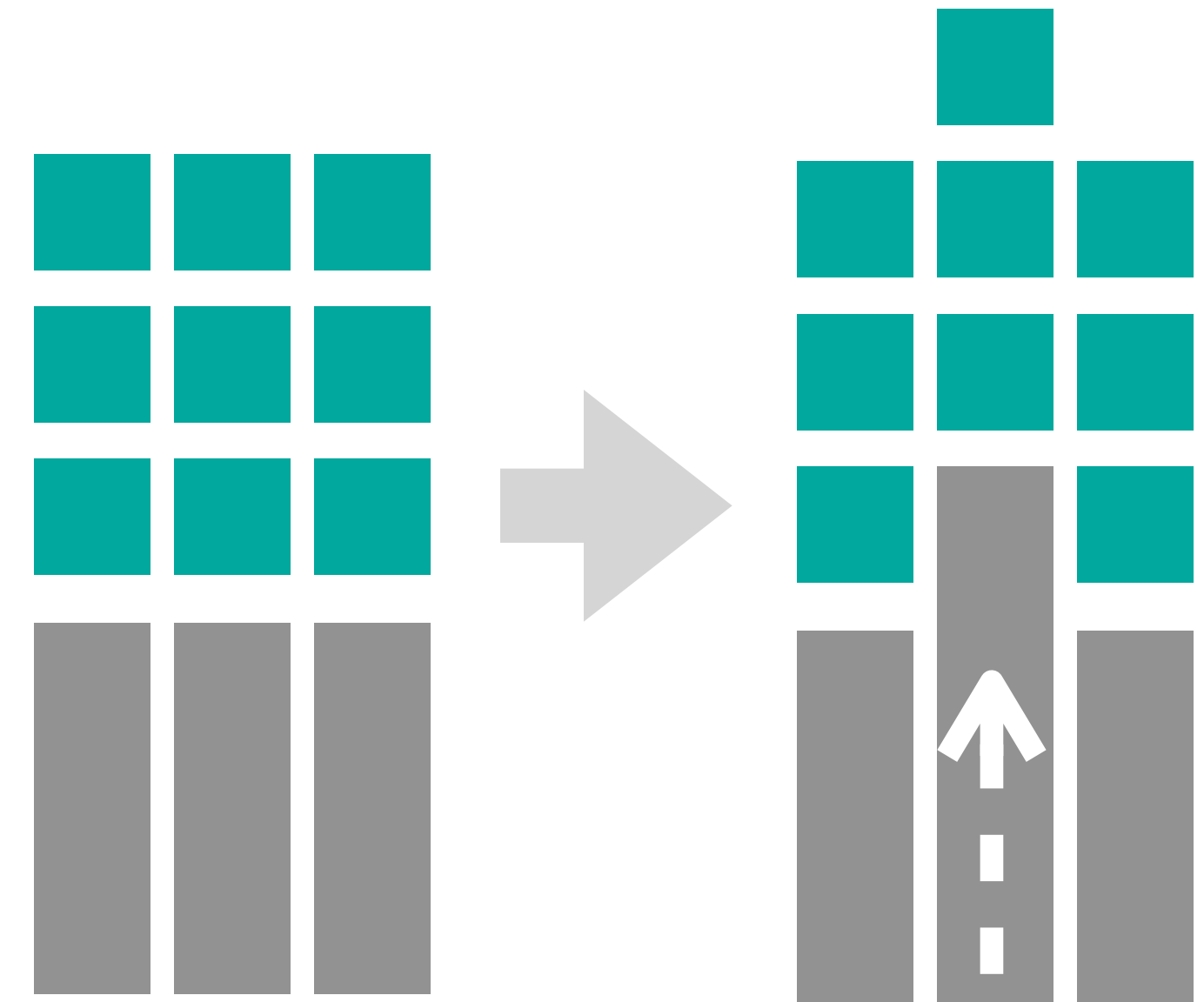


# Linear Assembler



$O(N^2)$

# Parallel Assembler

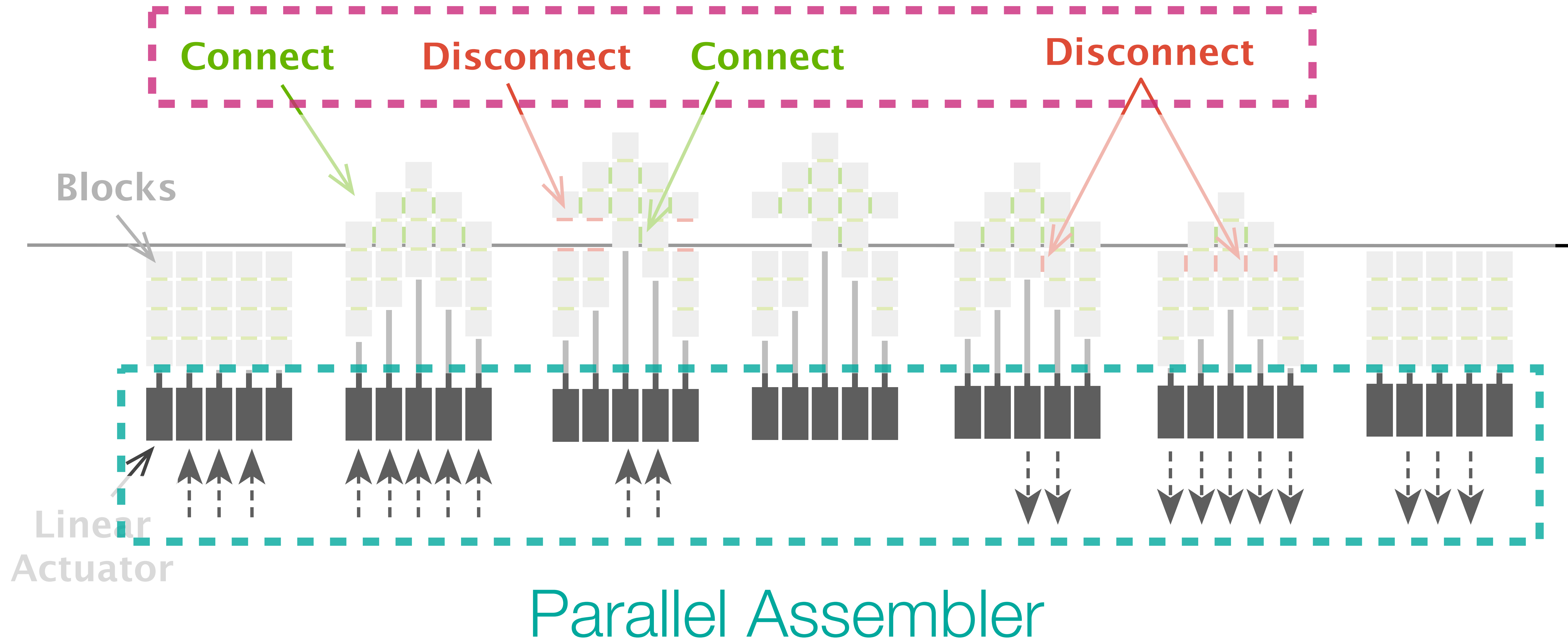


$O(1)$

Building Time

One Layer  
( $N \times N$ )

# Switchable Connector



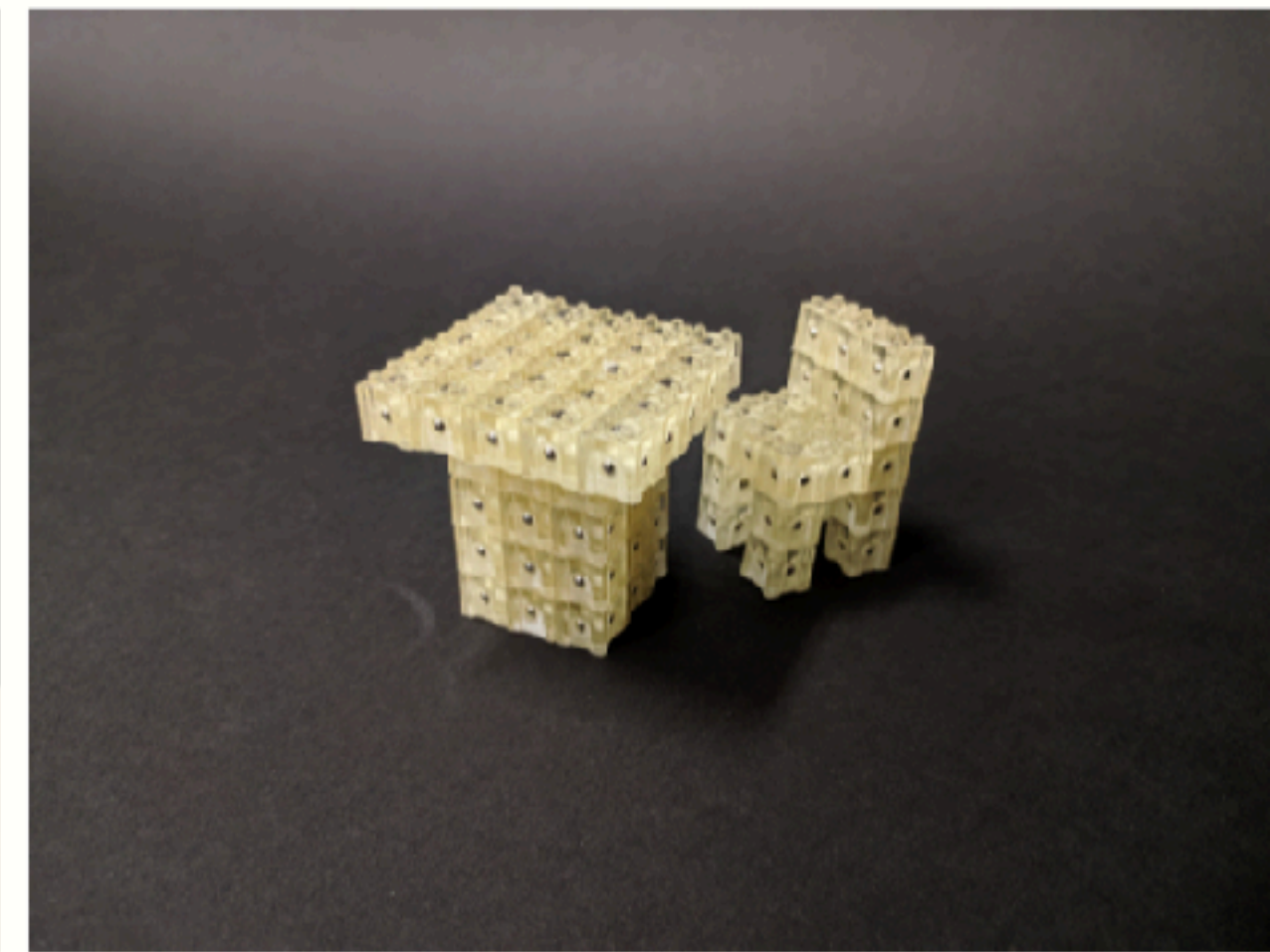
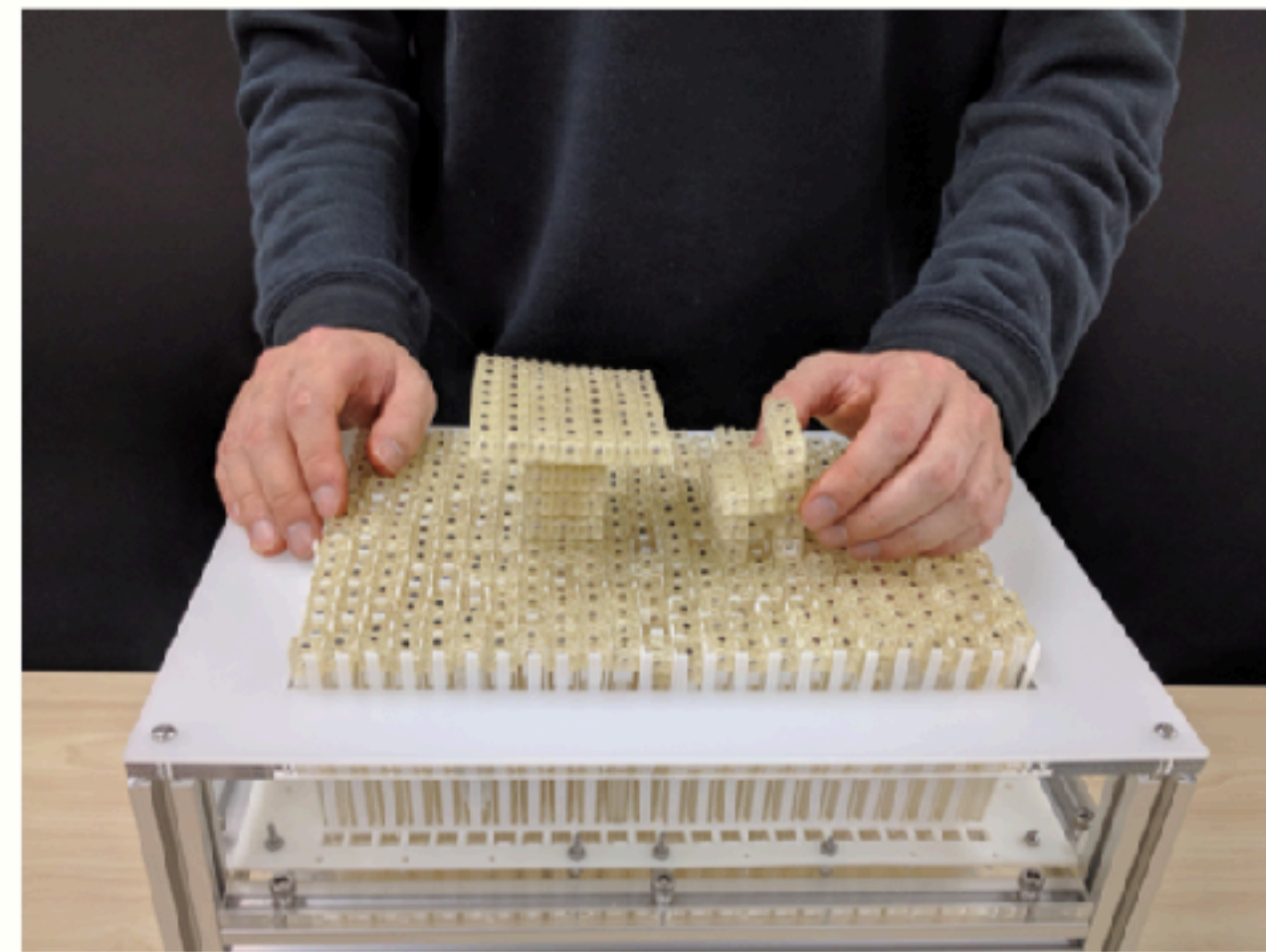
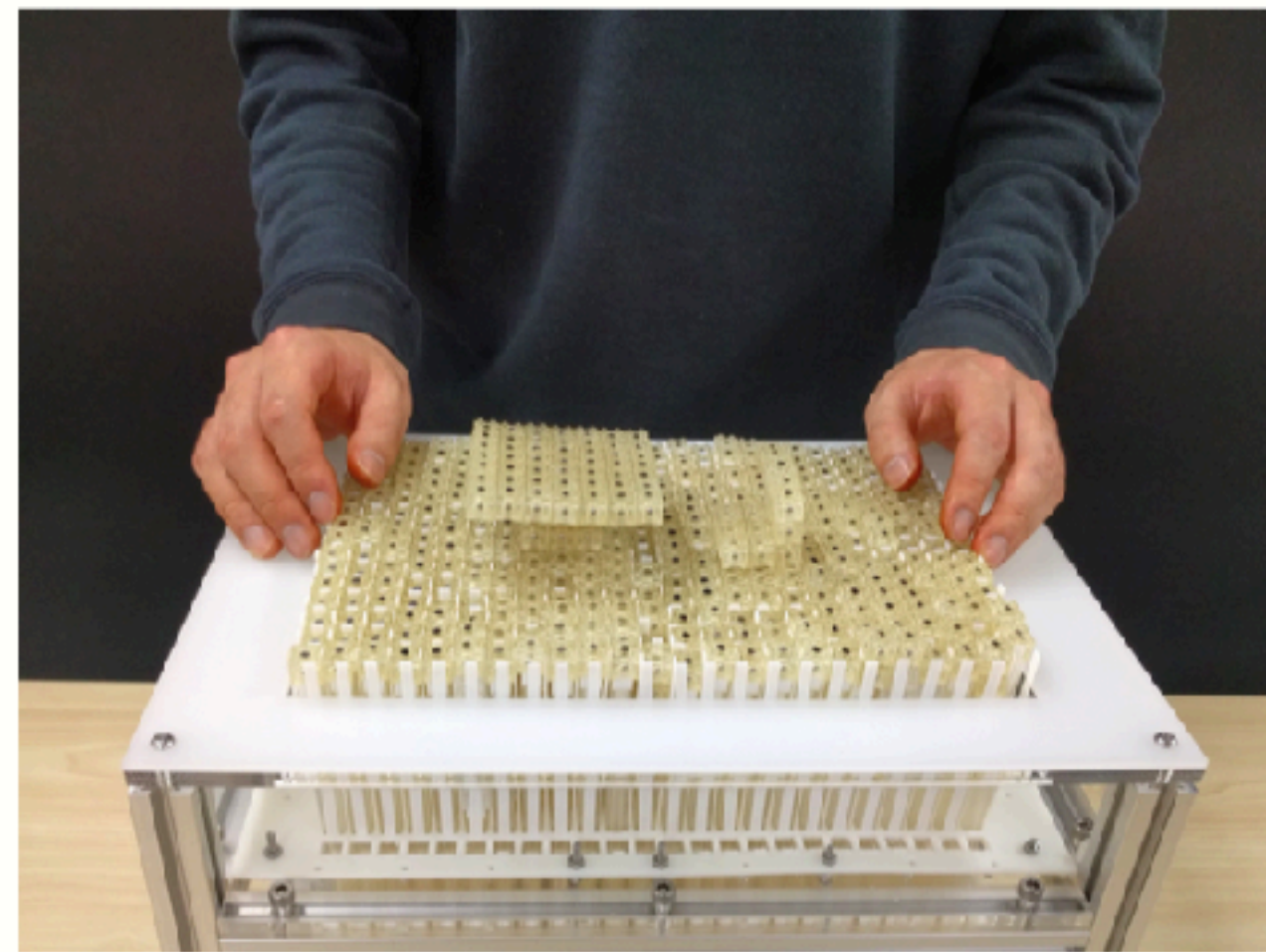
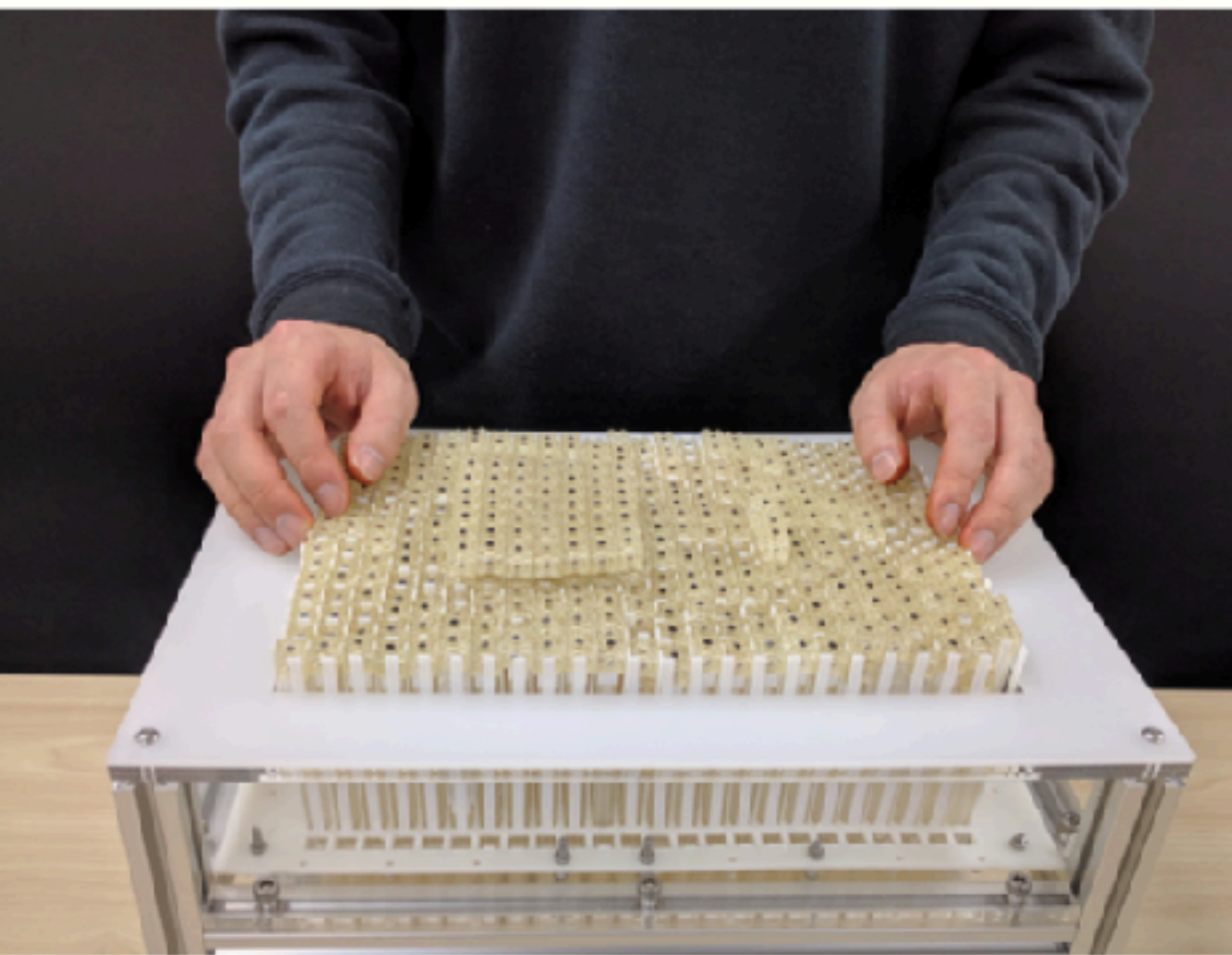
1. Summary
2. Related Work
3. Dynamic 3D Printing: Design Architecture

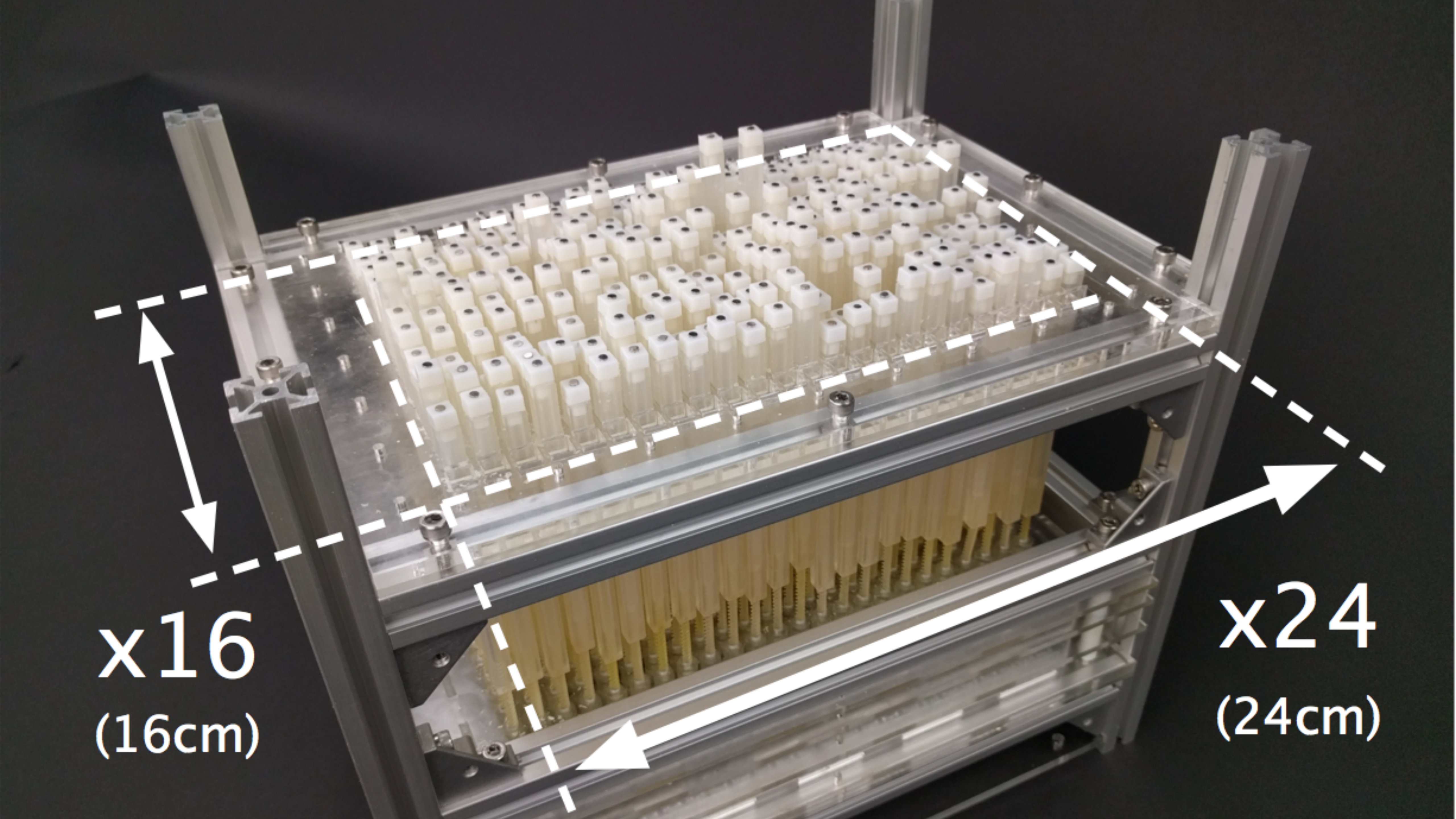
# 4. Dynablock

5. Limitations and Future Work

# Dynablock

A proof-of-concept prototype for dynamic 3D printing



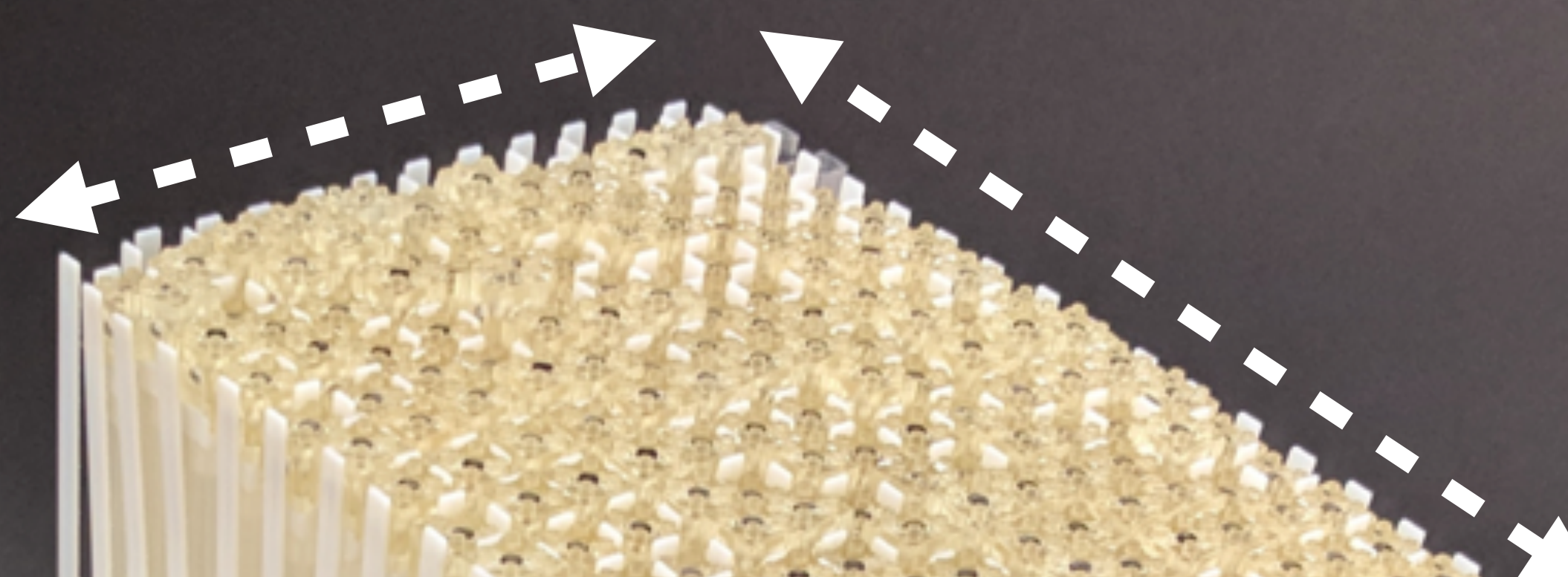


x16  
(16cm)

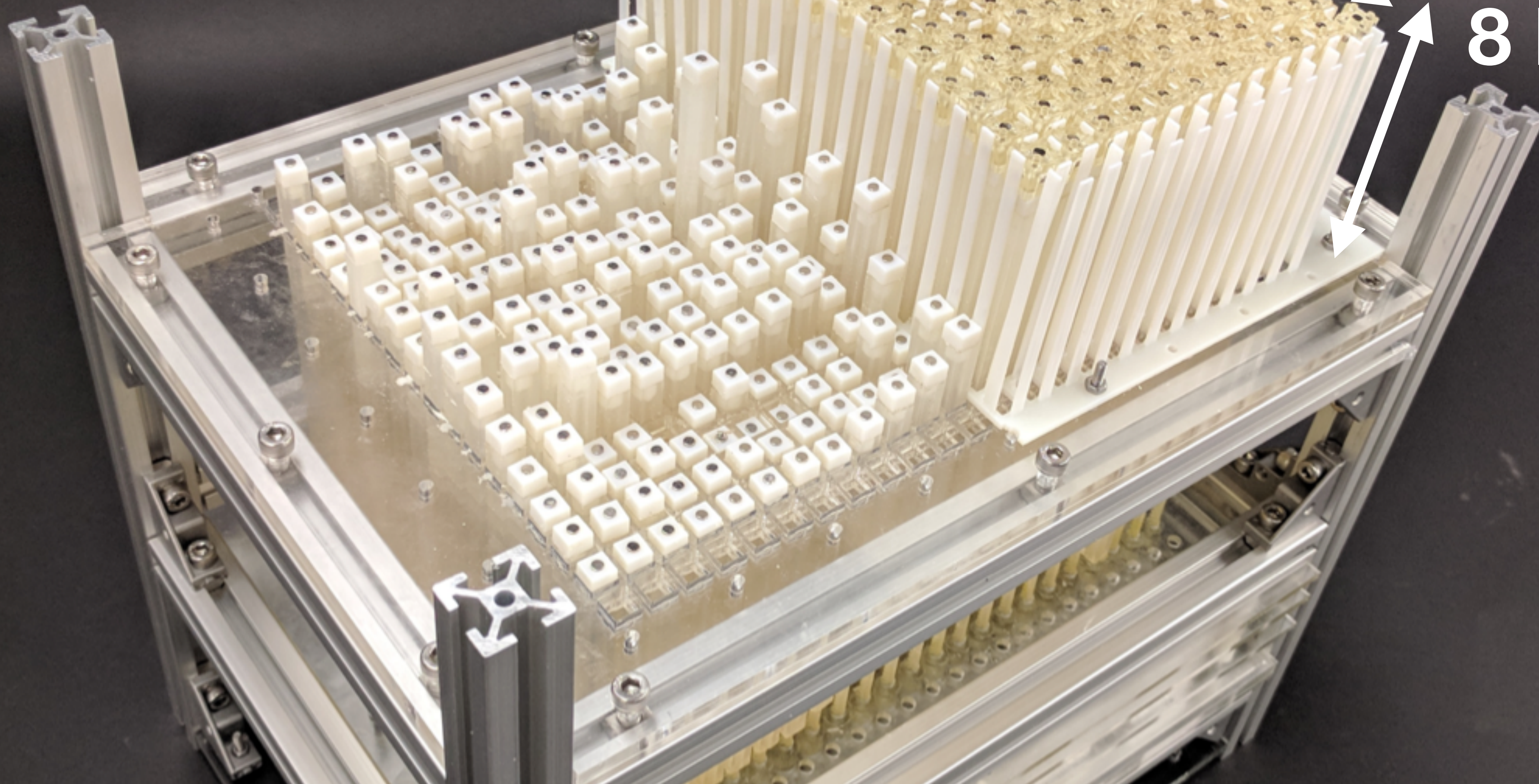
x24  
(24cm)



**Stacked Blocks**

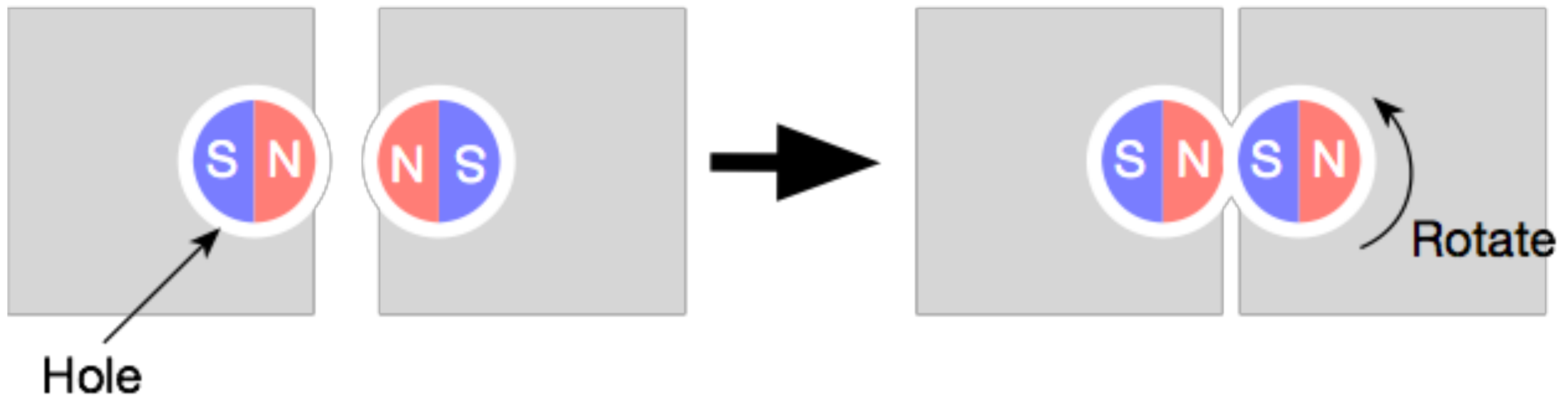
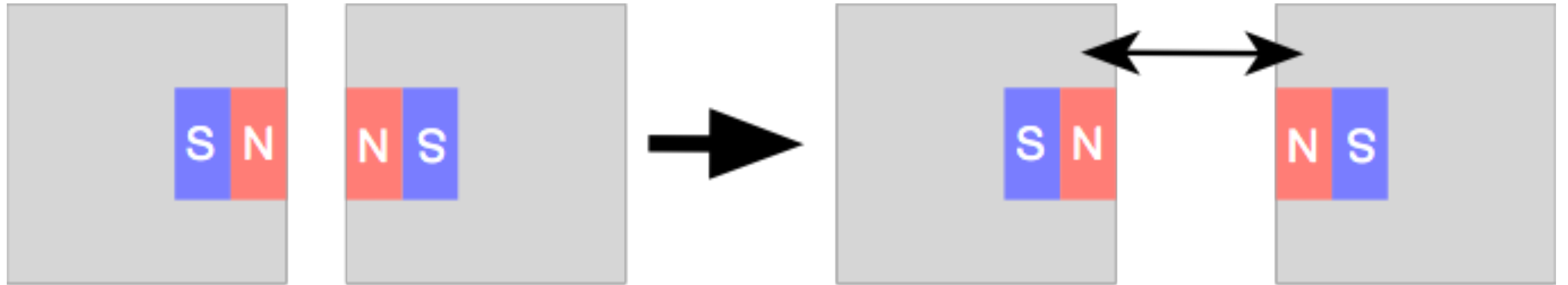


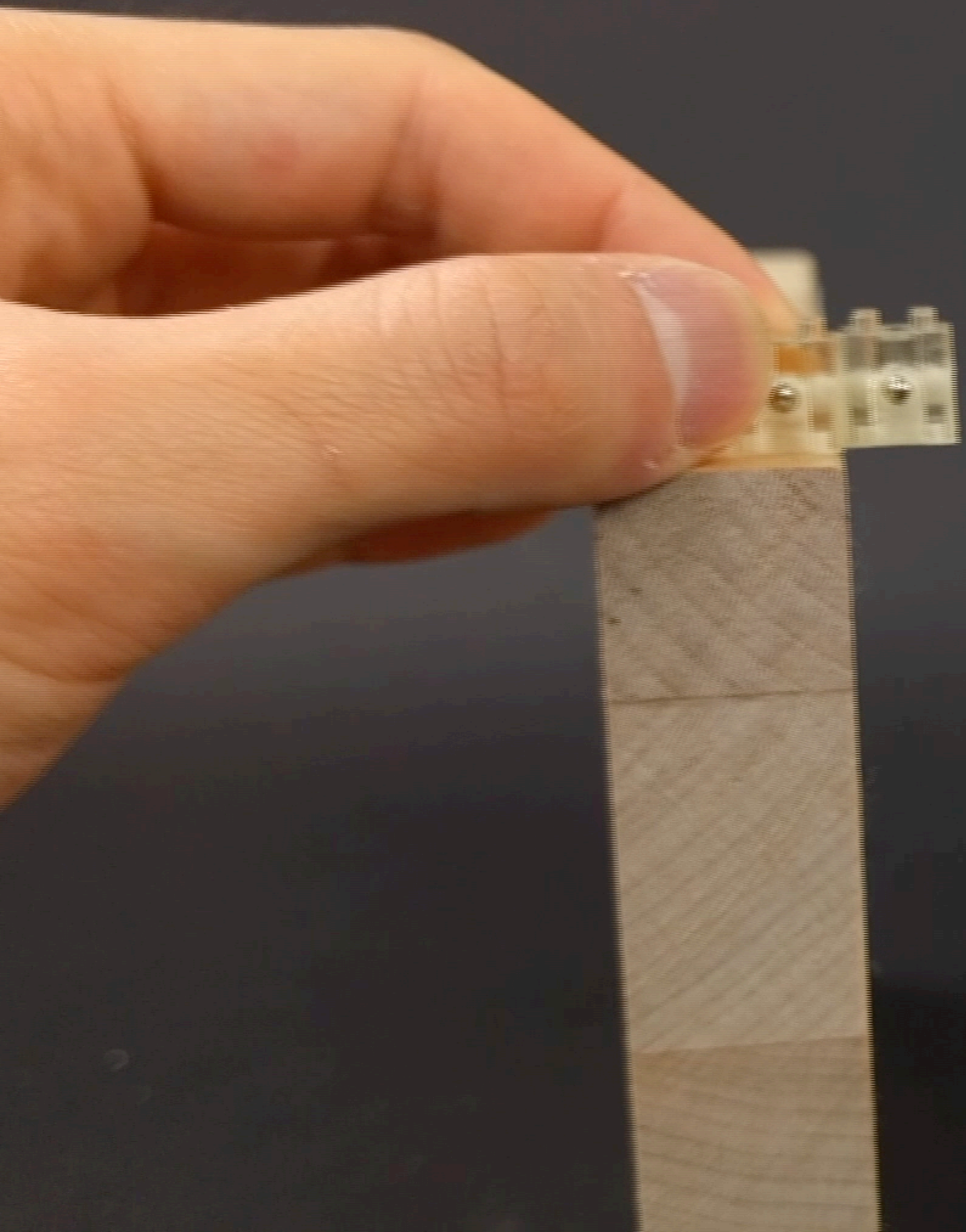
**8 layers**

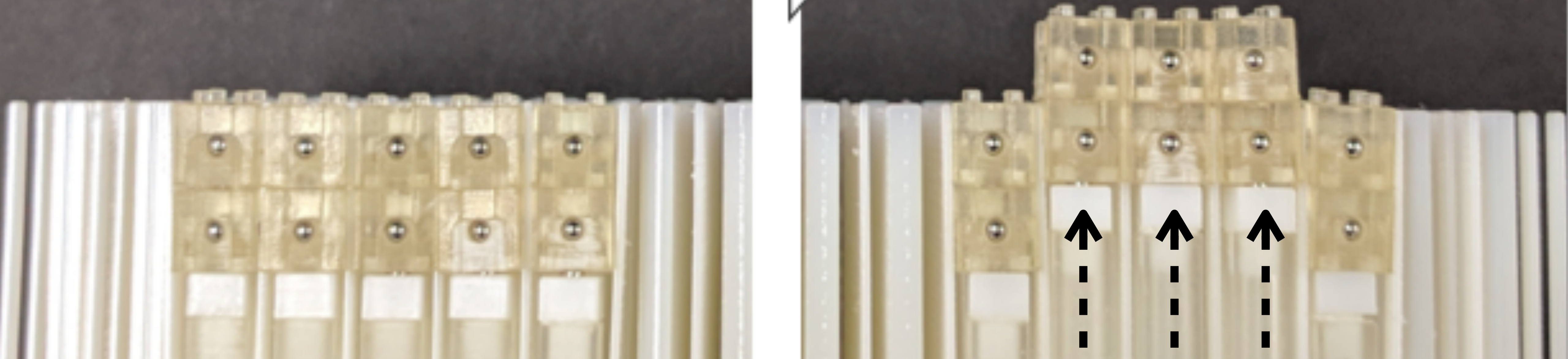
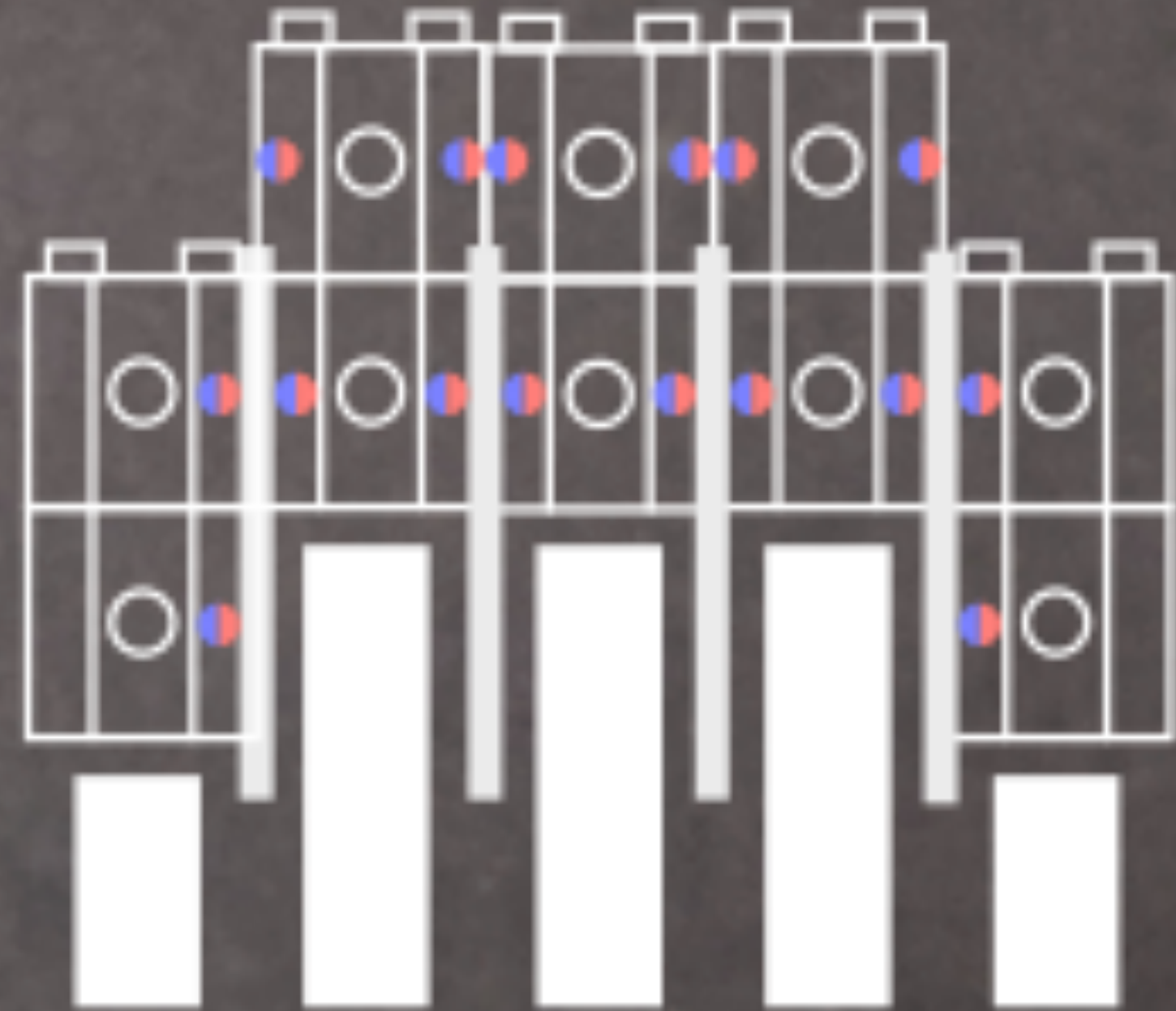
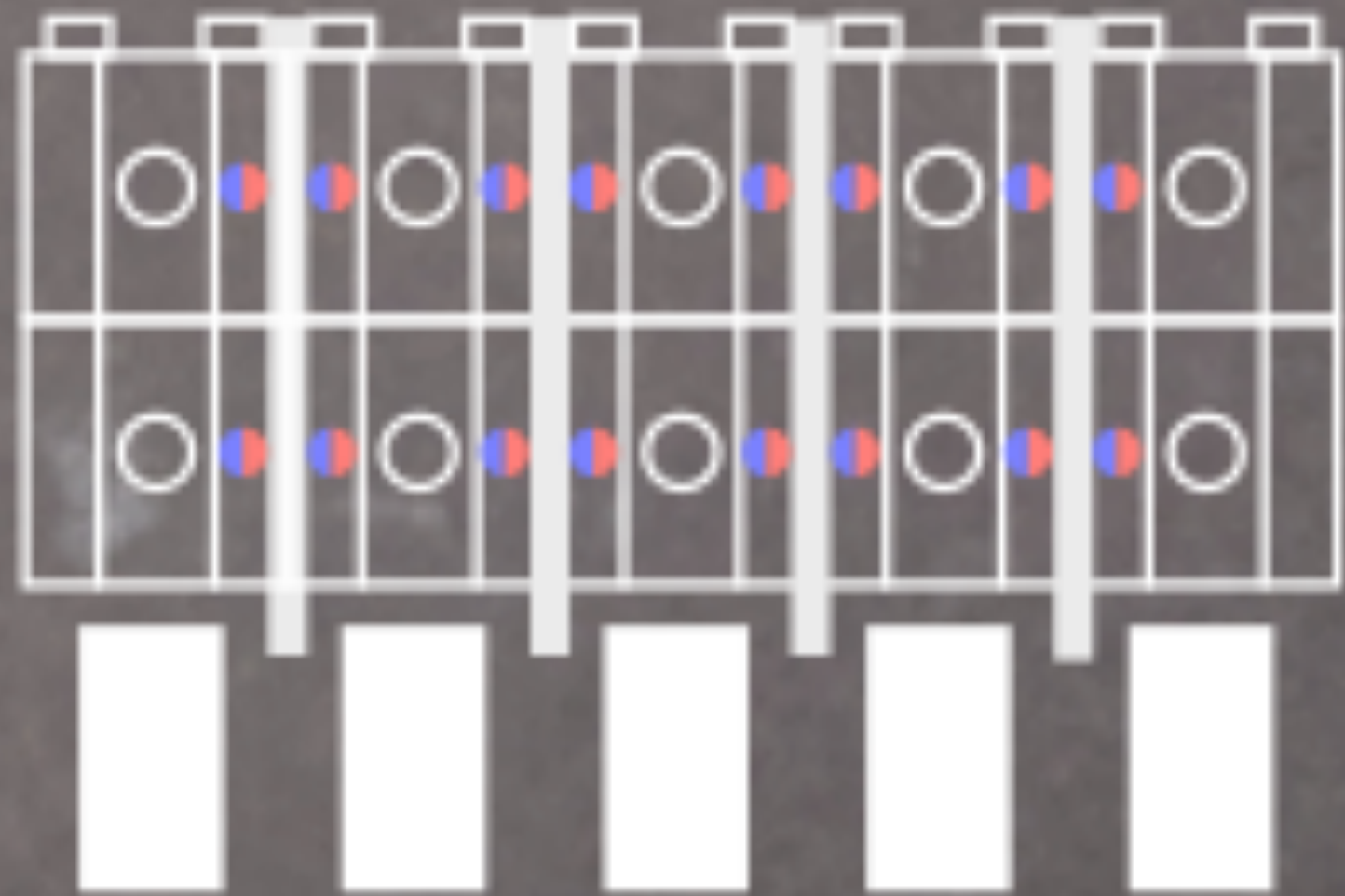


**Horizontal**  
Connection  
Disconnection

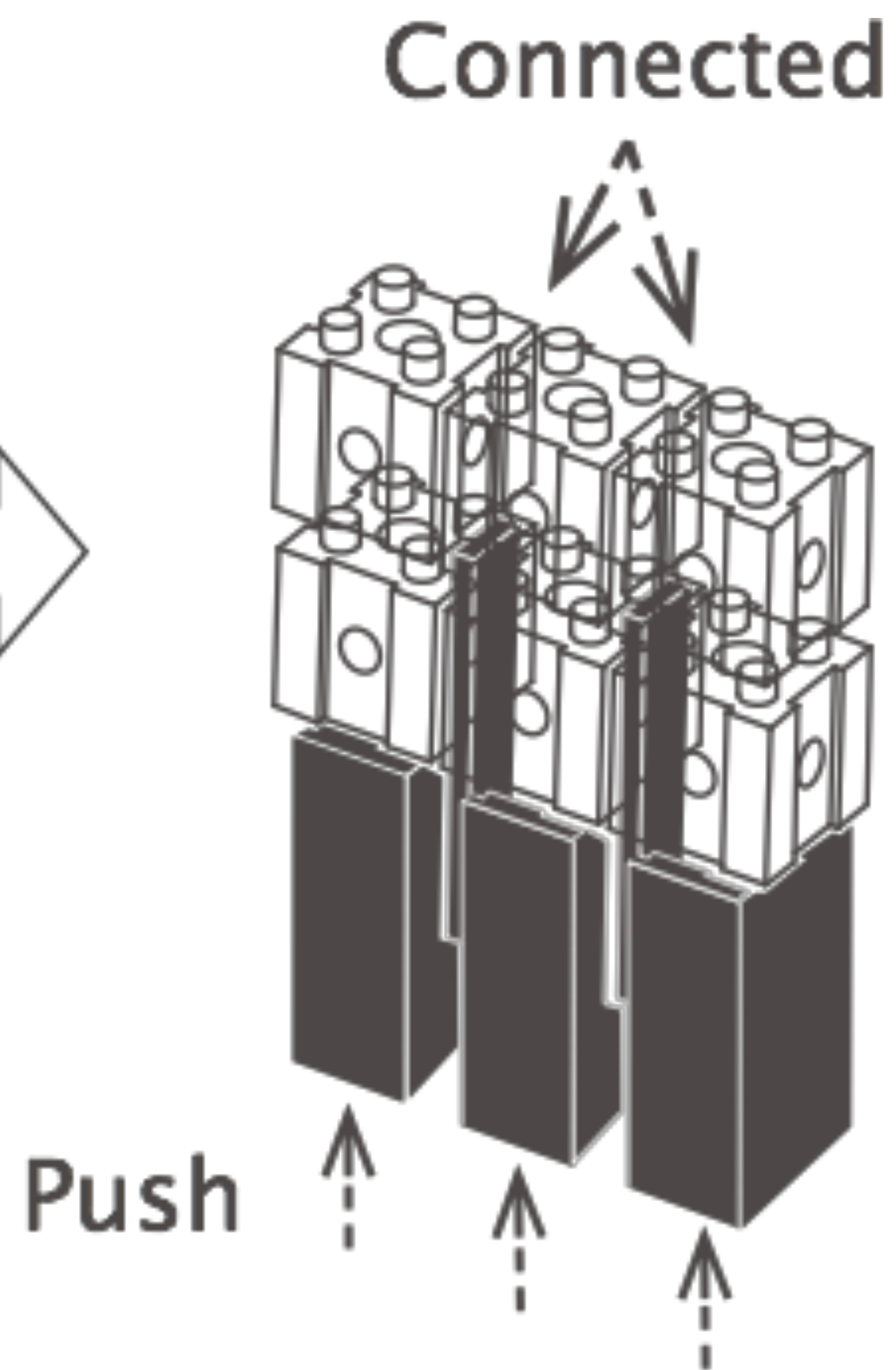
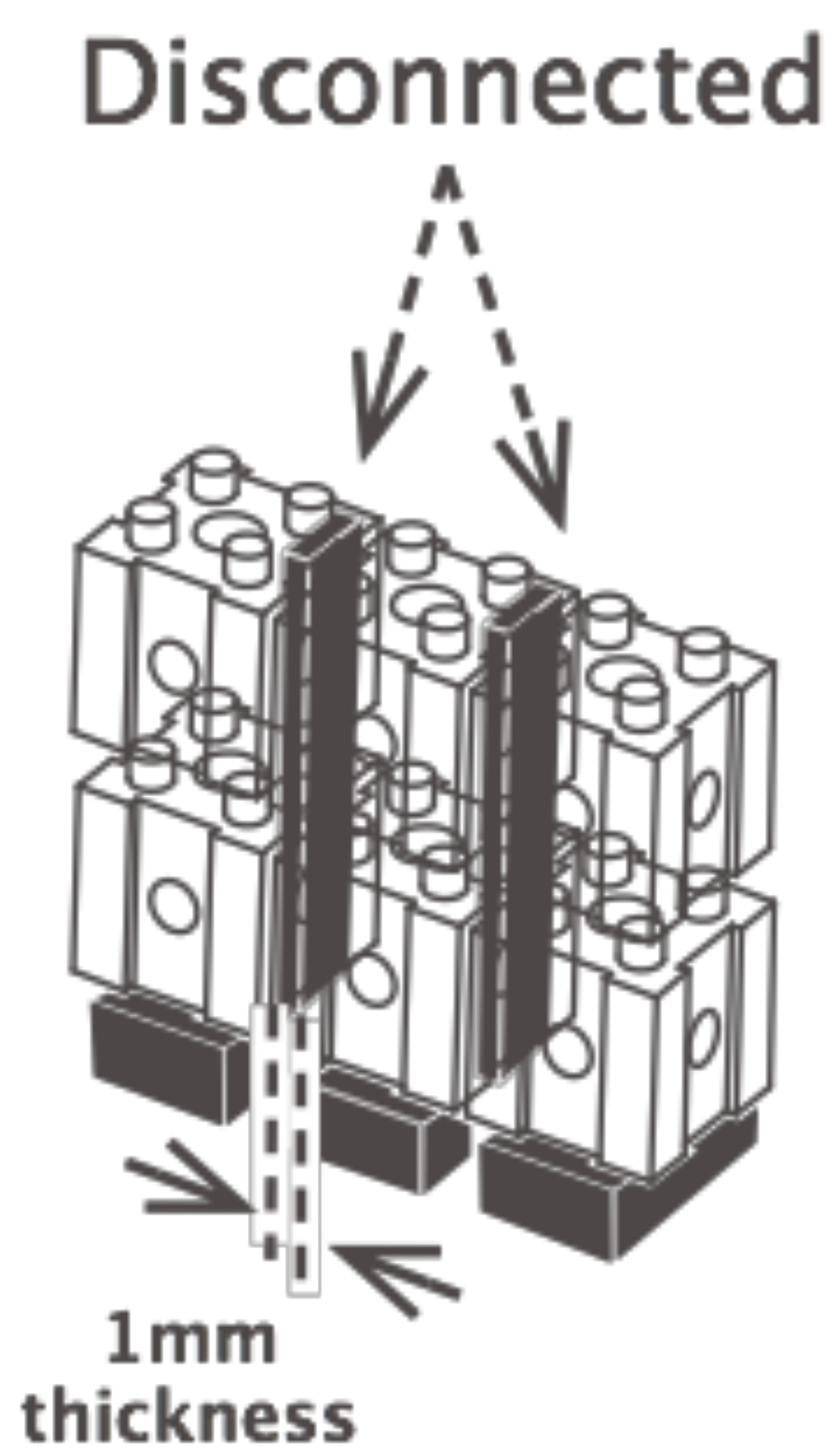
# Horizontal Connection



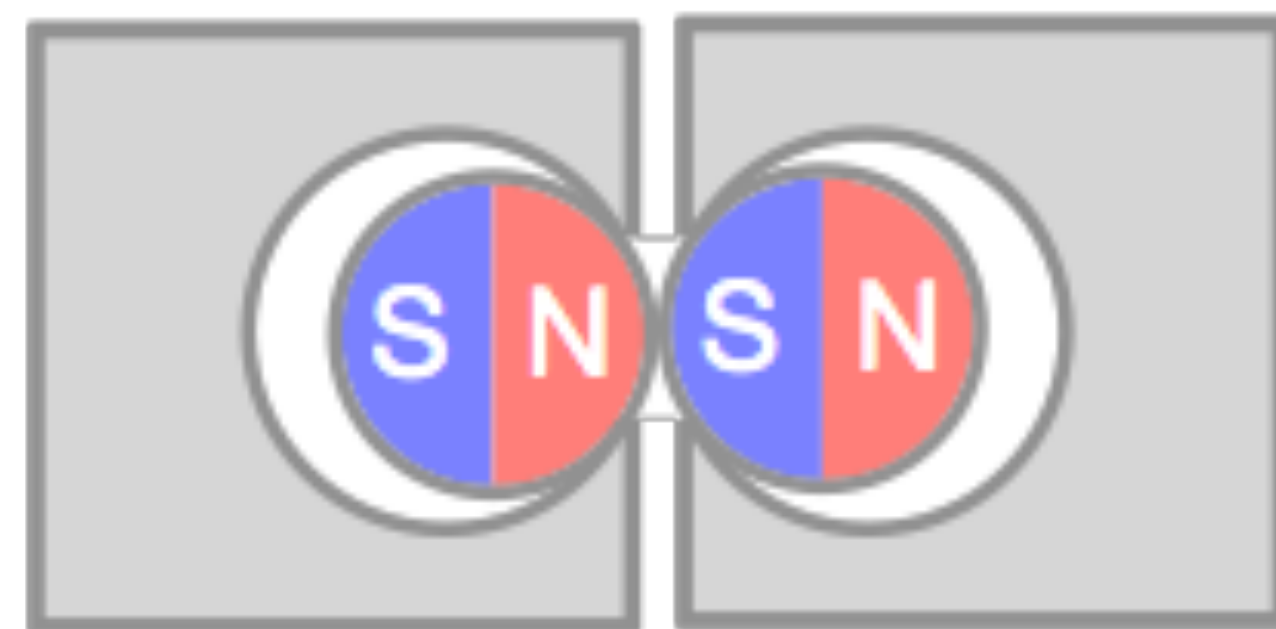
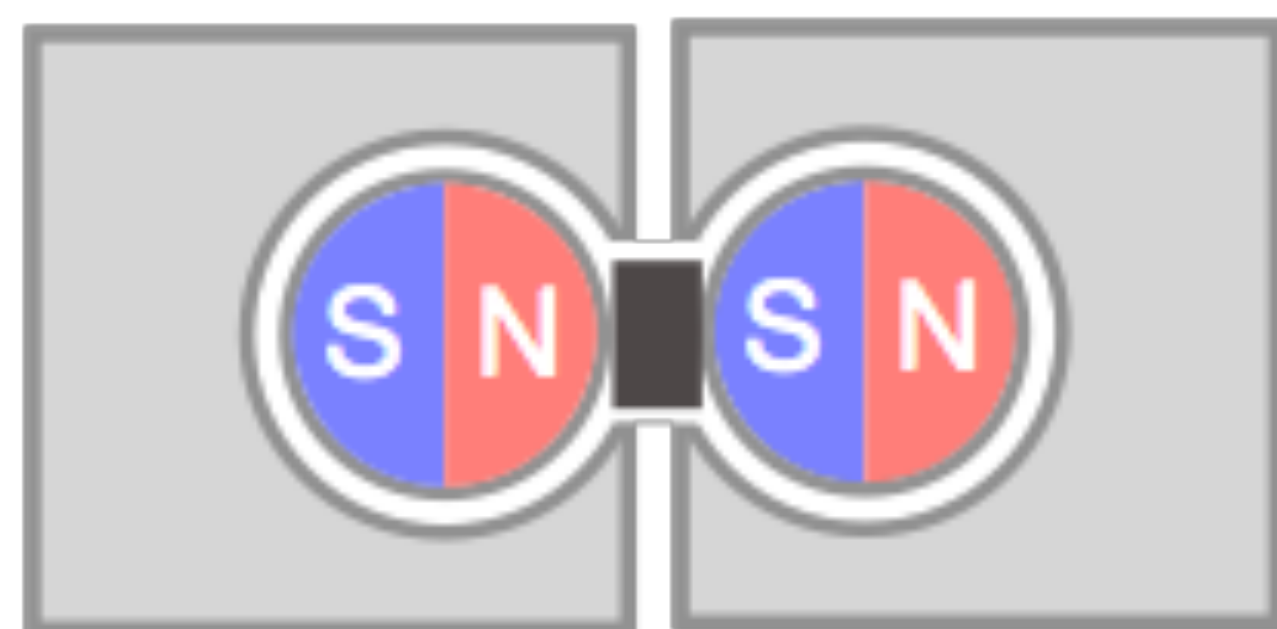




3D View



Top View

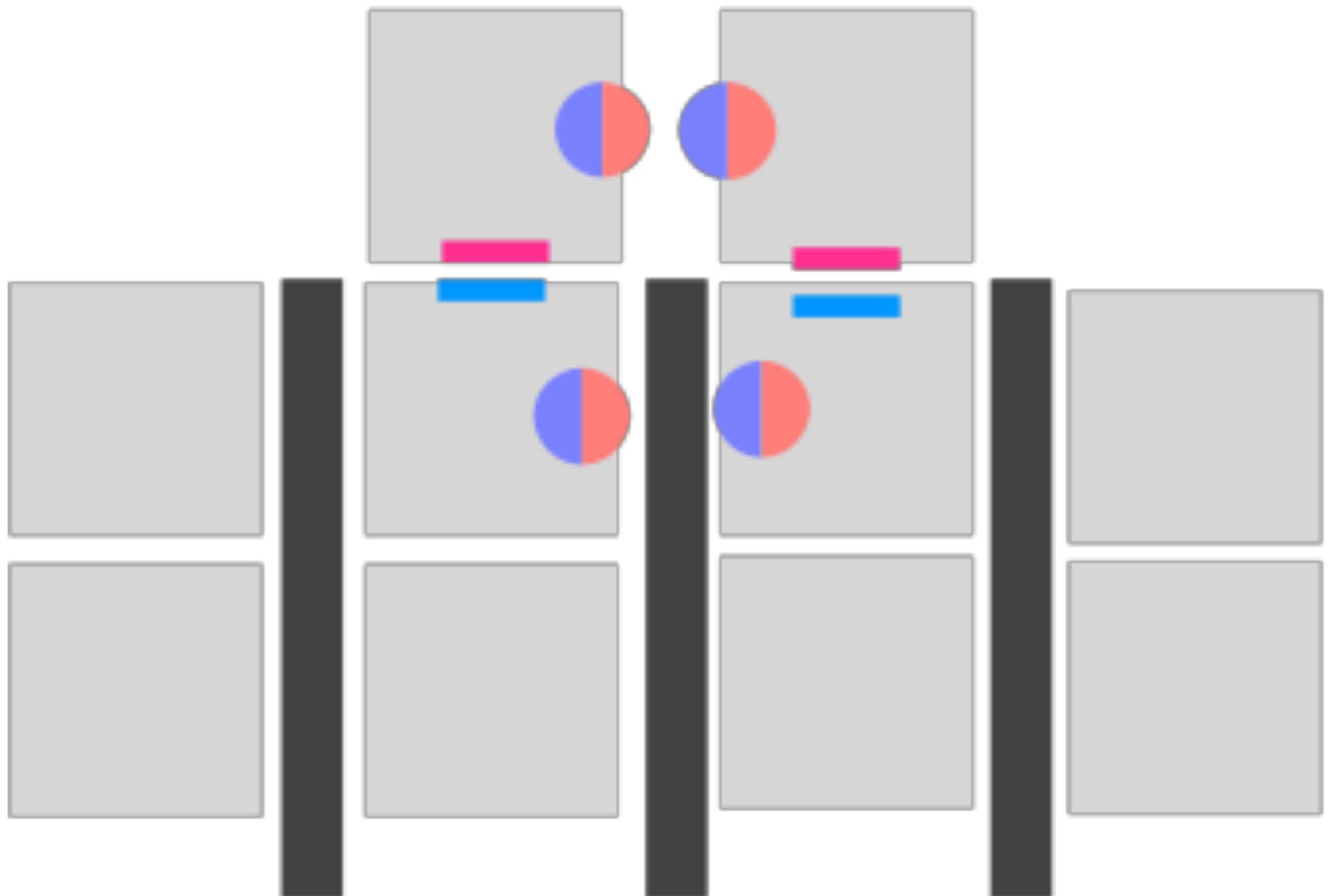
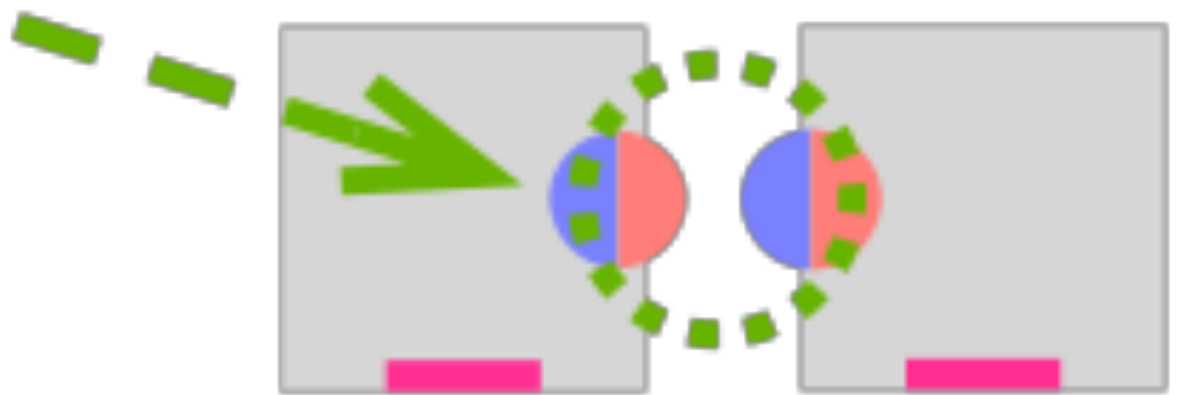


**Vertical**

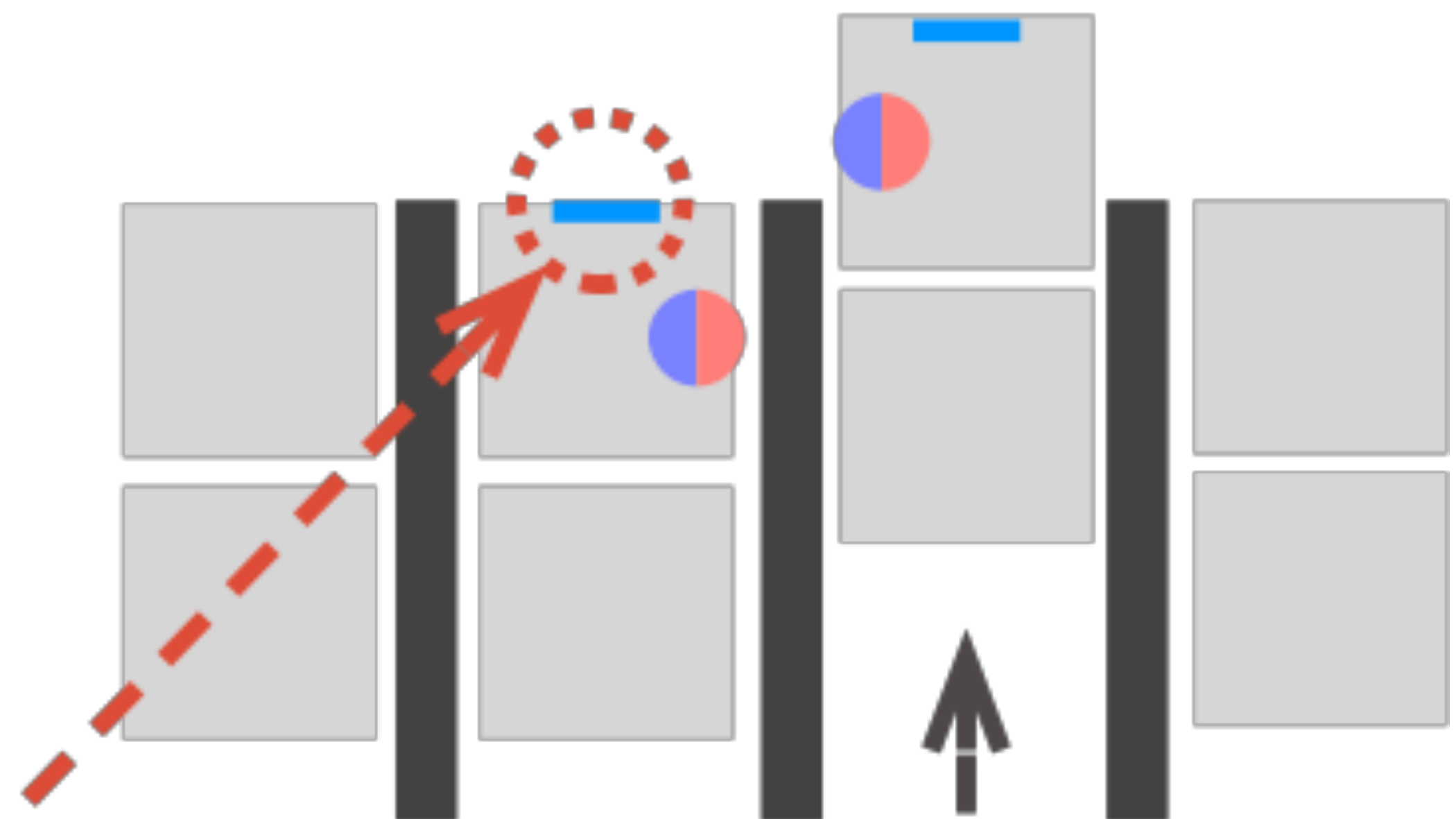
Connection

Disconnection

**Stay Connected**  
(Strong Connection)



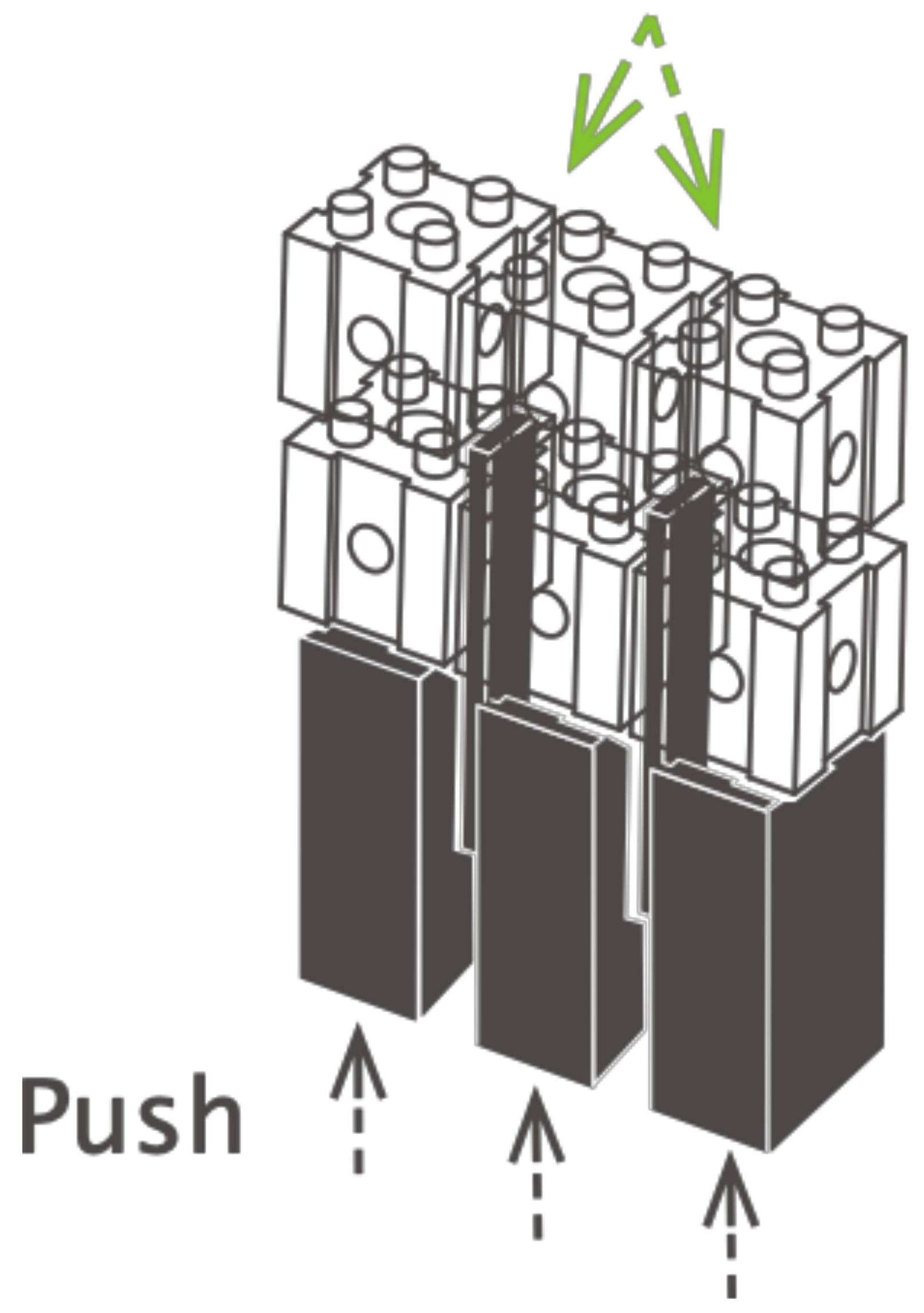
**Disconnected**  
(Weak Connection)



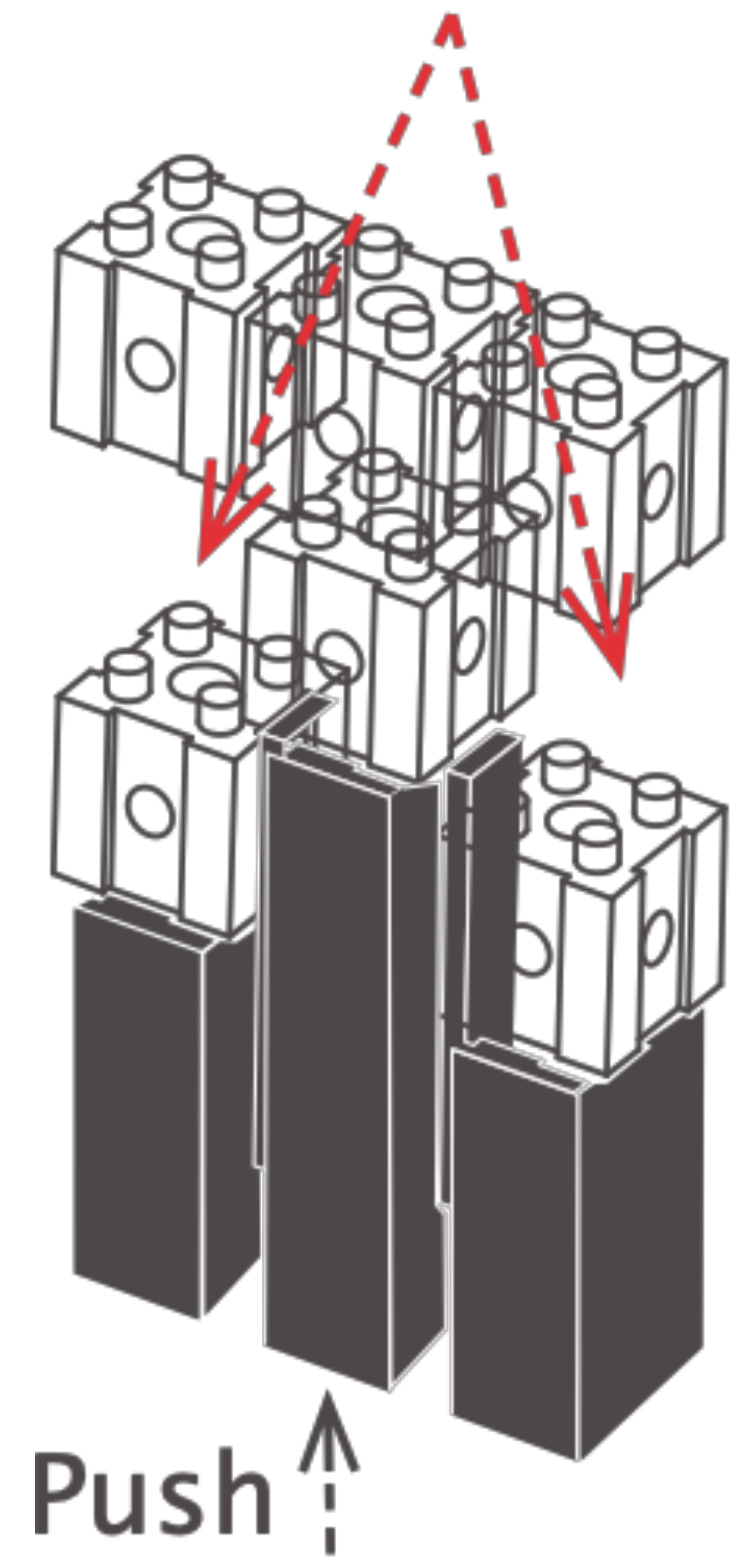
Push



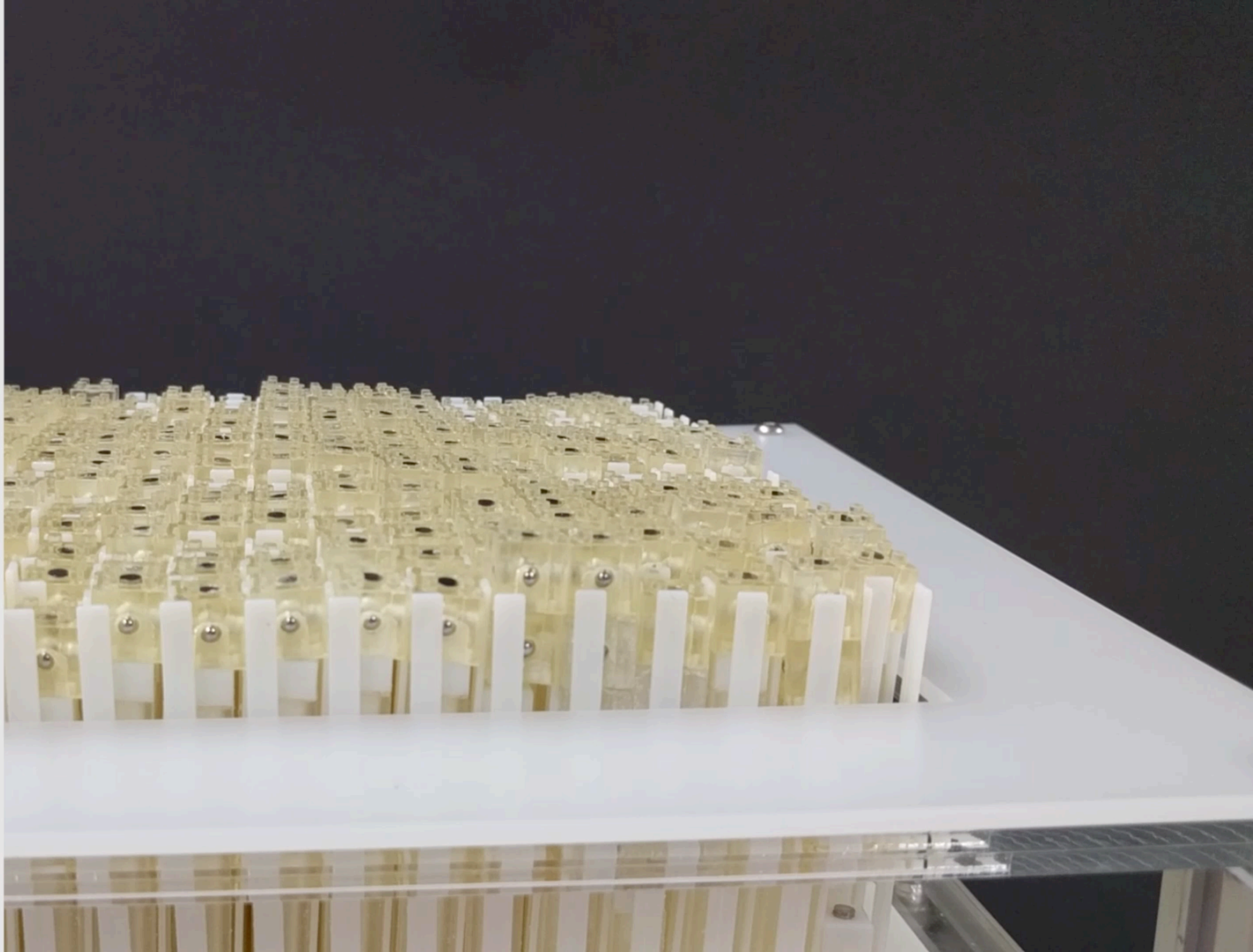
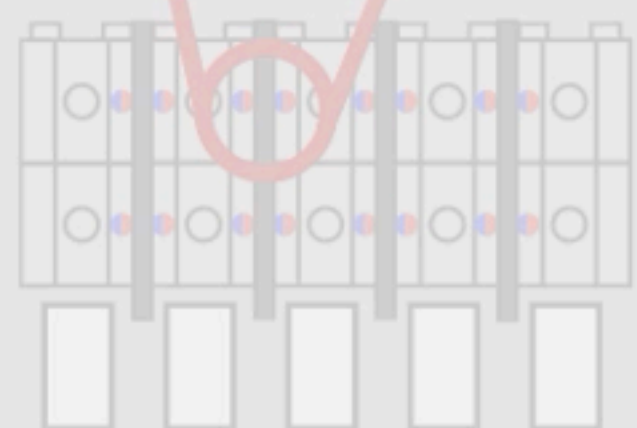
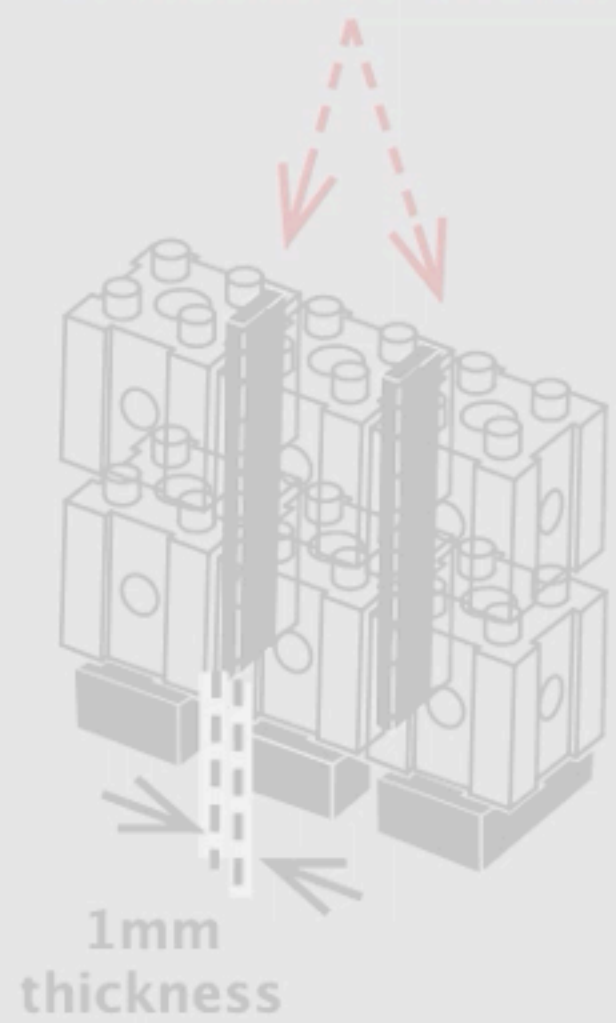
Connected

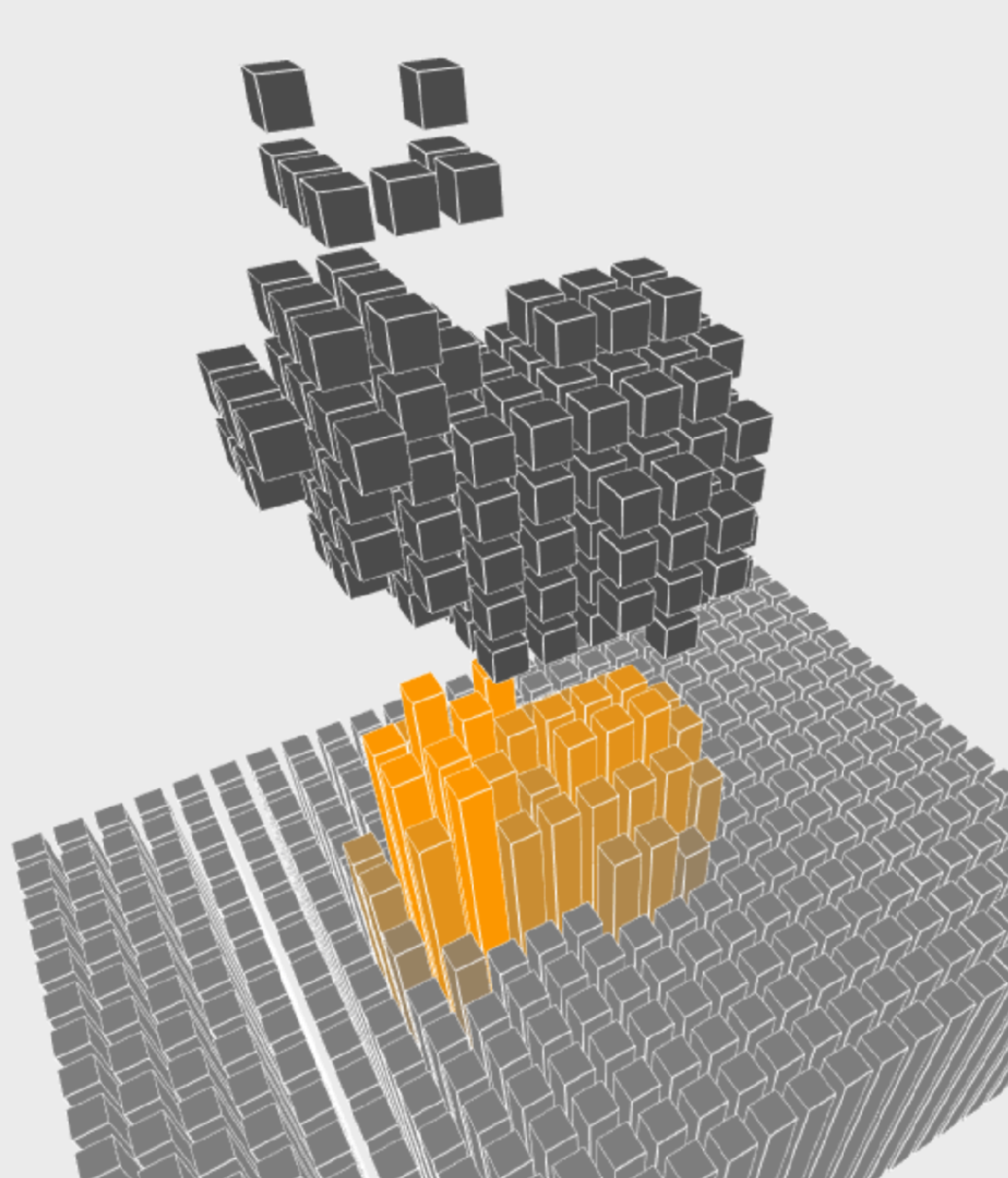
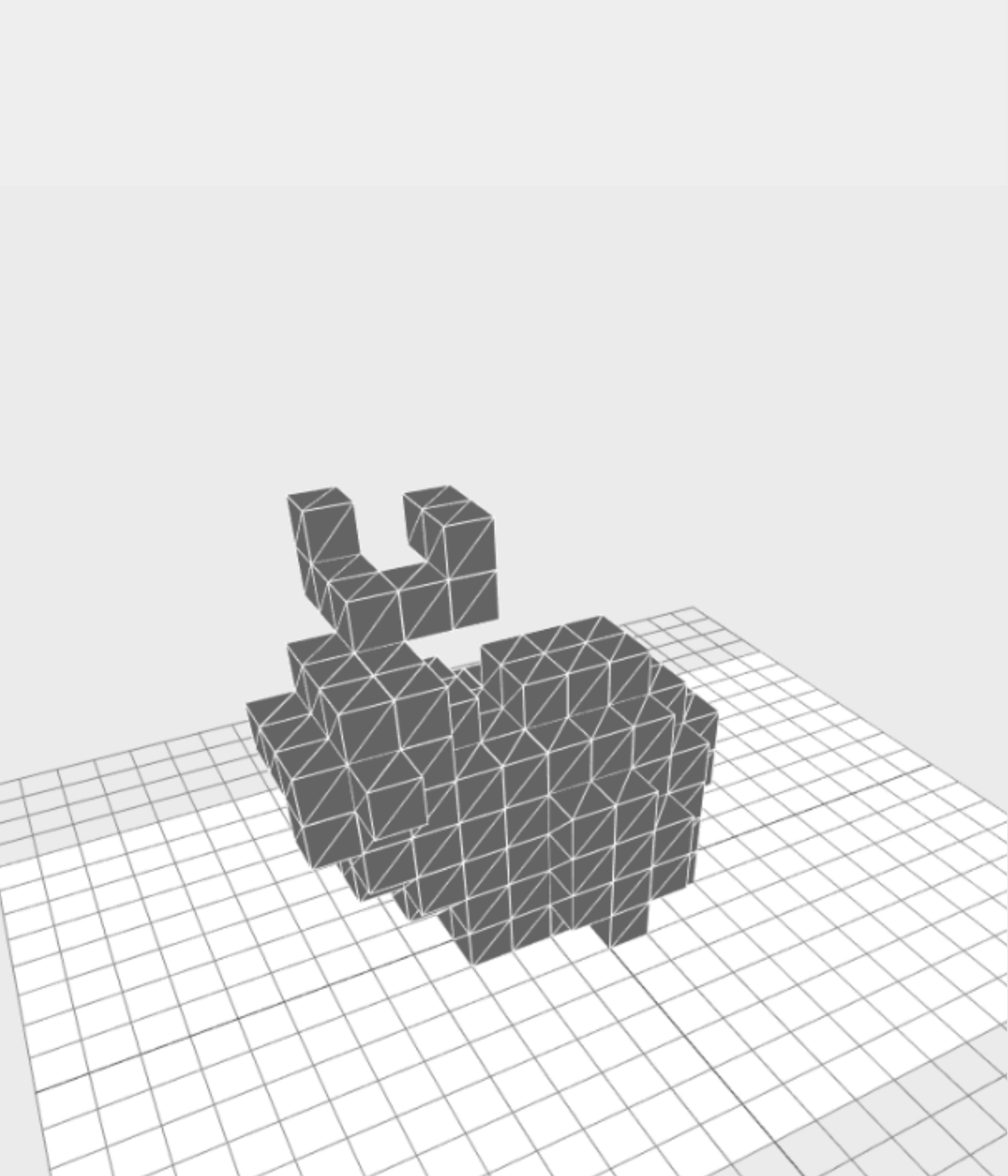


Disconnected



Disconnected





## Motion Tracking

## Depth Camera



## Position Tracking

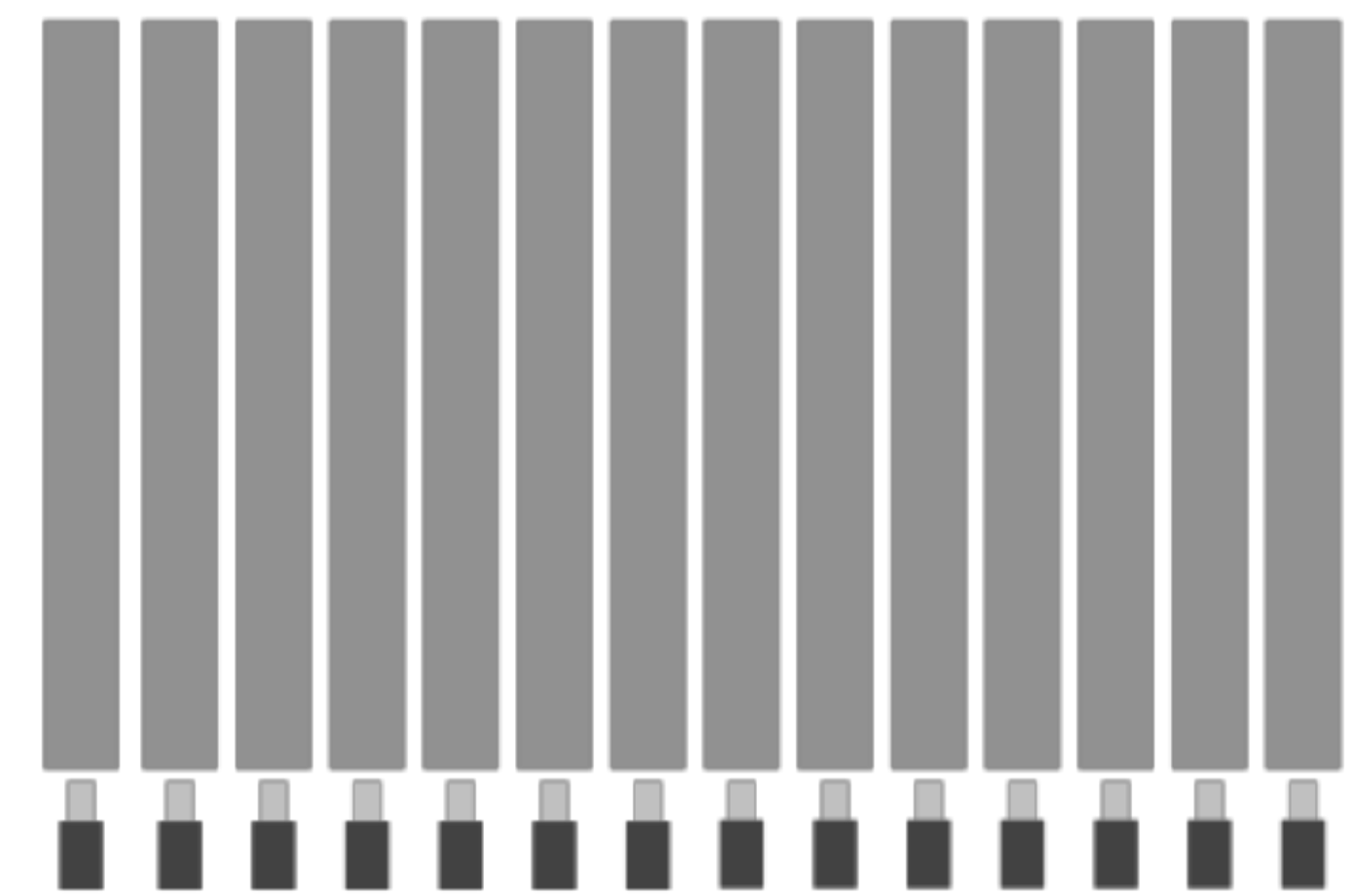
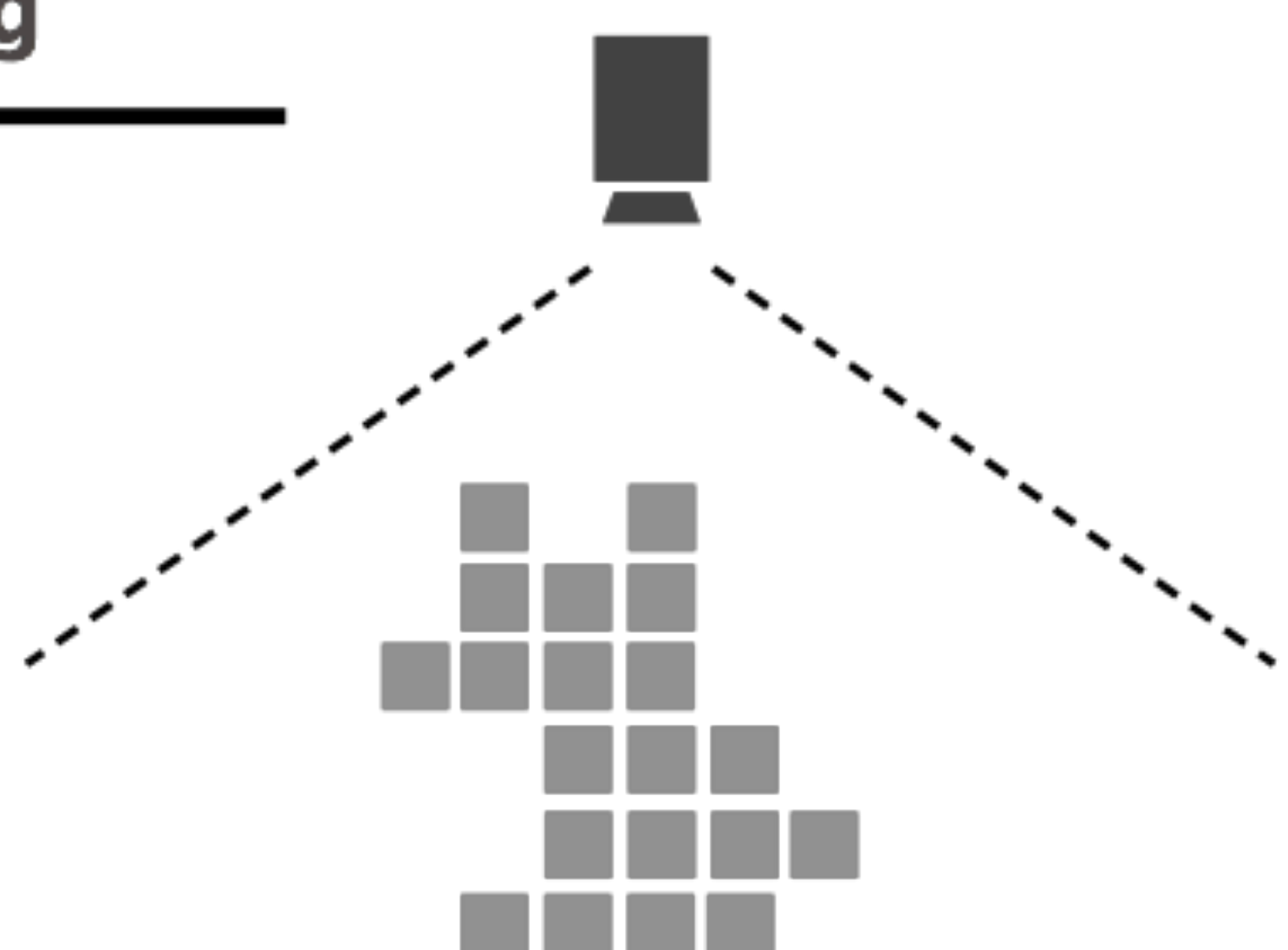
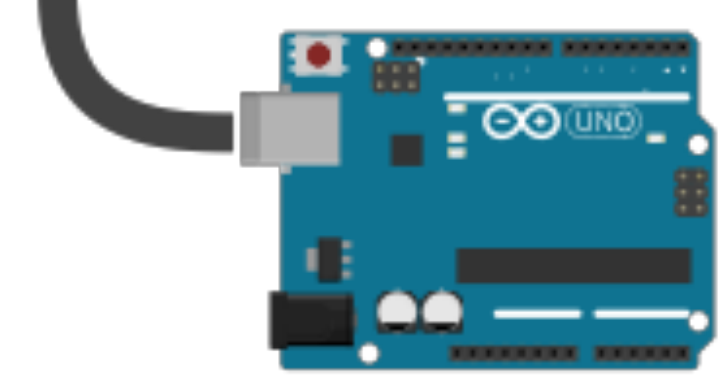
**Pin : Position**

Pin 1: 2

Pin 2: 7

...

Pin N: 3



## External Power Supply



x384 (24x16)

x96 (6x16)

## Daisy-chained Shift Register (Serial-in Parallel-out)

1. Summary
2. Related Work
3. Dynamic 3D Printing: Design Architecture
4. Dynablock: System and Implementation

# **5. Limitations and Future Work**

# **Limitation 1:**

Error Handling and Correction

# **Limitation 2:** Stability of the Object

# **Limitation 3:**

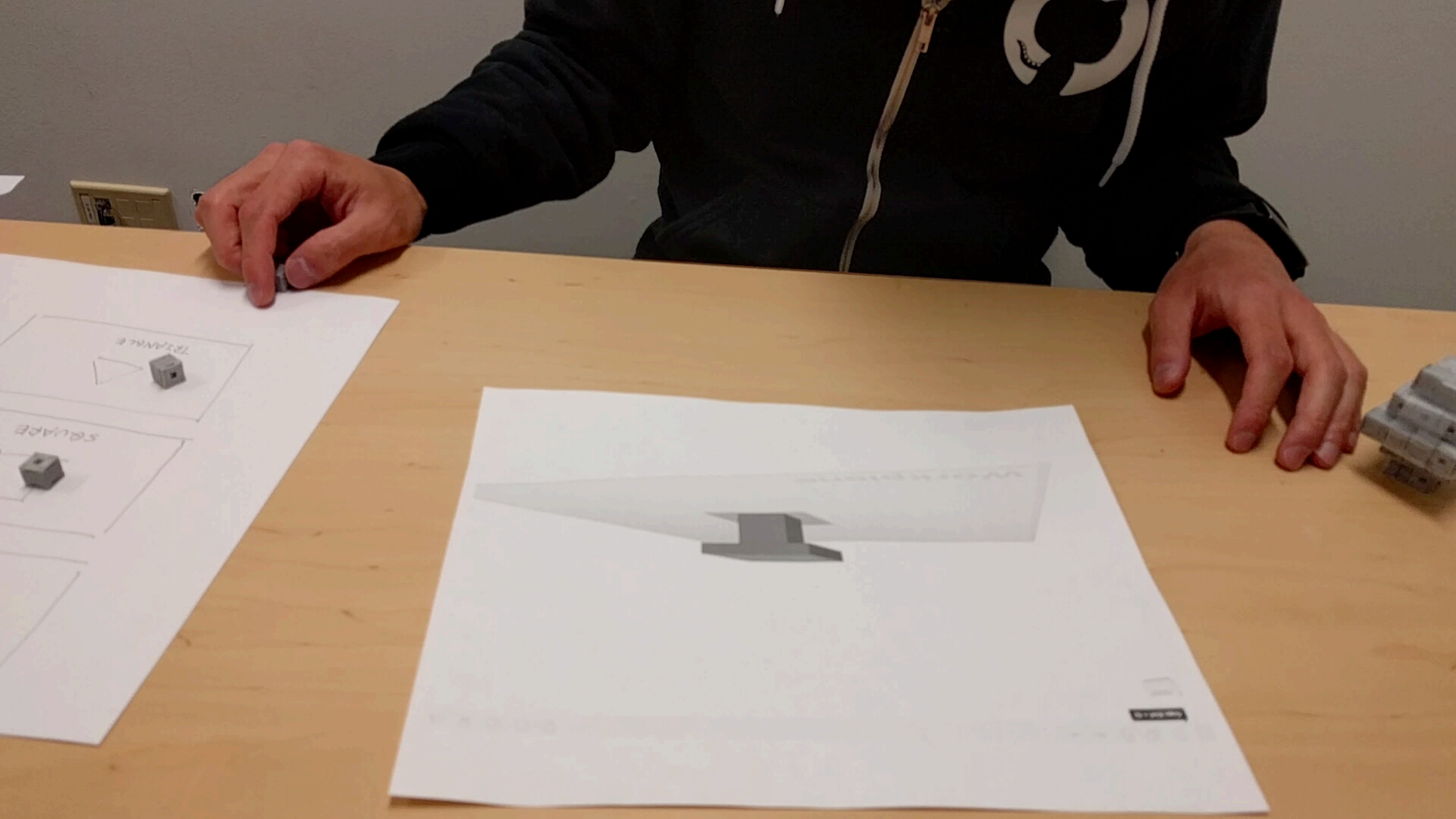
Process for Reconstruction

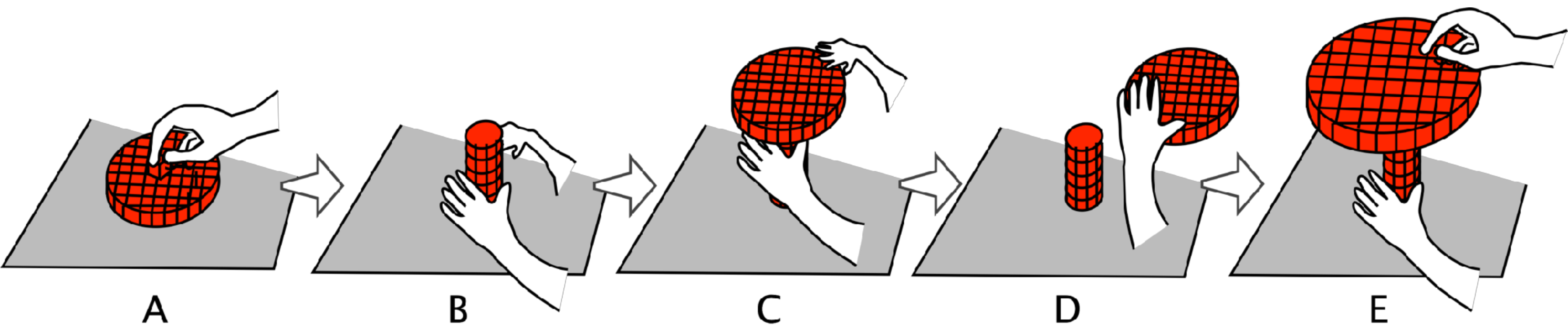


**Vision**



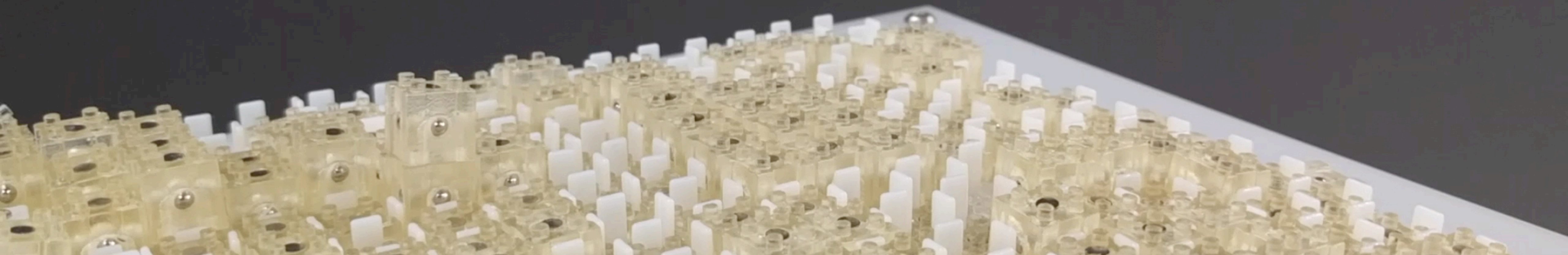
**Claytronics** (CMU 2006)





# Dynablock

## Dynamic 3D Printing for Instant and Reconstructable Shape Formation



**Ryo Suzuki, Junichi Yamaoka, Daniel Leithinger, Tom Yeh, Mark D. Gross, Yoshihiro Kawahara, Yasuaki Kakehi**

University of Colorado Boulder, The University of Tokyo

