

# **Enabling non-experts to author tangible interactions**

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# About Me



# About Me

- BS Systems Engineering • 2012  
Pontificia Universidad Católica Madre y Maestra  
Santiago, Dominican Republic
- MS Information Science • 2016  
Rochester Institute of Technology  
Rochester, New York, USA
- PhD Computer Science • 2020  
University of Copenhagen  
Copenhagen, Denmark



# How to create interactive devices?



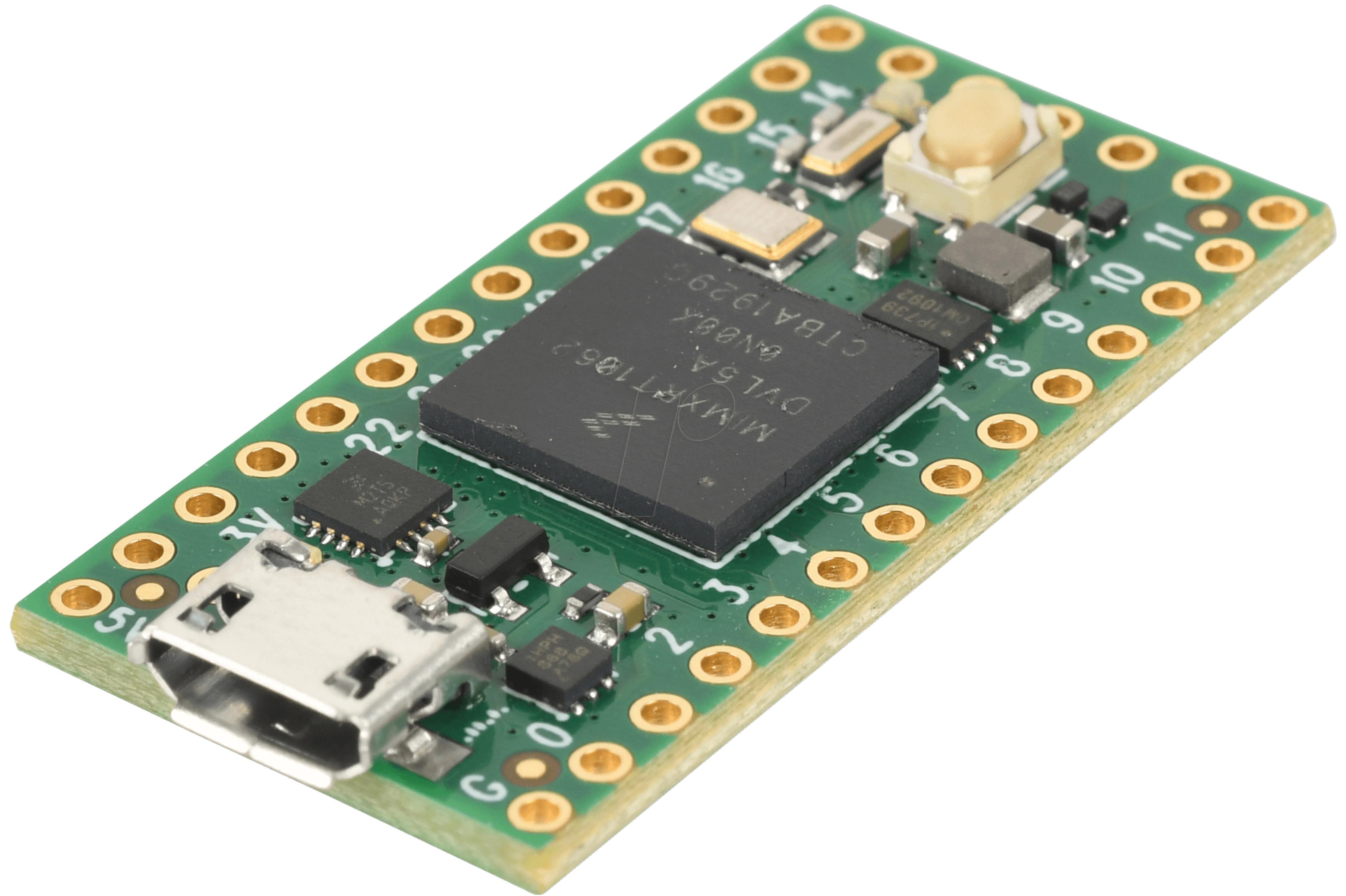
Why is physicality important in interactions?

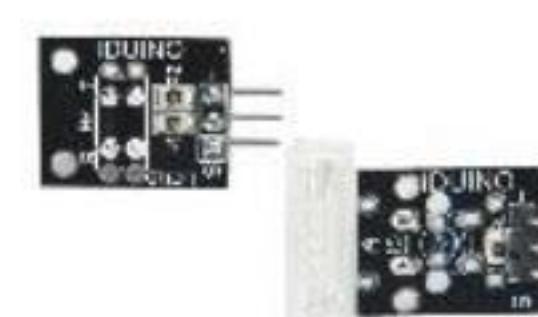
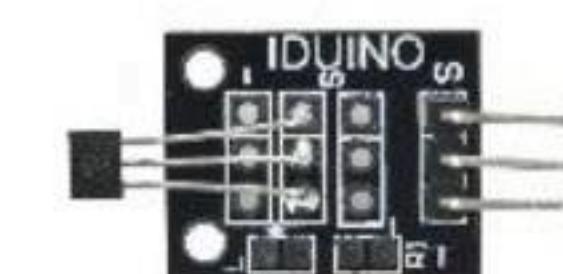
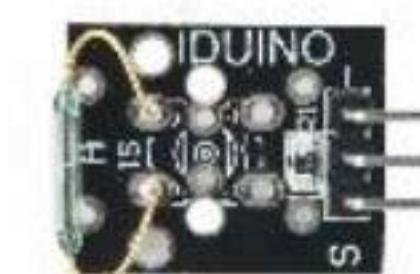
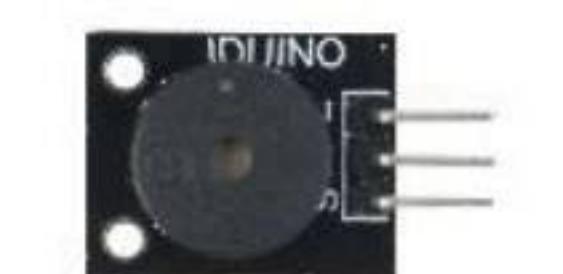
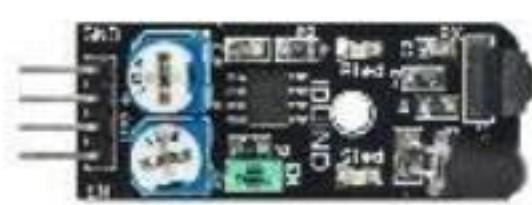
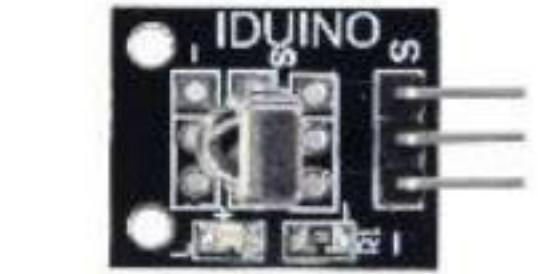
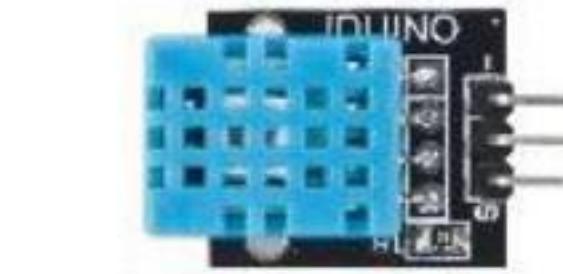
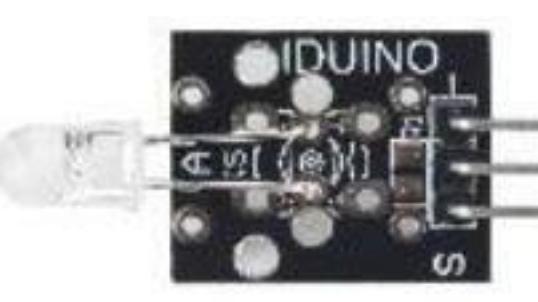
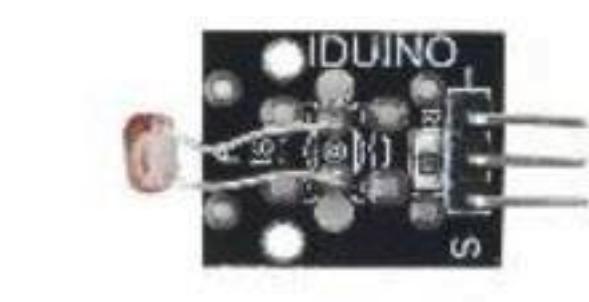
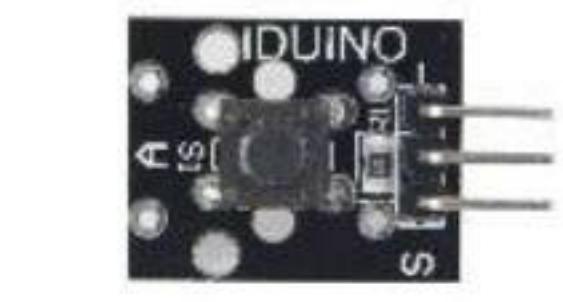
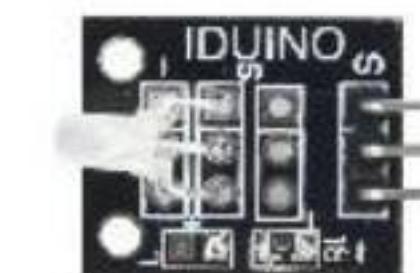
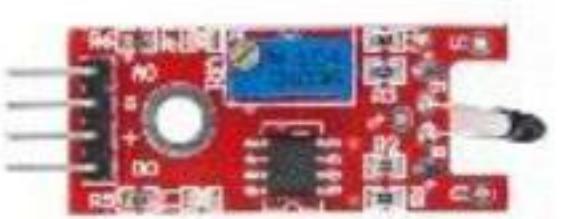
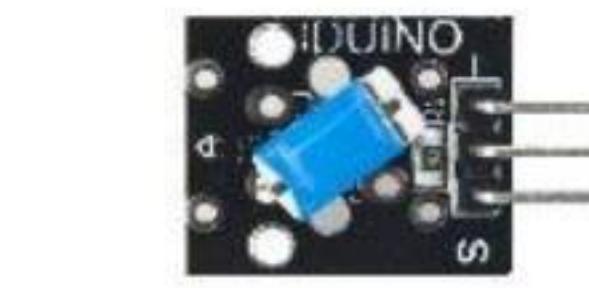
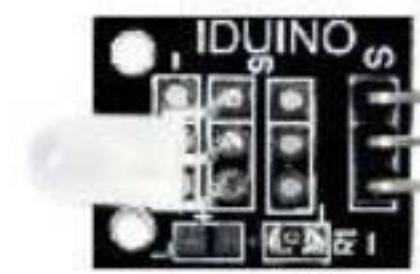
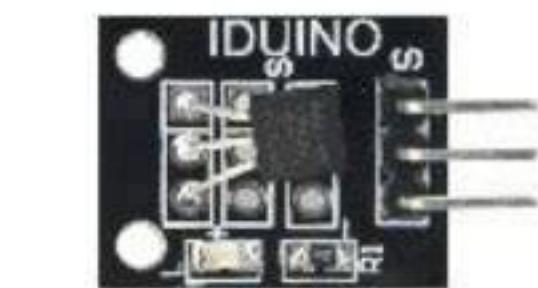
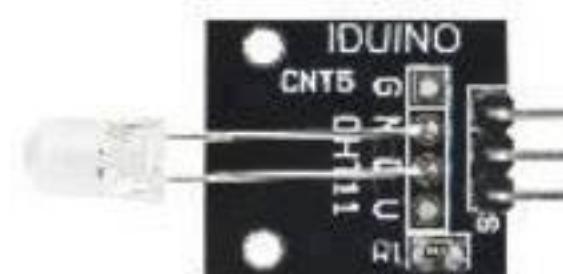
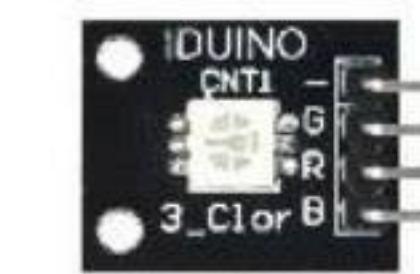
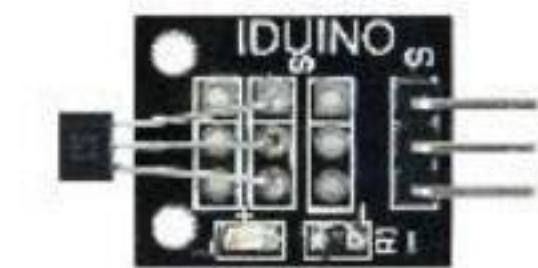
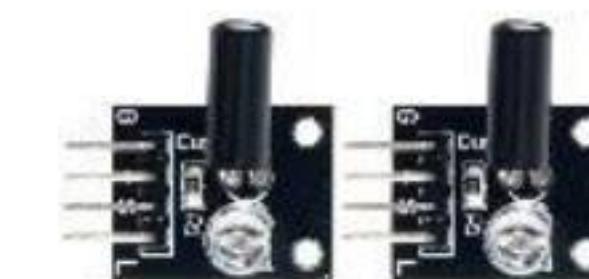
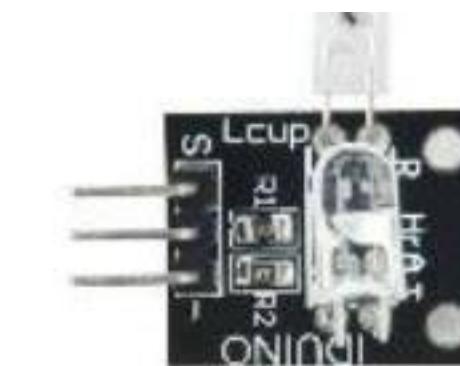
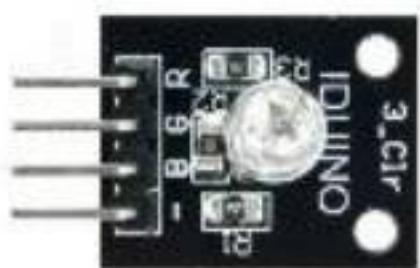
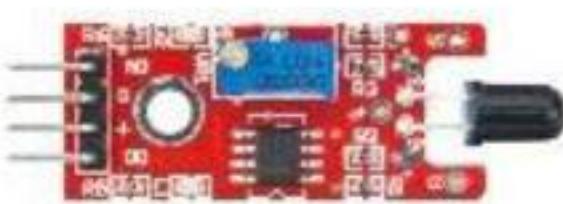






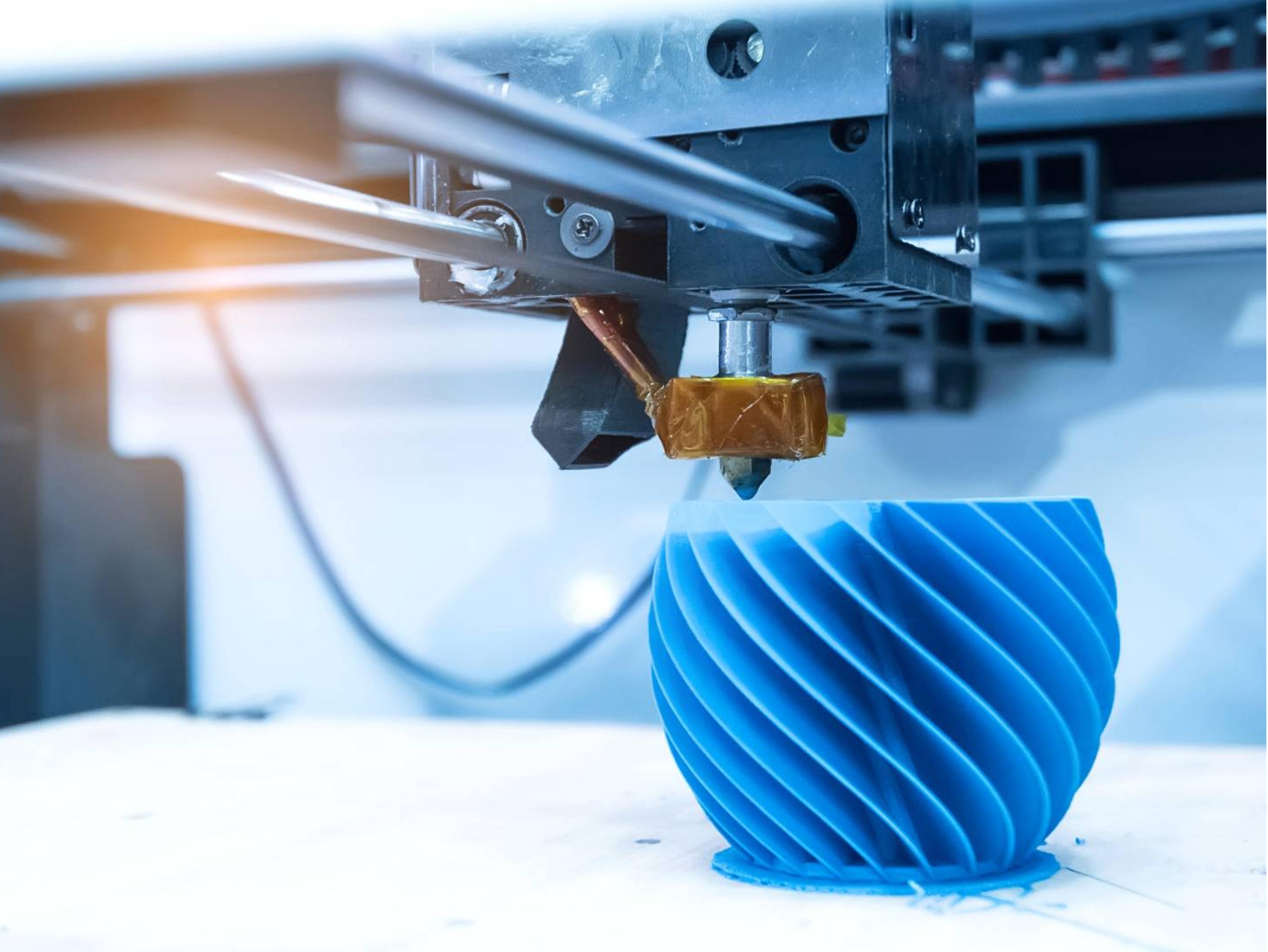
# How to create interactive devices?

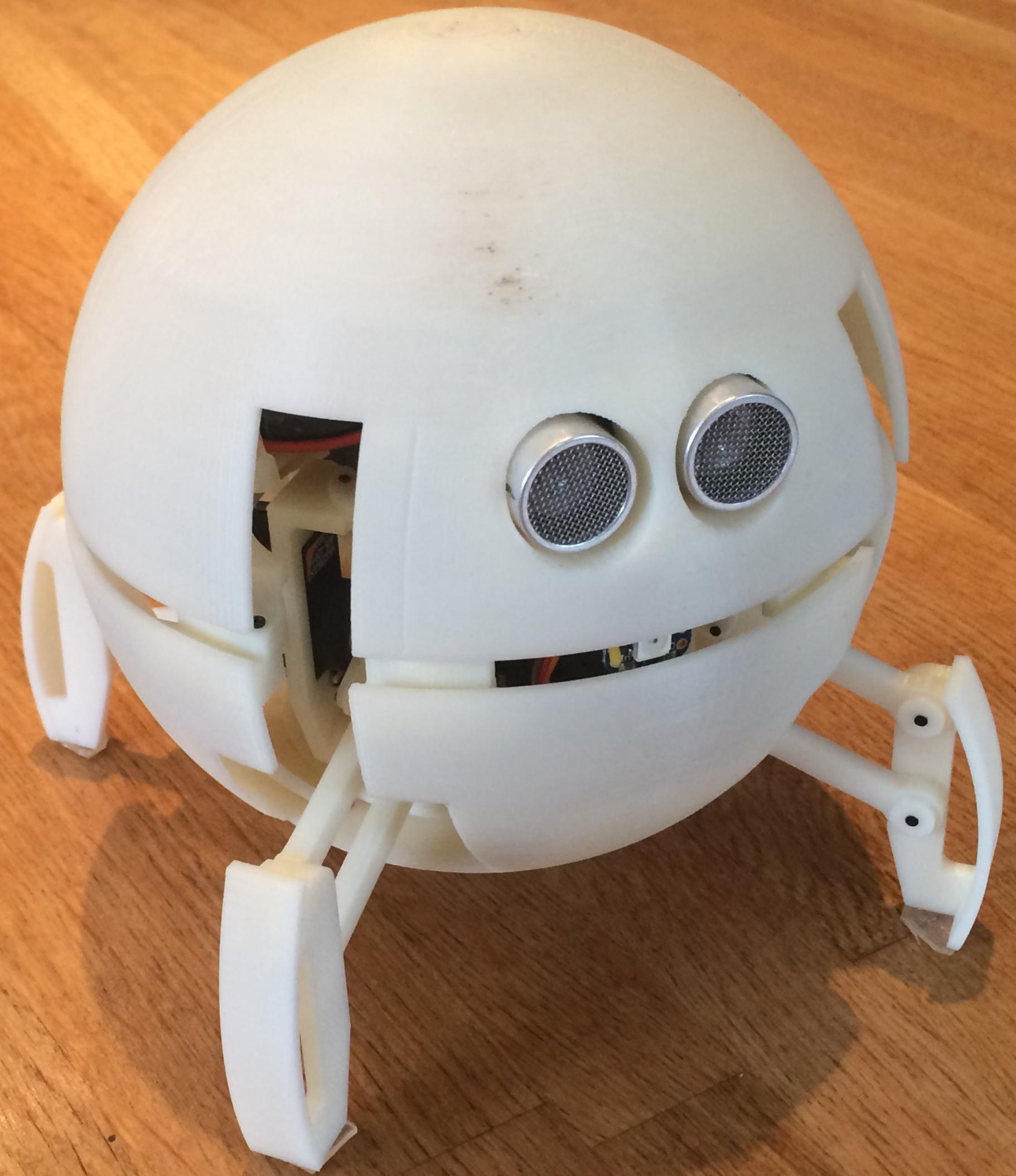






```
31     def __init__(self, path=None):
32         self.file = None
33         self.fingerprints = set()
34         self.logduplicates = True
35         self.debug = debug
36         self.logger = logging.getLogger(__name__)
37         if path:
38             self.file = open(os.path.join(path, "fingerprints.txt"), "w")
39             self.file.seek(0)
40             self.fingerprints.update(line.strip() for line in self.file)
41
42     @classmethod
43     def from_settings(cls, settings):
44         debug = settings.getbool("FINGERPRINT_DEBUG")
45         return cls(job_dir(settings), debug)
46
47     def request_seen(self, request):
48         fp = self.request_fingerprint(request)
49         if fp in self.fingerprints:
50             return True
51         self.fingerprints.add(fp)
52         if self.file:
53             self.file.write(fp + os.linesep)
54
55     def request_fingerprint(self, request):
56         return request_fingerprint(request)
```





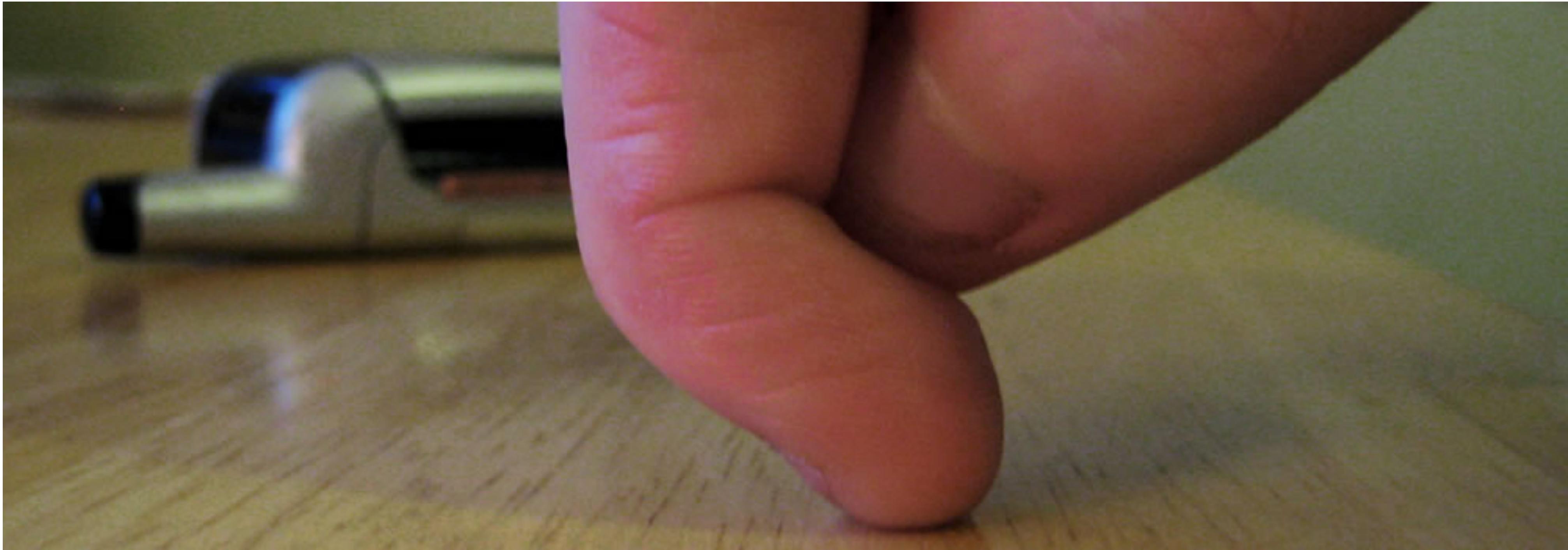
# Not trivial

# Not trivial

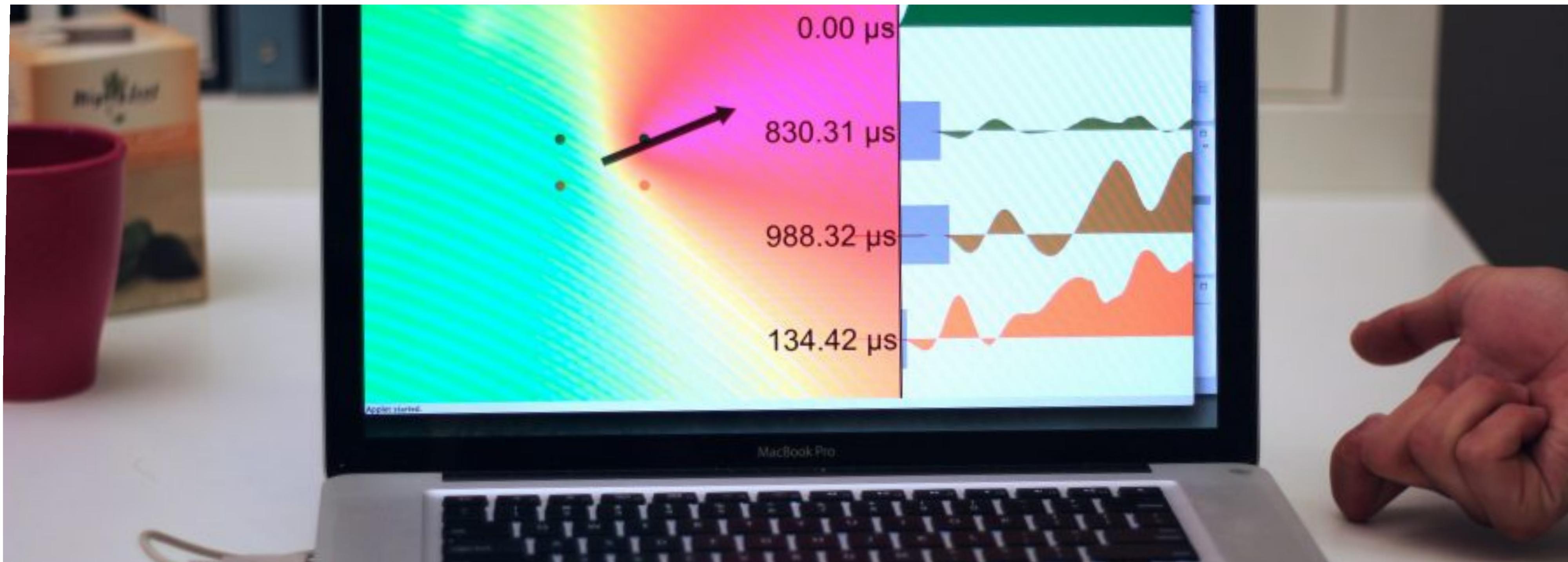
- Users need to have:
  - Electrical engineering expertise.
  - Programming knowledge.
  - Time to test and debug.



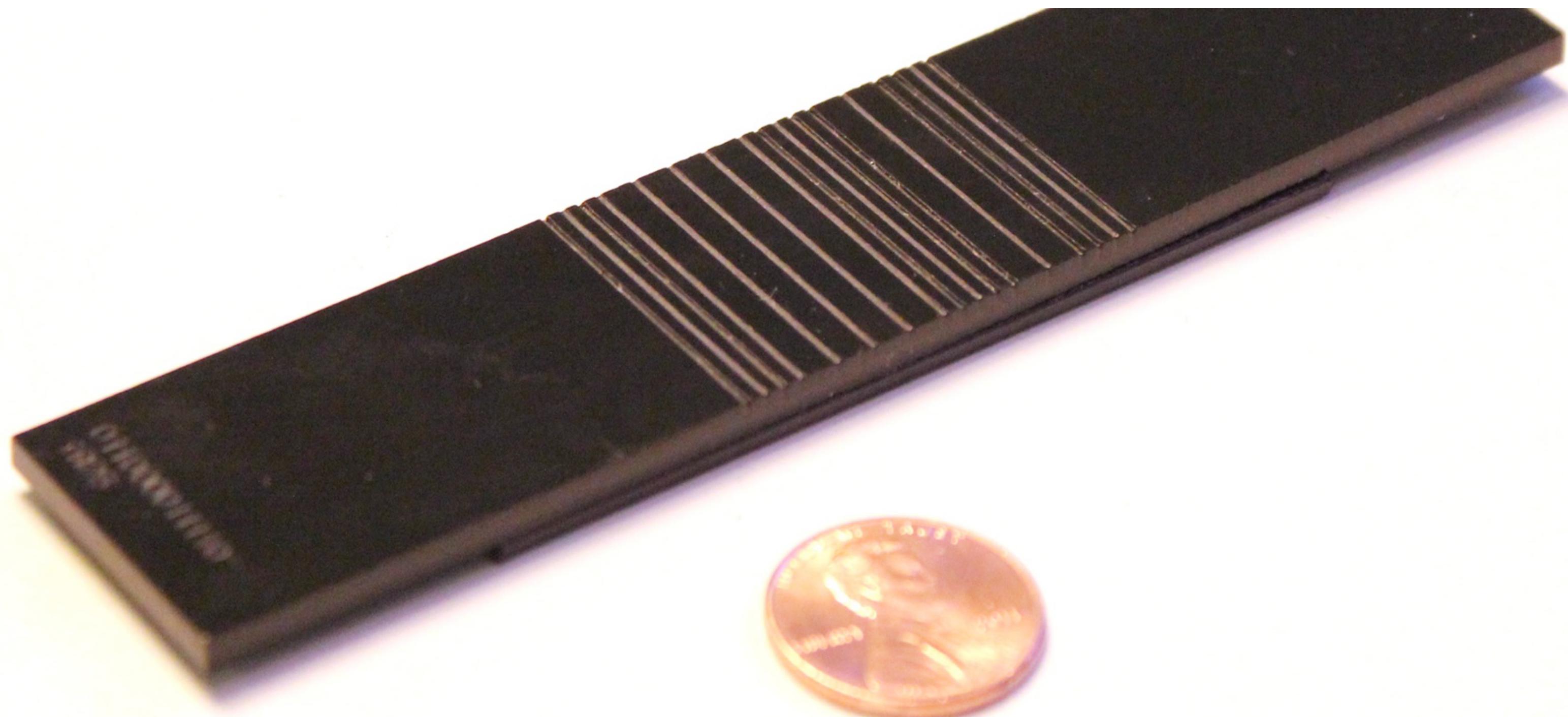
# Research



Scratch Input: Harrison et al.  
UIST '08



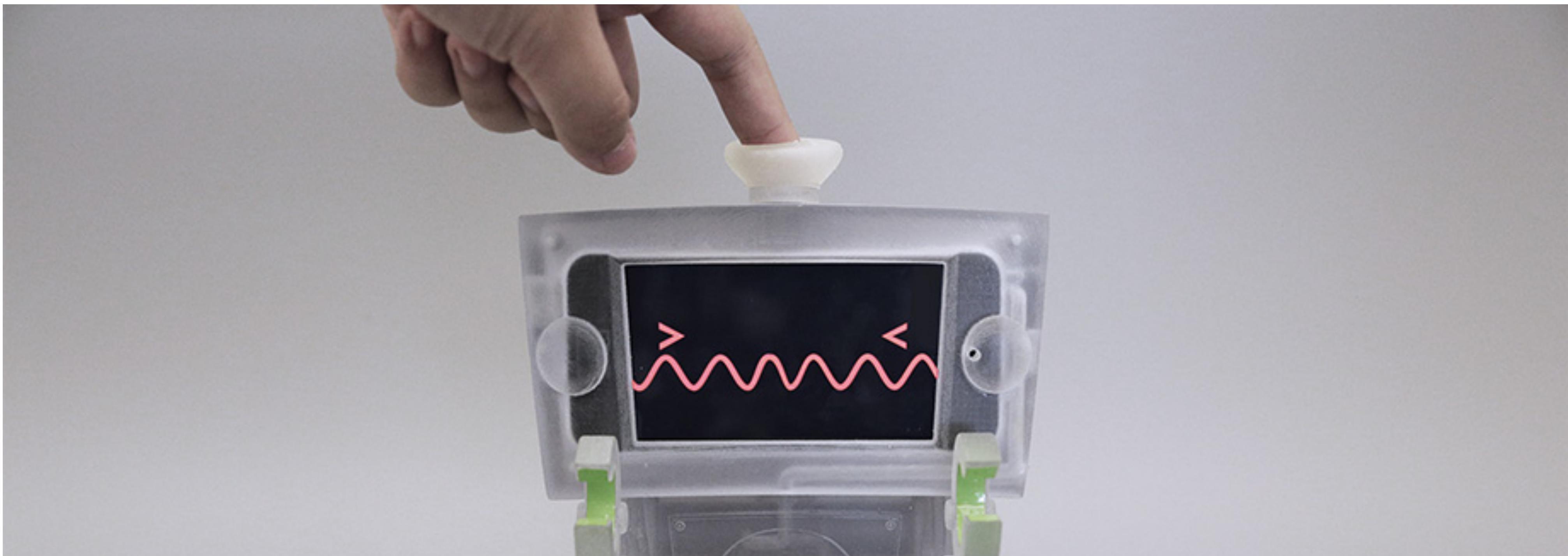
Toffee: Xiao et al.  
MobileHCI '14



Acoustic Barcodes: Xiao et al.  
UIST '12



Touch & Activate: Ono et al.  
UIST '13



Acoustruments: Laput et al.  
CHI '15

# Limitations

# Limitations

- Become data scientists:
  - Get clean data.
  - Label it.
  - Train a machine learning model.
  - Evaluate its performance

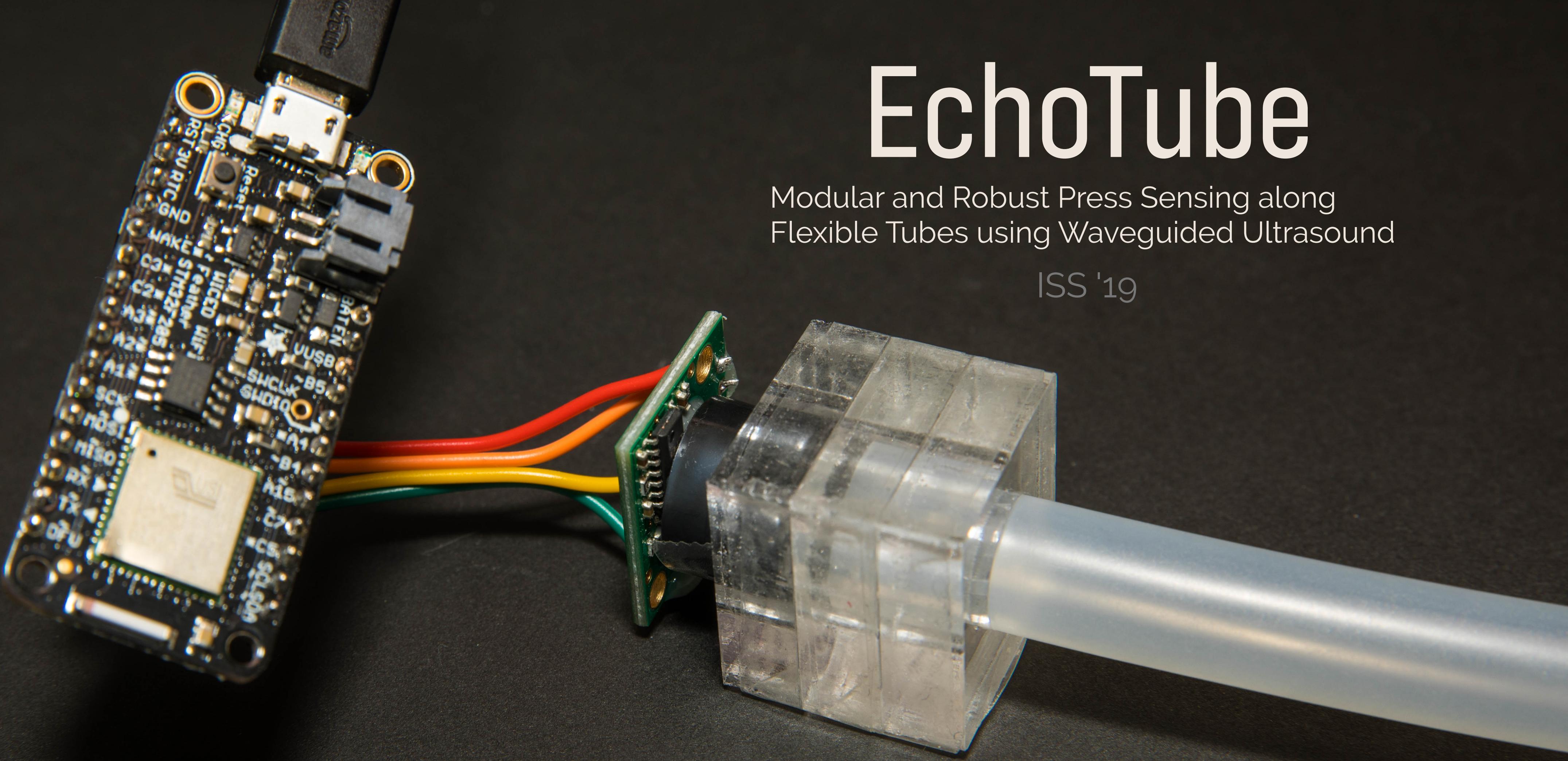
**Engineering expertise is required**

Enable domain-experts to create  
interactive devices

# EchoTube

Modular and Robust Press Sensing along  
Flexible Tubes using Waveguided Ultrasound

ISS '19



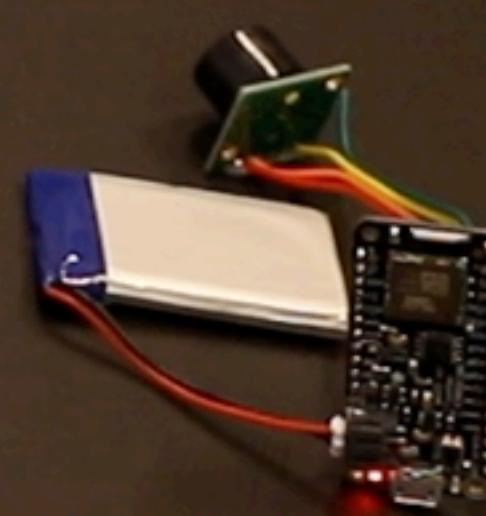
**Carlos Tejada**  
Sebastian Boring

Jess McIntosh  
Daniel Ashbrook

Klæs Bergen  
Azier Marzo





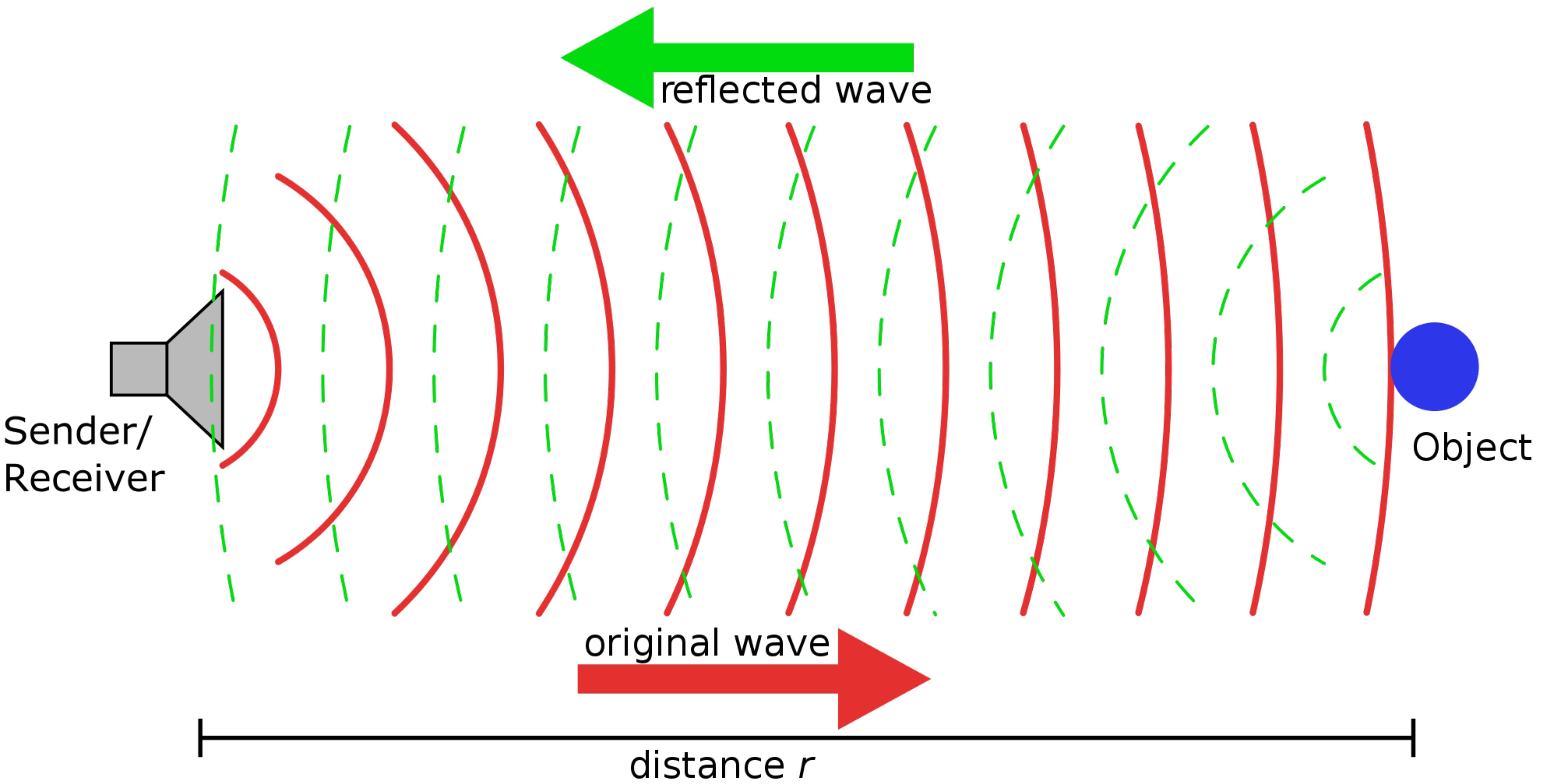


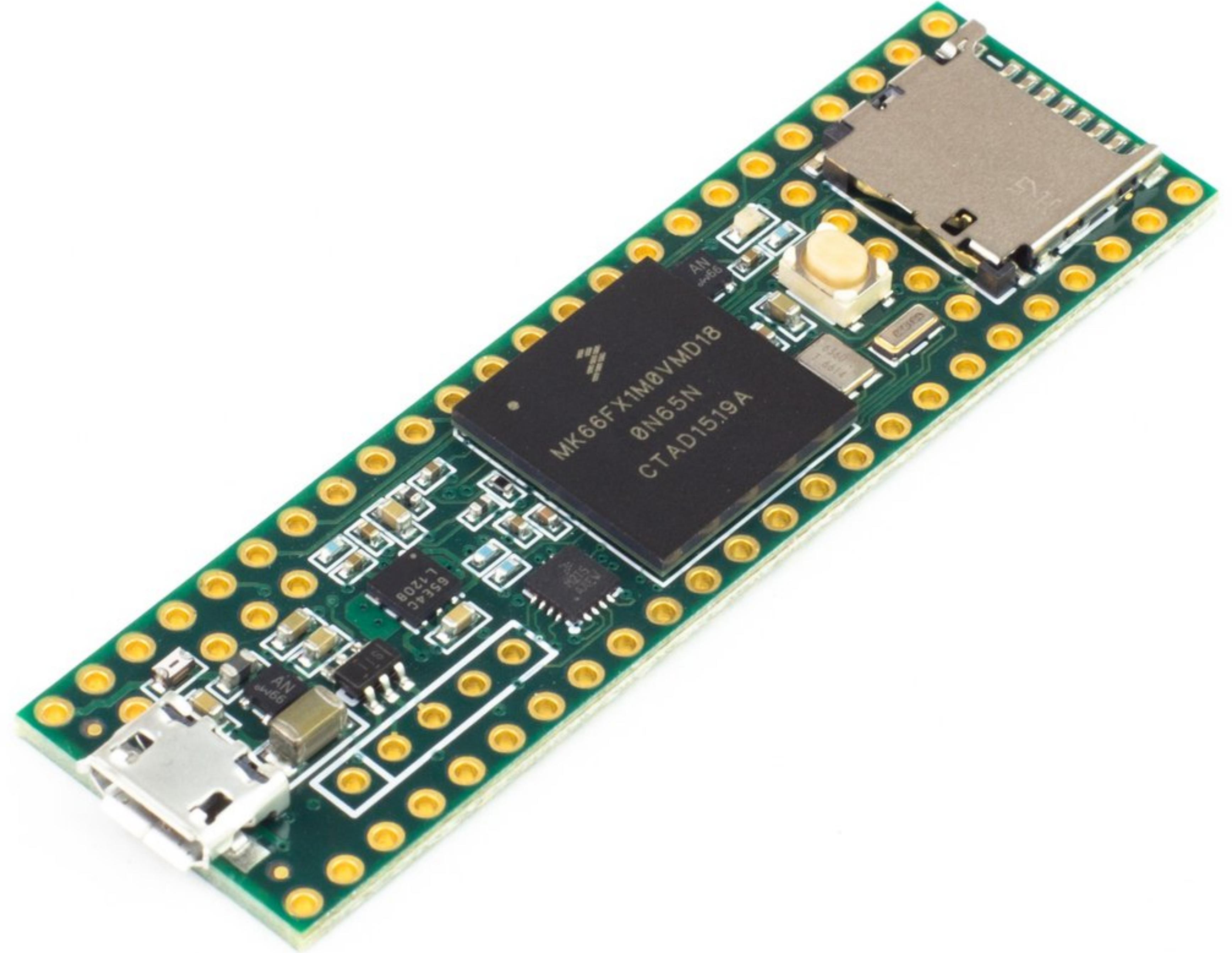


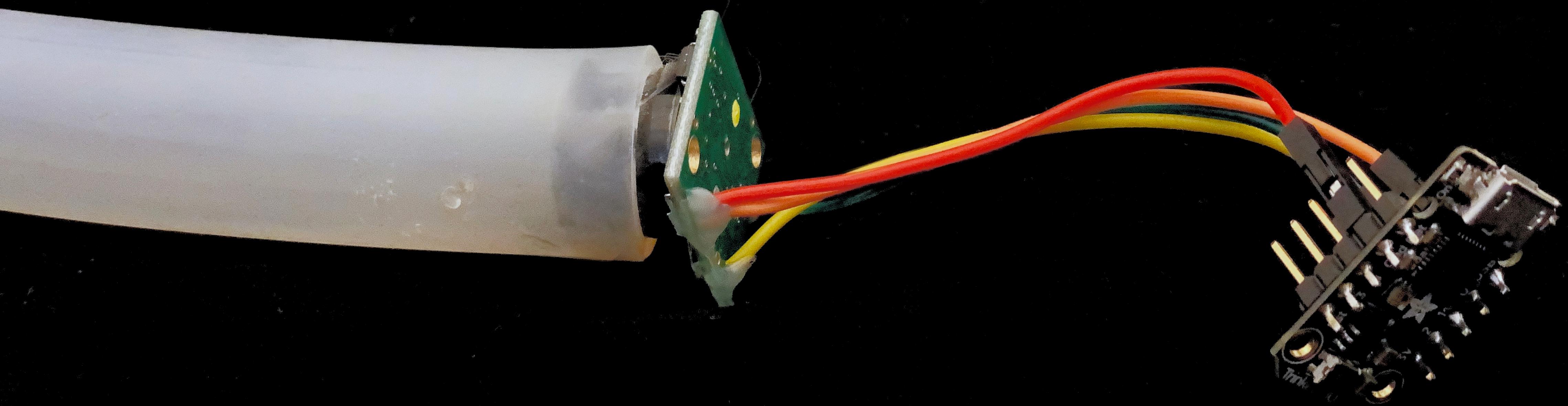


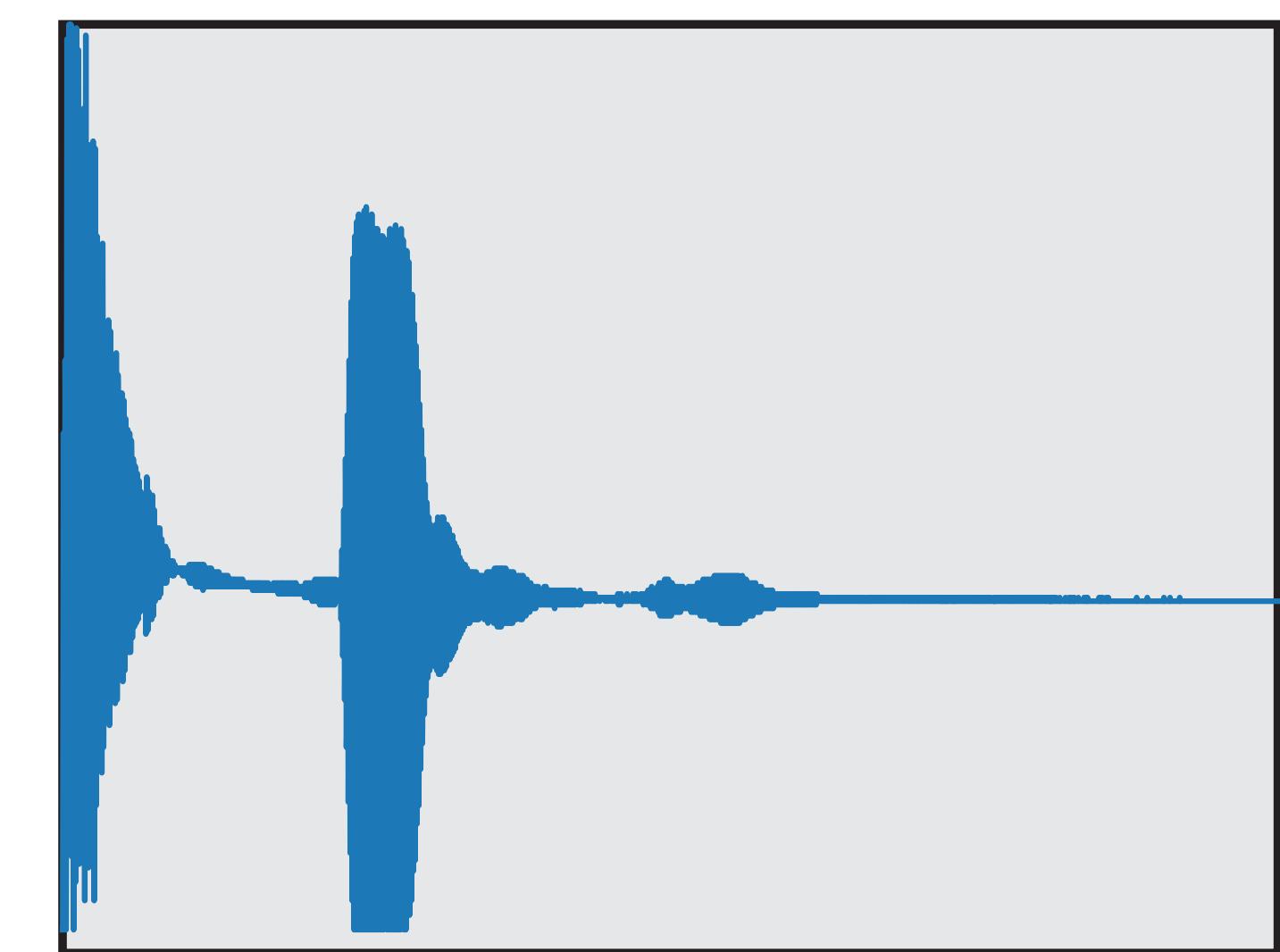
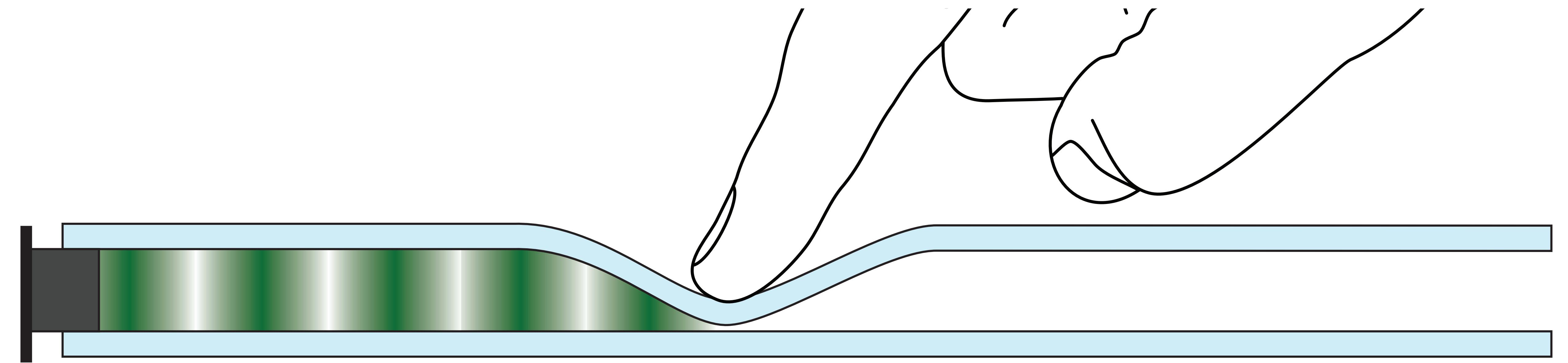




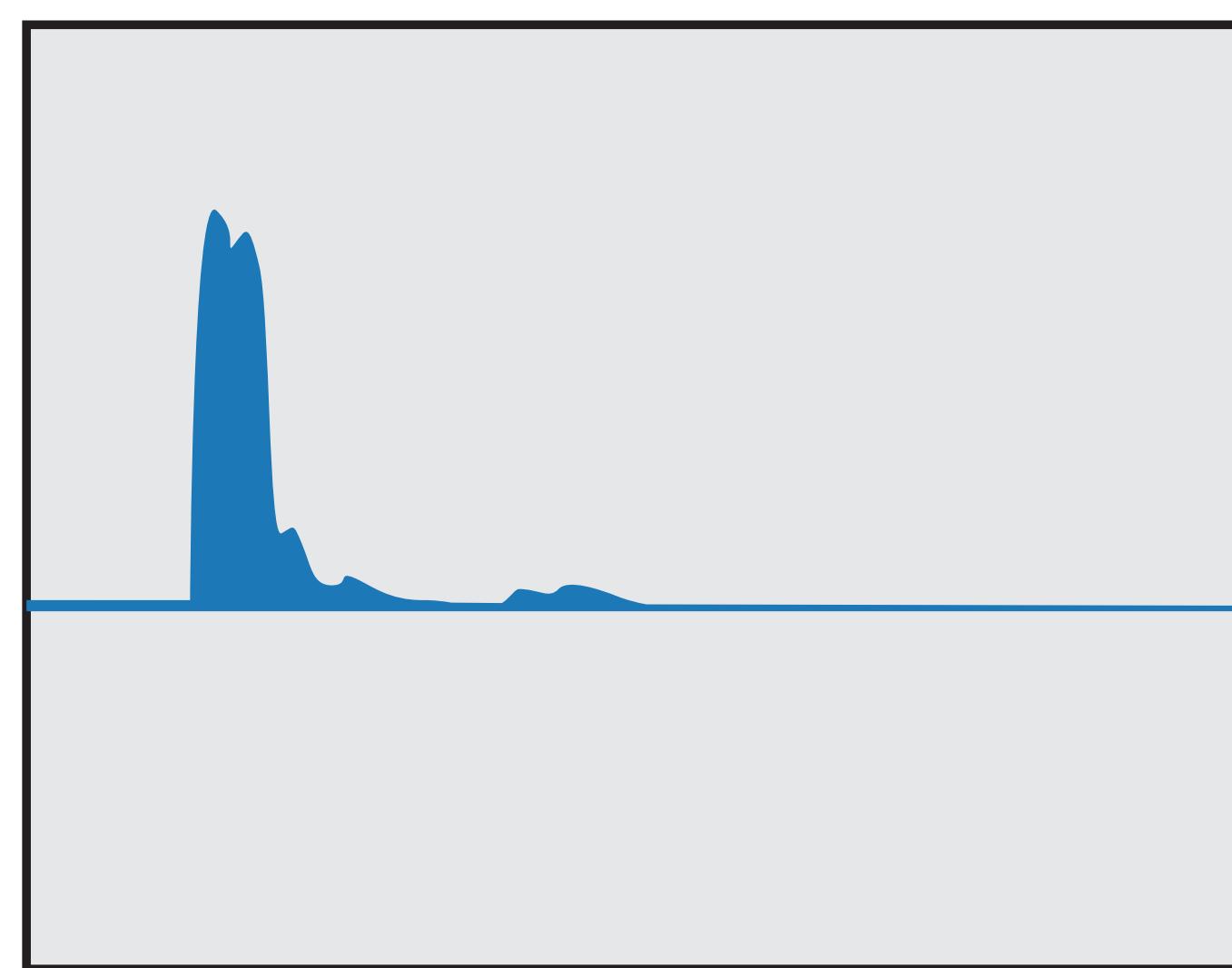




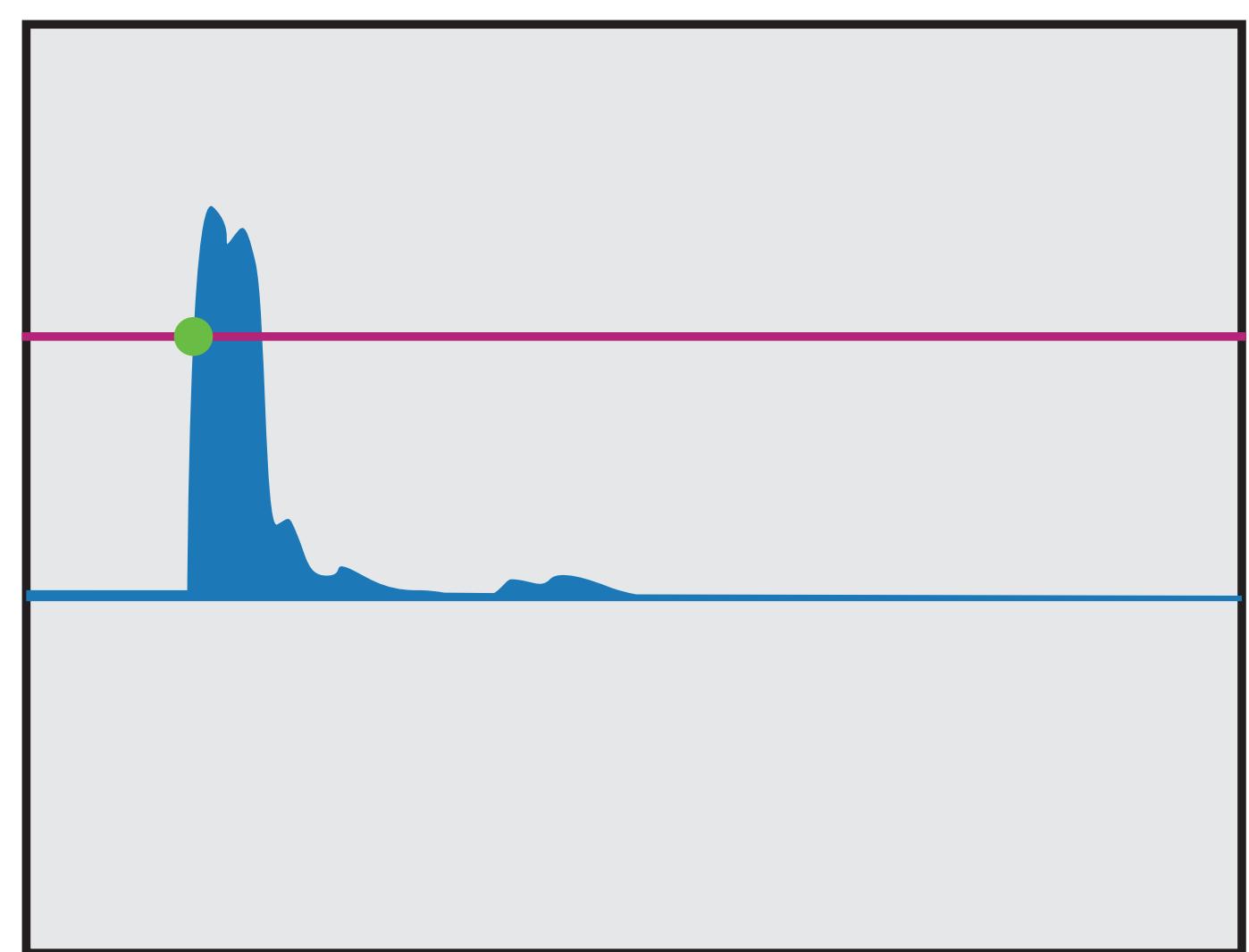




Raw signal



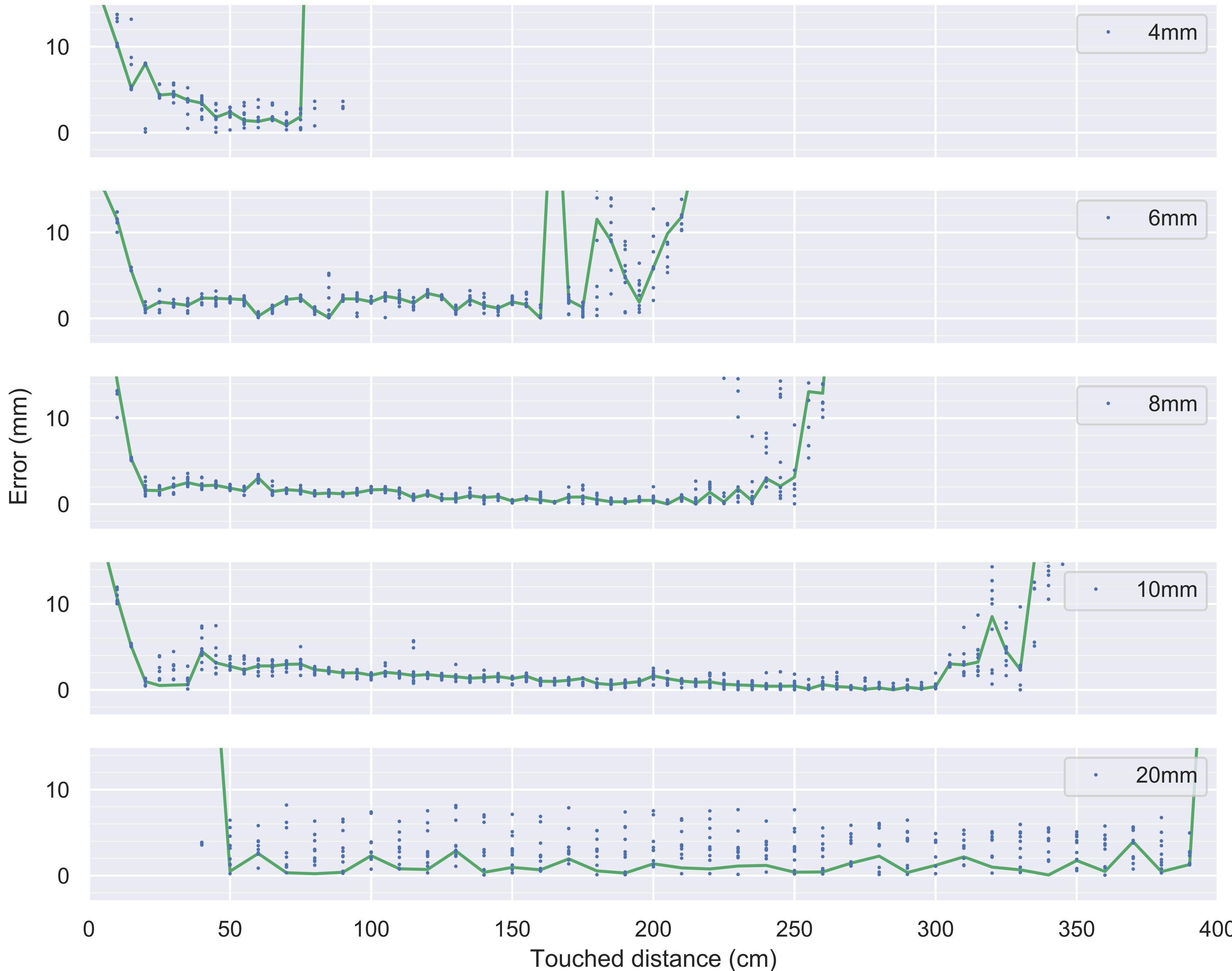
Processed signal



Threshold finding

# Performance Testing





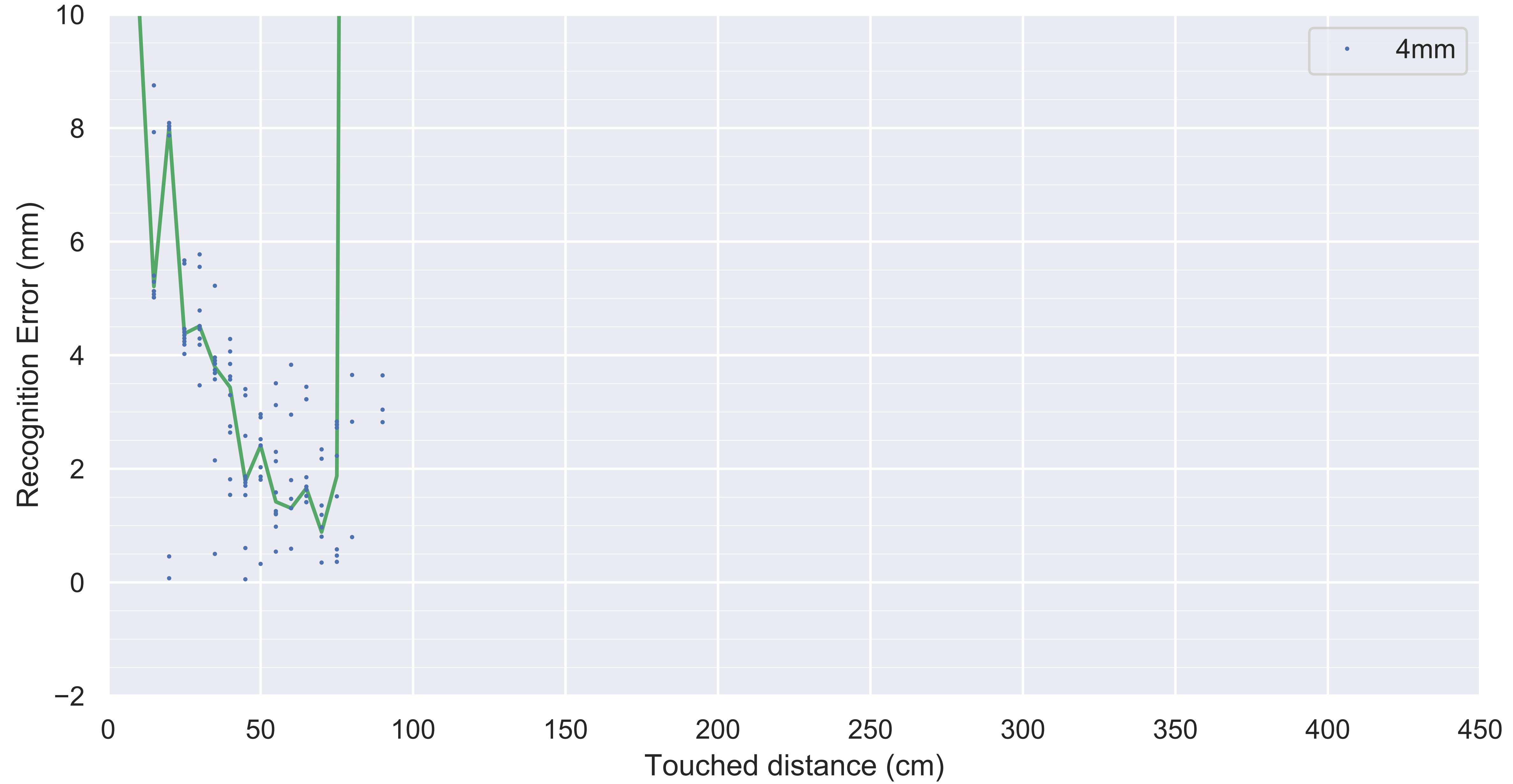
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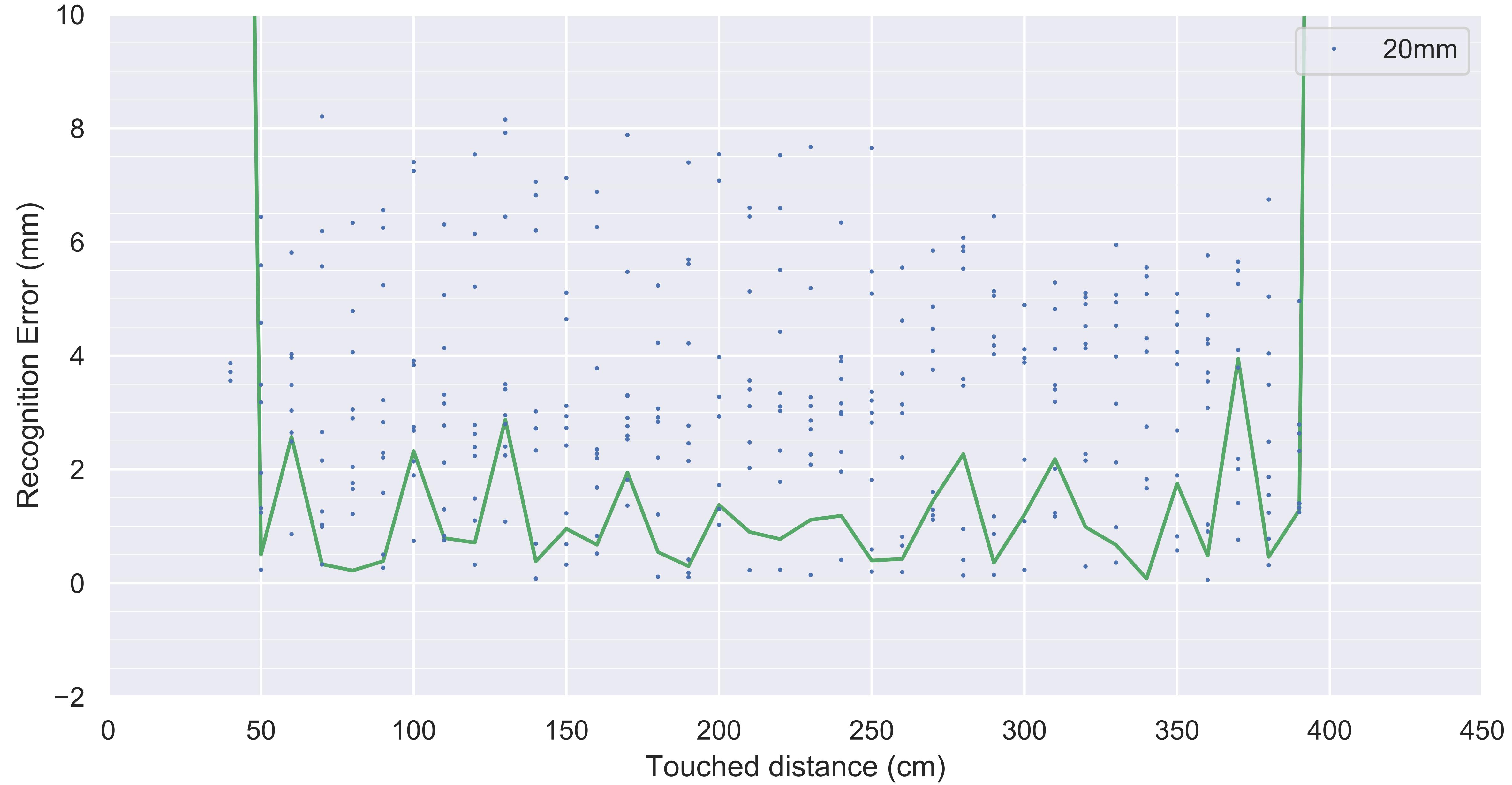
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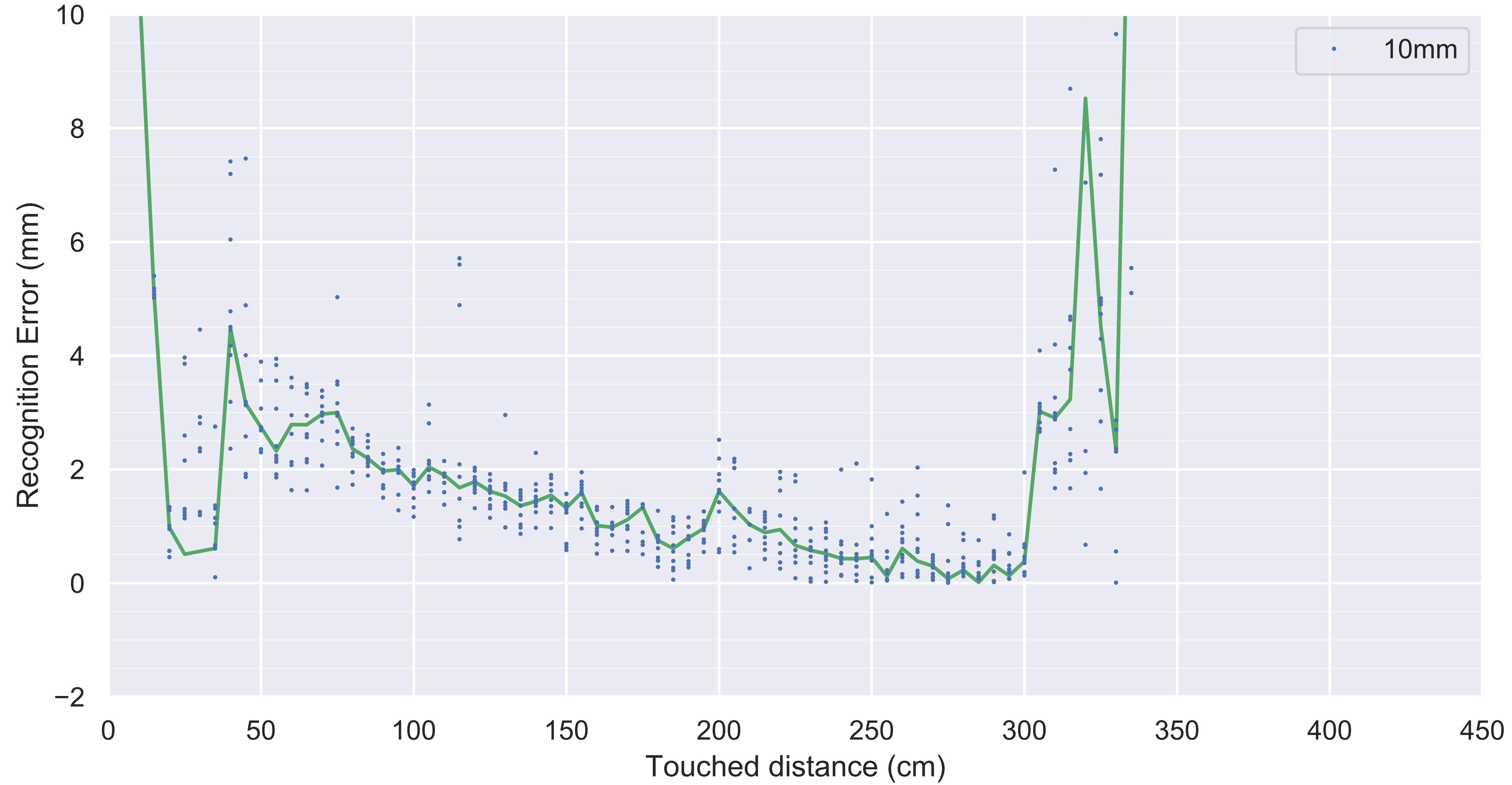
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10

20



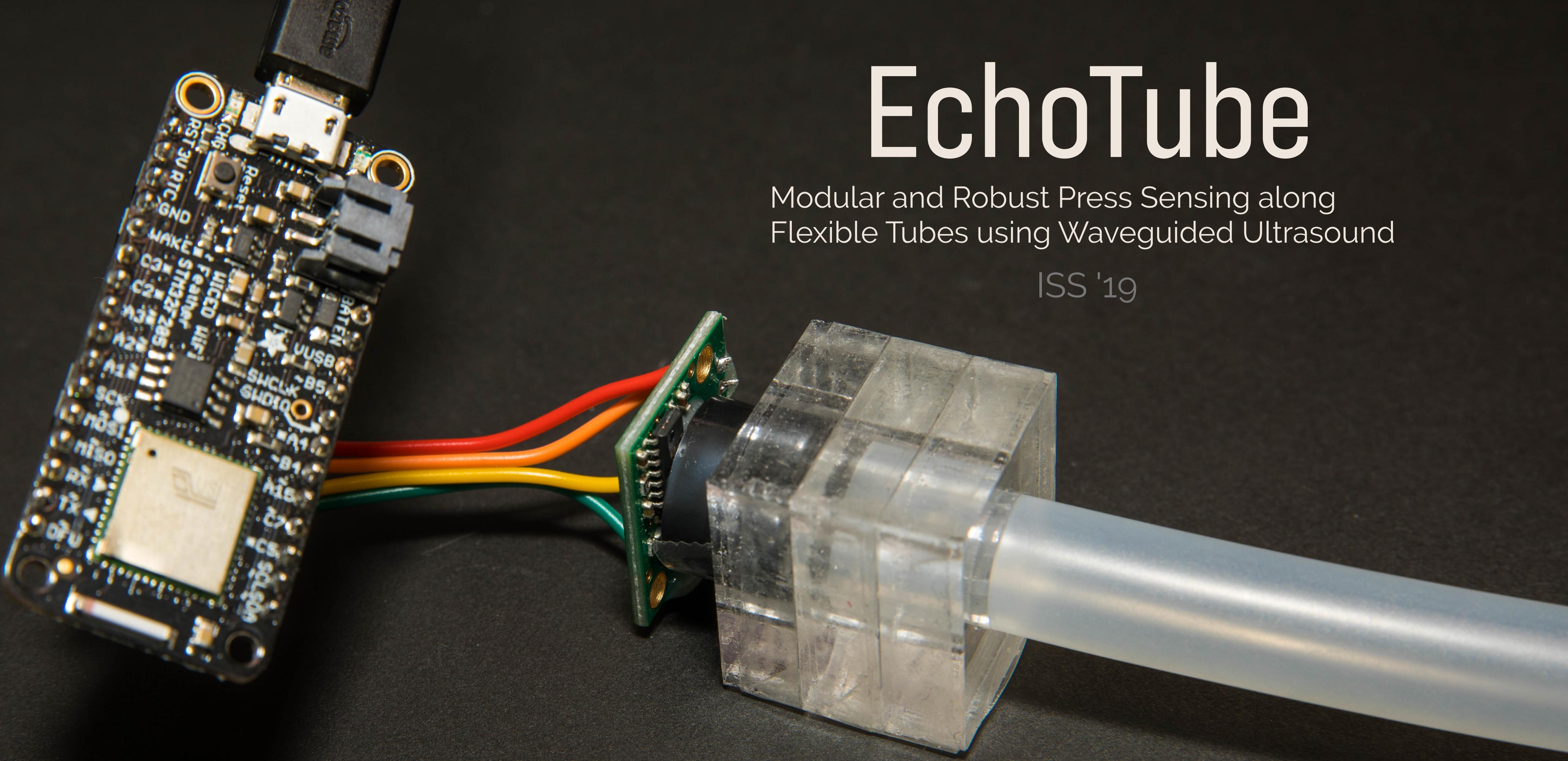




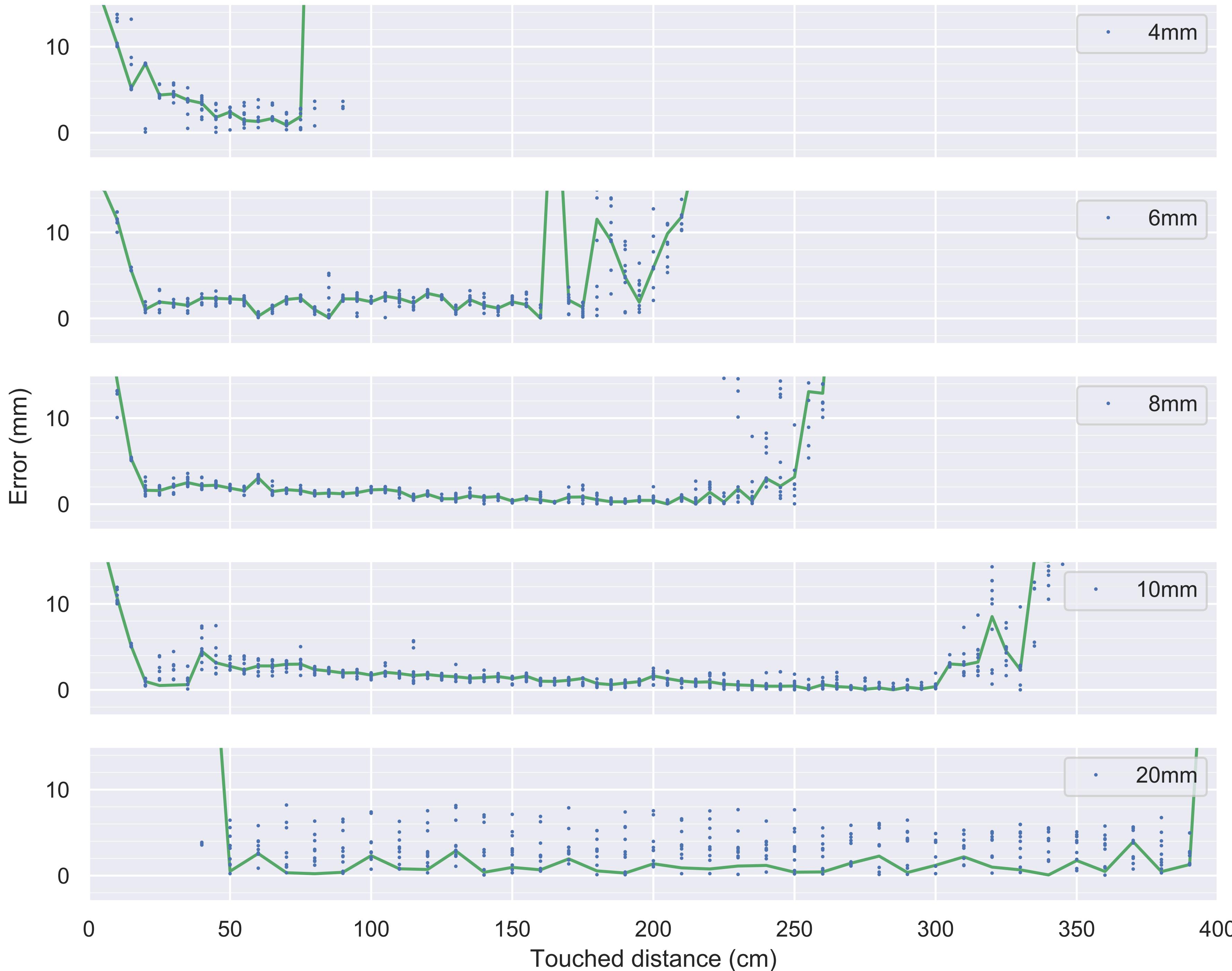
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Modular and Robust Press Sensing along  
Flexible Tubes using Waveguided Ultrasound

ISS '19



# Limitations



4

6

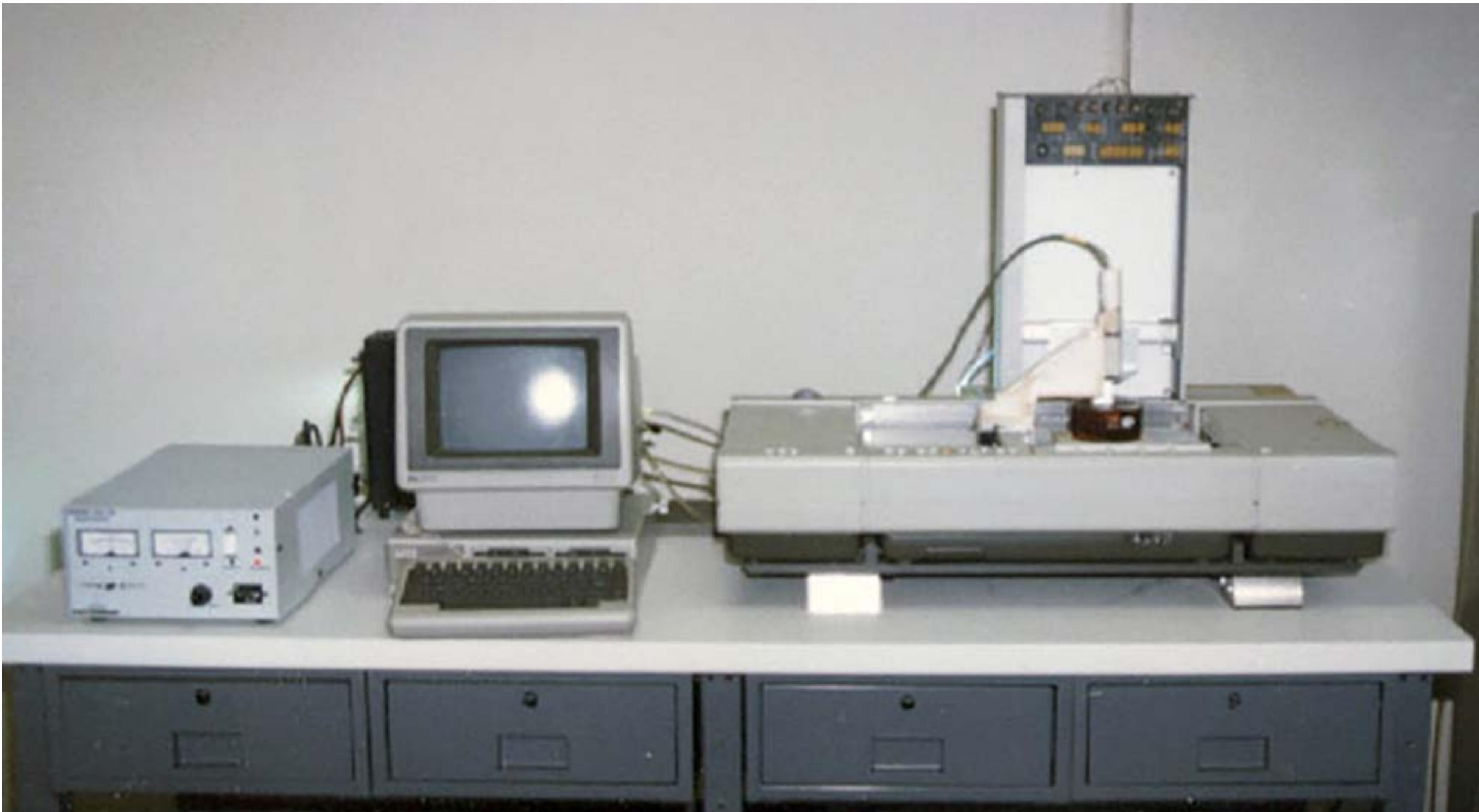
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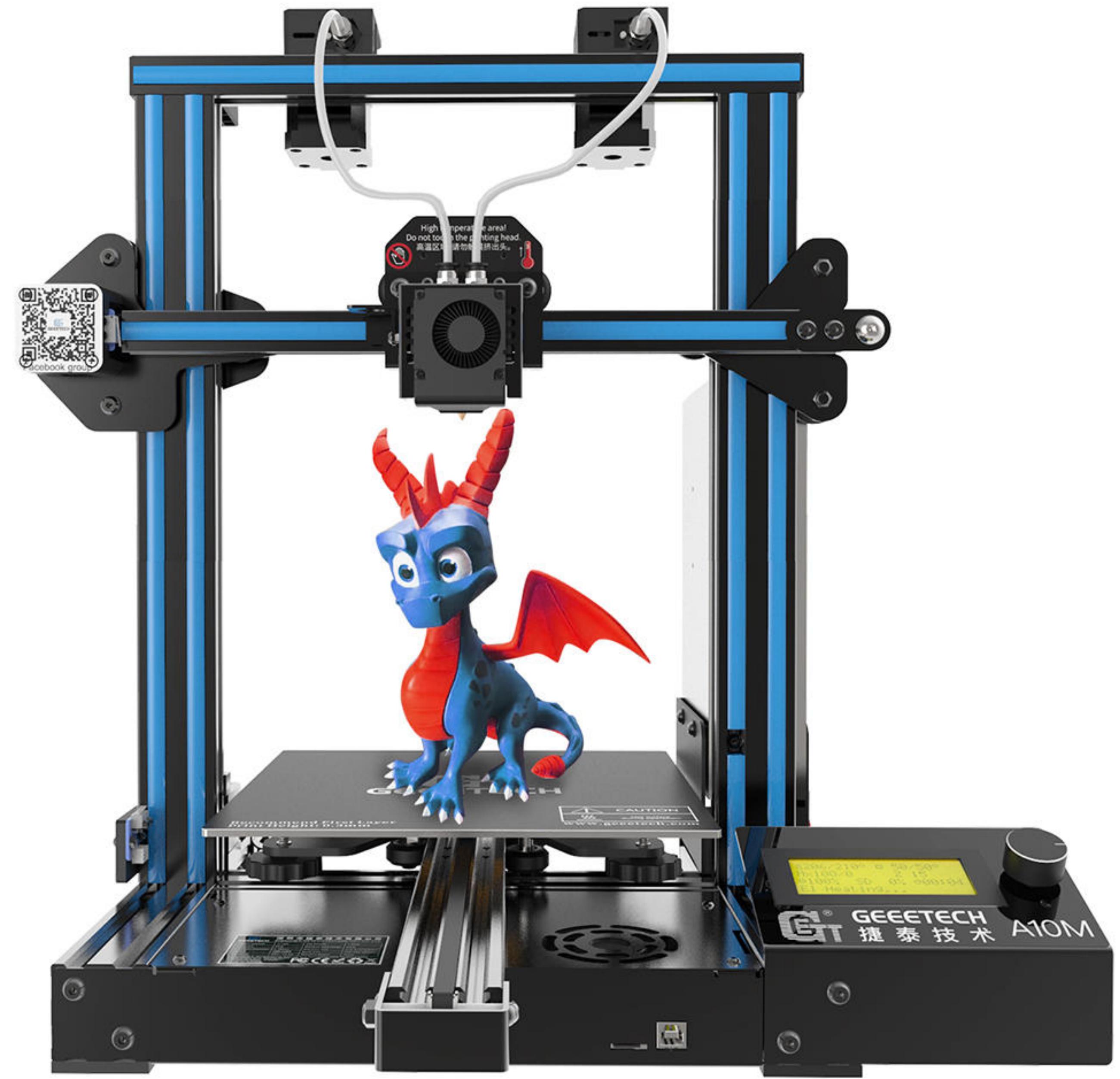
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**Scale is a problem**

# Fabricate interactive objects



The first 3D printer: The SLA-1 from 3D Systems



**From passive to interactive**

# Assembly

# Calibration

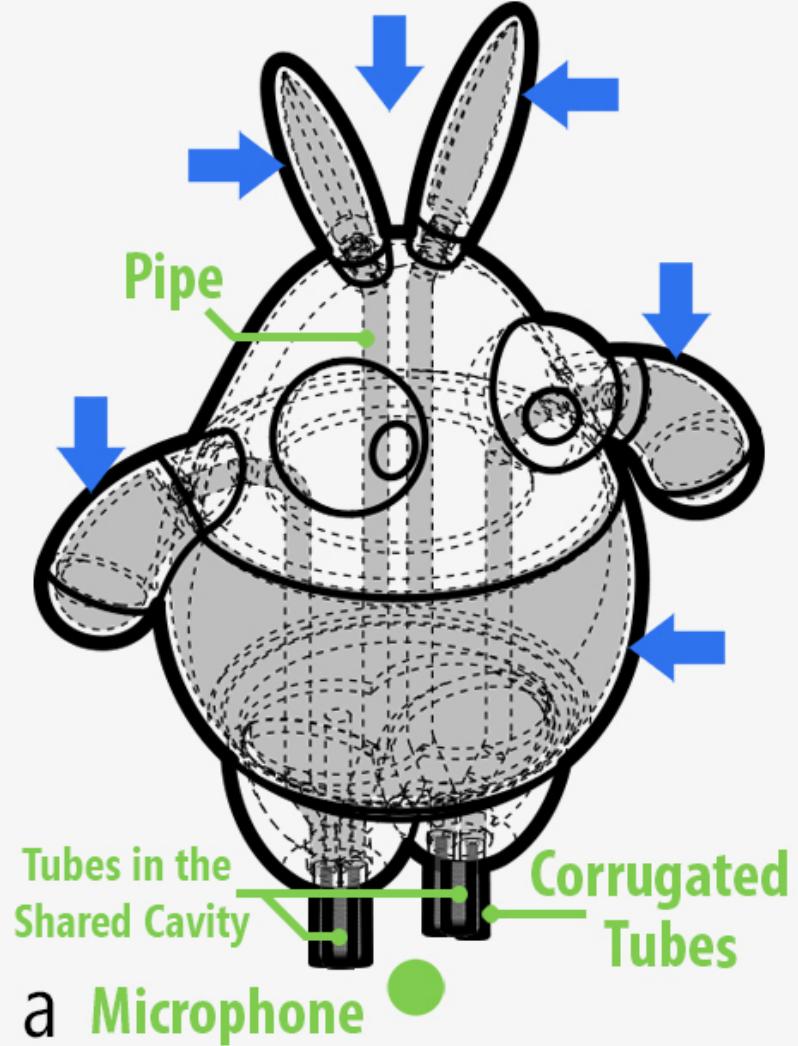
# Use limitations

# Assembly

## Calibration

## Use limitations

# Assembly



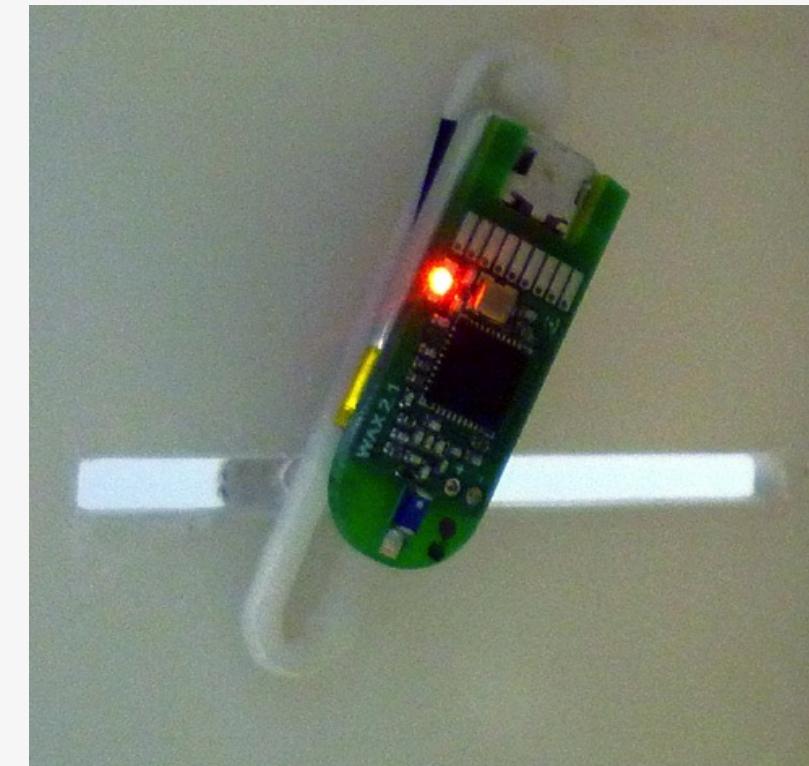
Le et al.  
TEI '17

# Calibration



Savage et al.  
UIST '13

# Use limitations



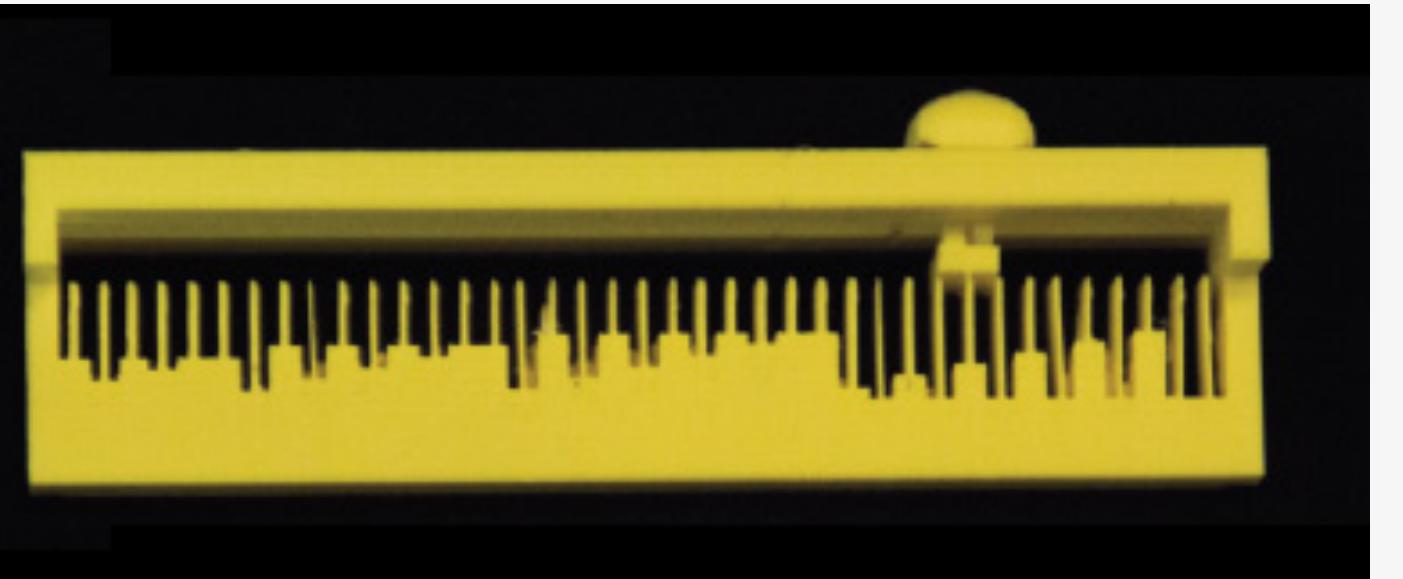
Hook et al.  
CHI EA '14

# Assembly

# Calibration

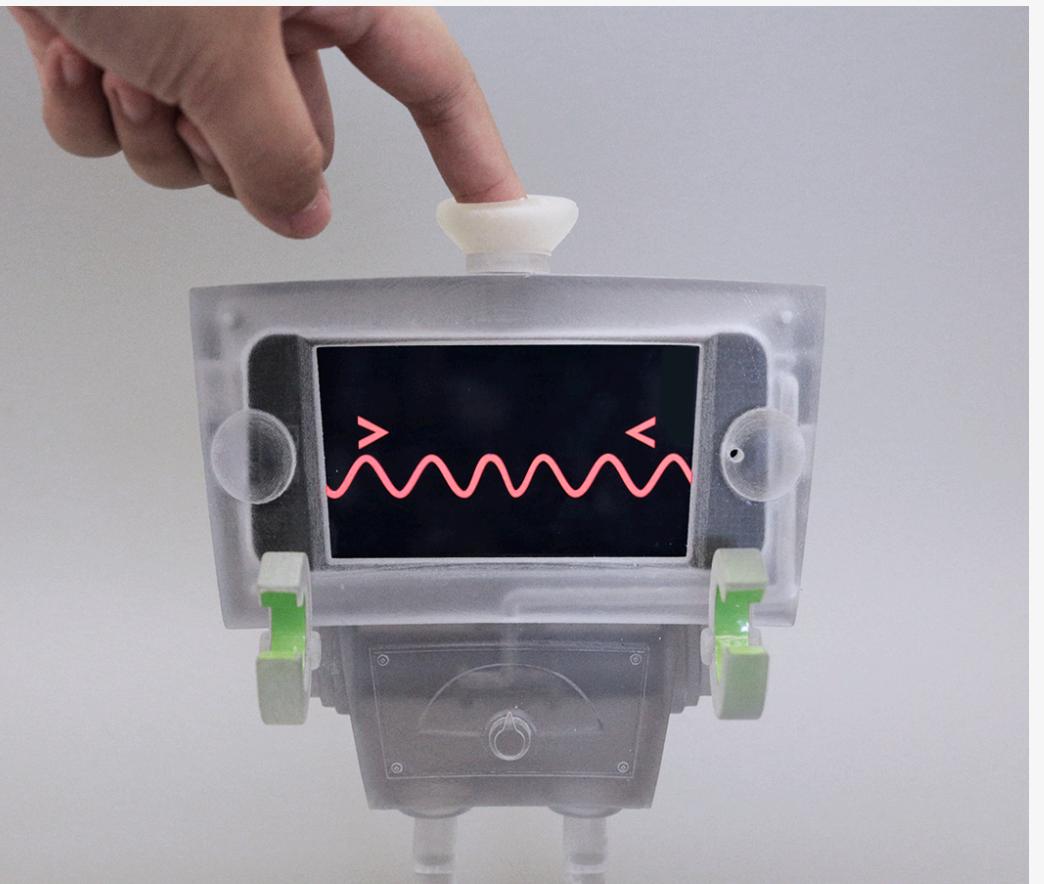
# Use limitations

# Assembly



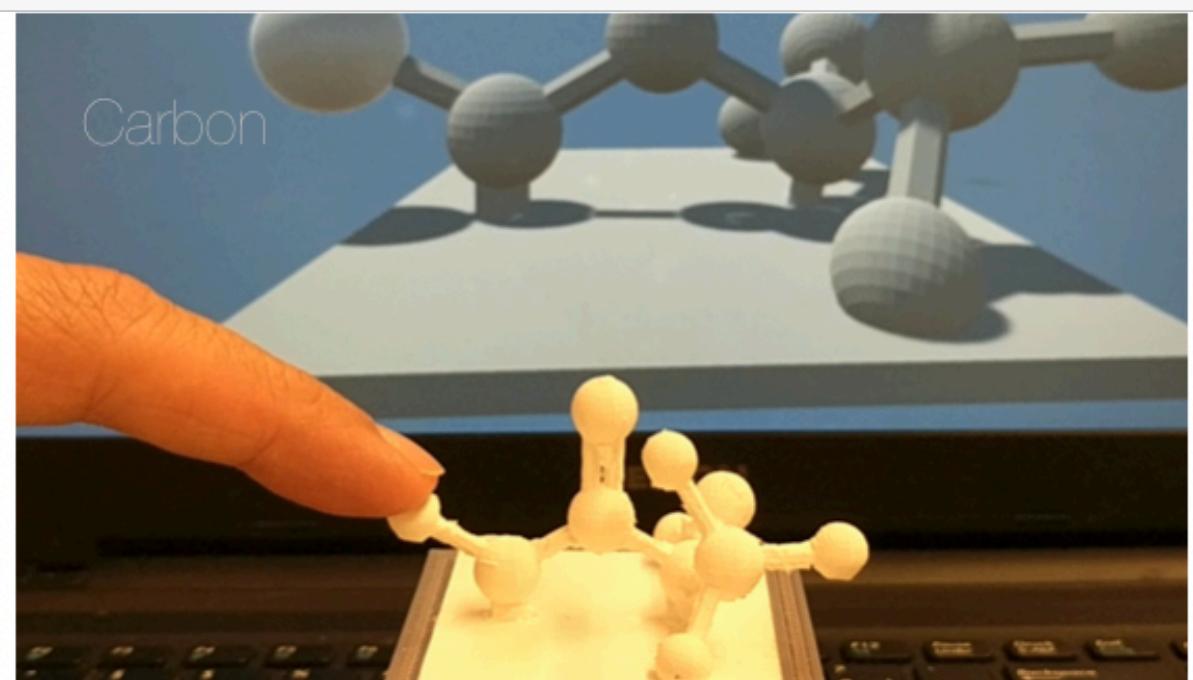
Savage et al.  
CHI '15

# Calibration



Laput et al.  
CHI '16

# Use limitations



Schmitz et al.  
CHI '19

# Assembly

# Calibration

# Use limitations

# Assembly



Hudin et al.  
CHI EA '15

# Calibration

# Use limitations



Shi et al.  
CHI '16

How to fabricate interactive objects in a  
designer-friendly way?



# Blowhole

Blowing-Activated Tags for Interactive 3D-Printed Models

Carlos Tejada

Osamu Fujimoto

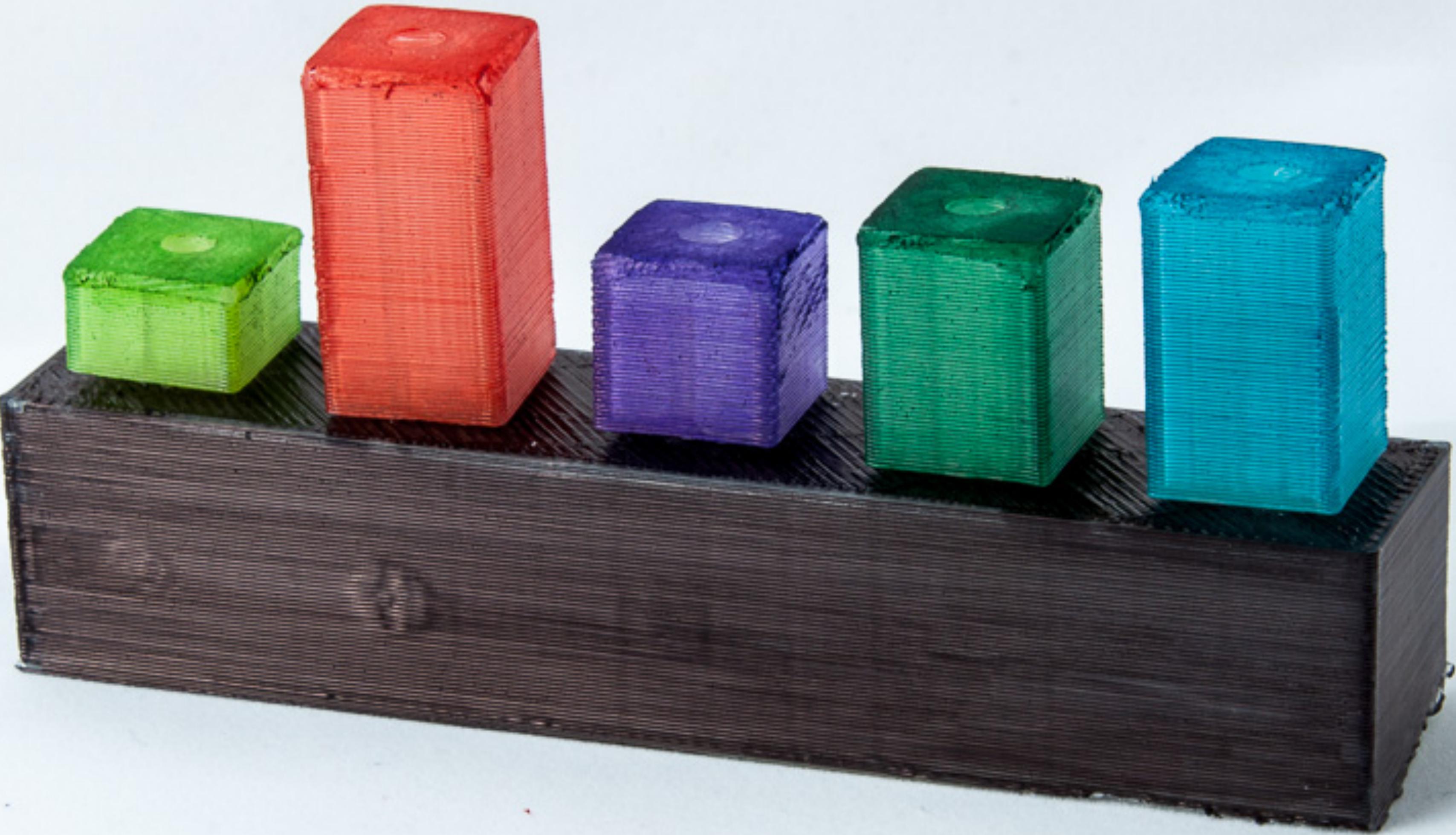
Zhiyuan Li

Daniel Ashbrook



GI '18





# Introduction

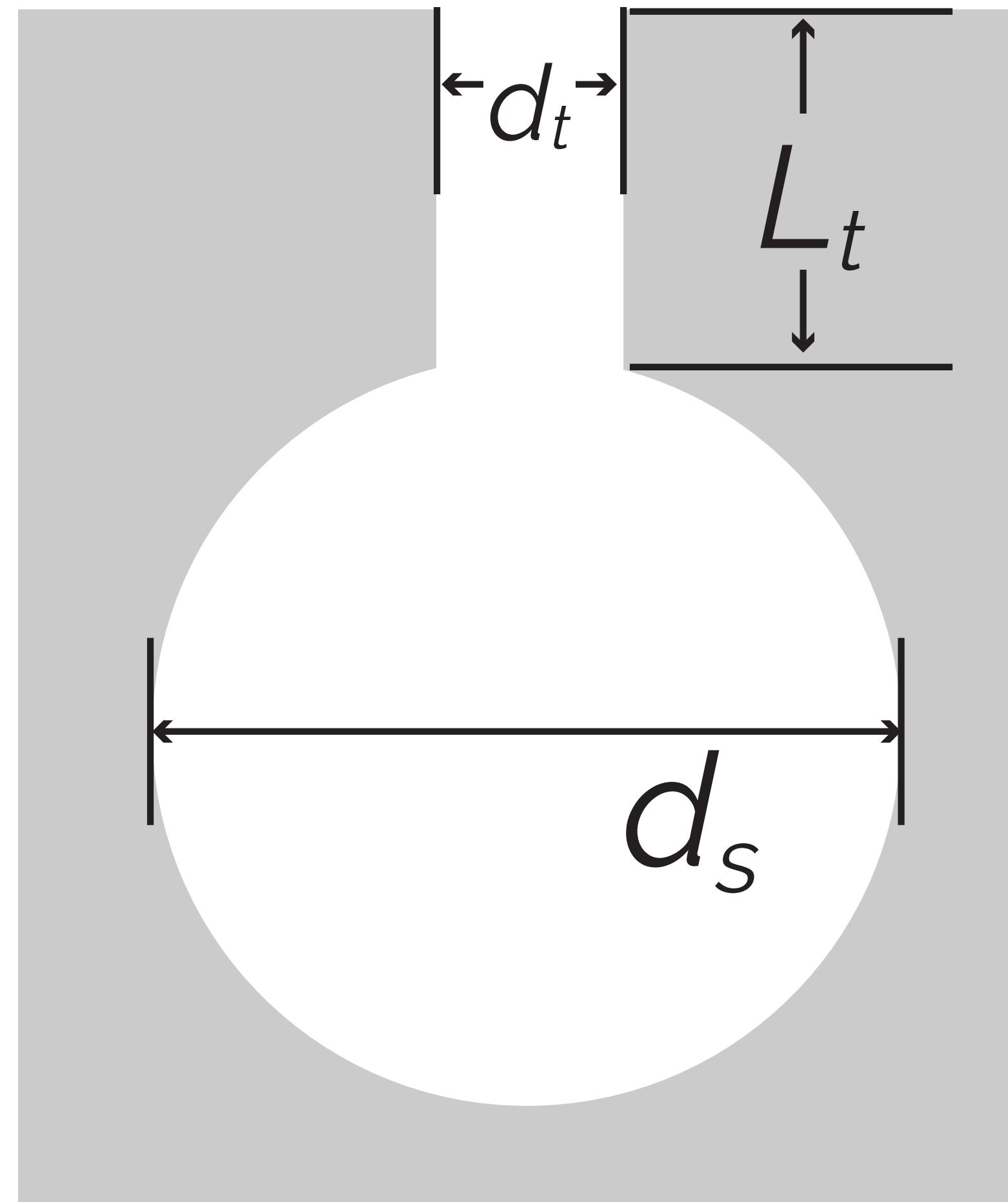
# Blowhole



# Blowhole Characterization

- Acoustic resonance.
- Modifying  $d_t$ ,  $l_t$  and  $d_s$  varies the frequency emitted from the cavity.
- Modeled by Helmholtz's resonance equation.

$$f = \frac{cd_t}{\pi} \sqrt{\frac{3}{8(L_t + .75d_t)d_s^3}}$$

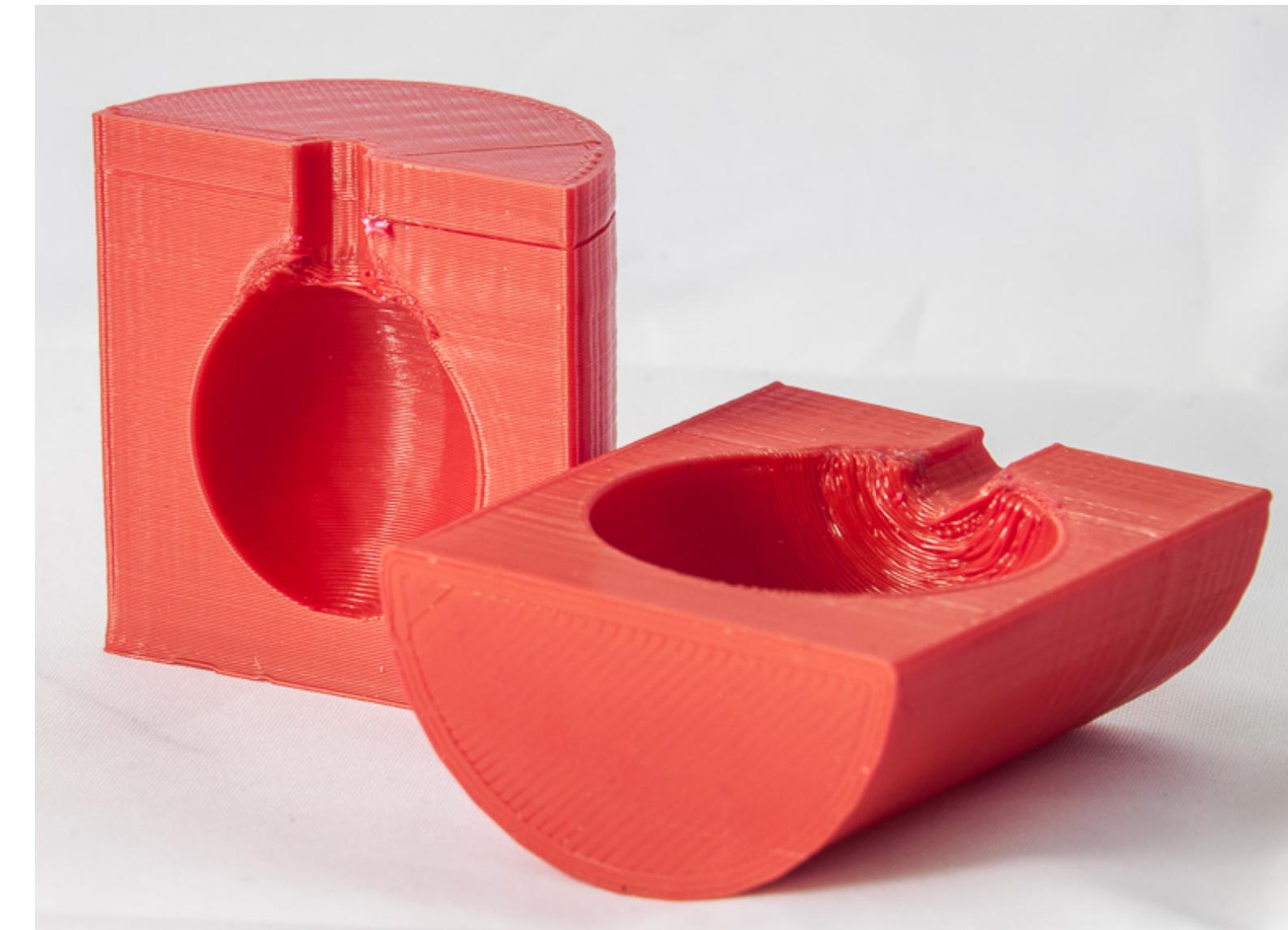


# Blowhole Characterization

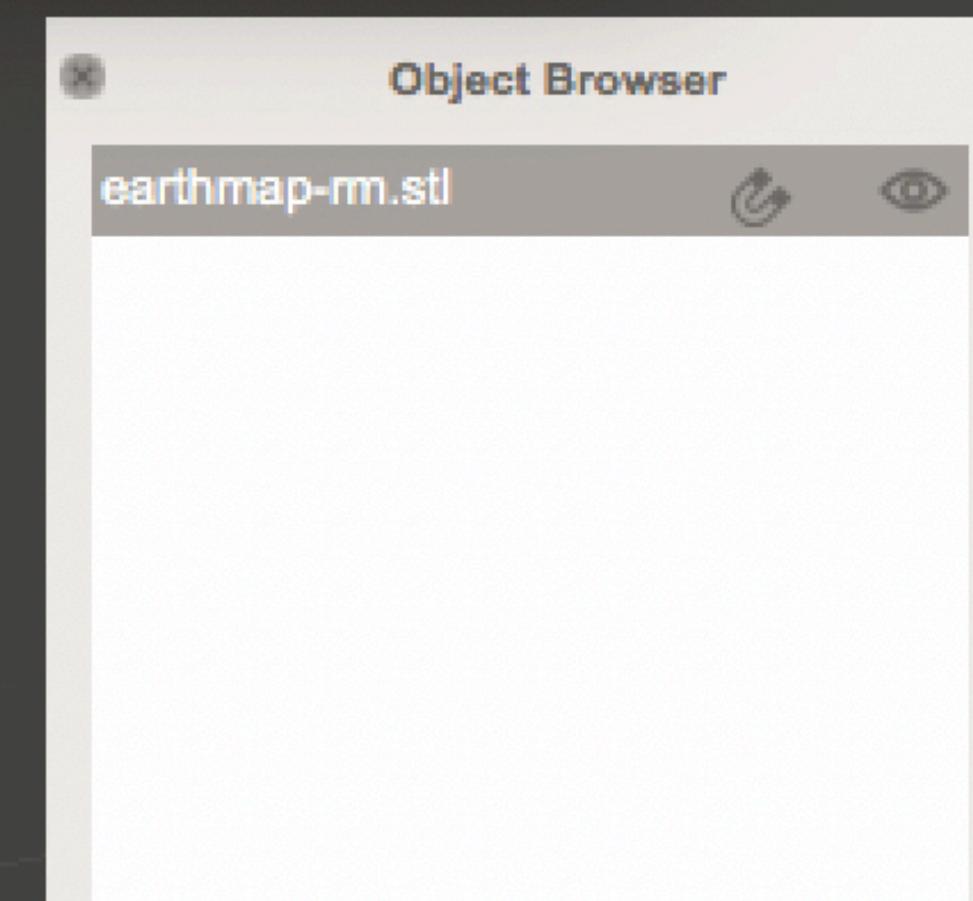
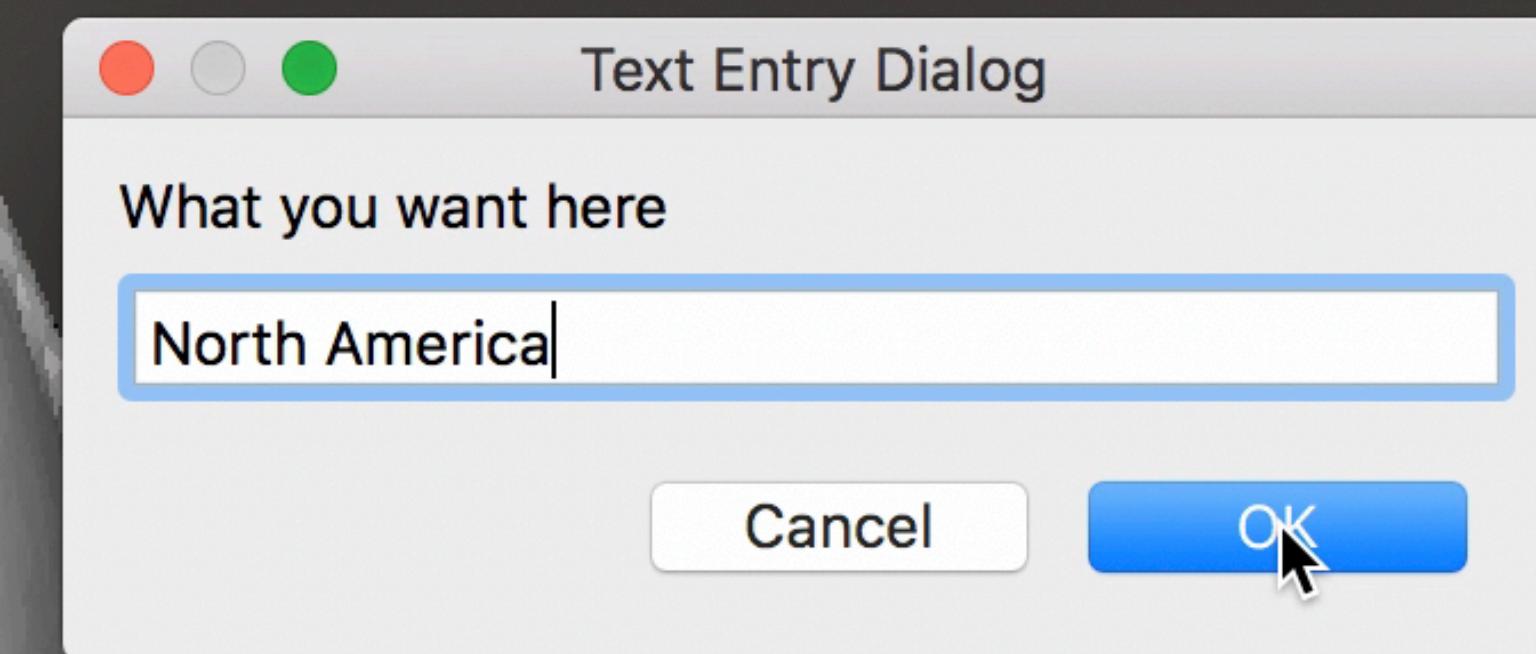
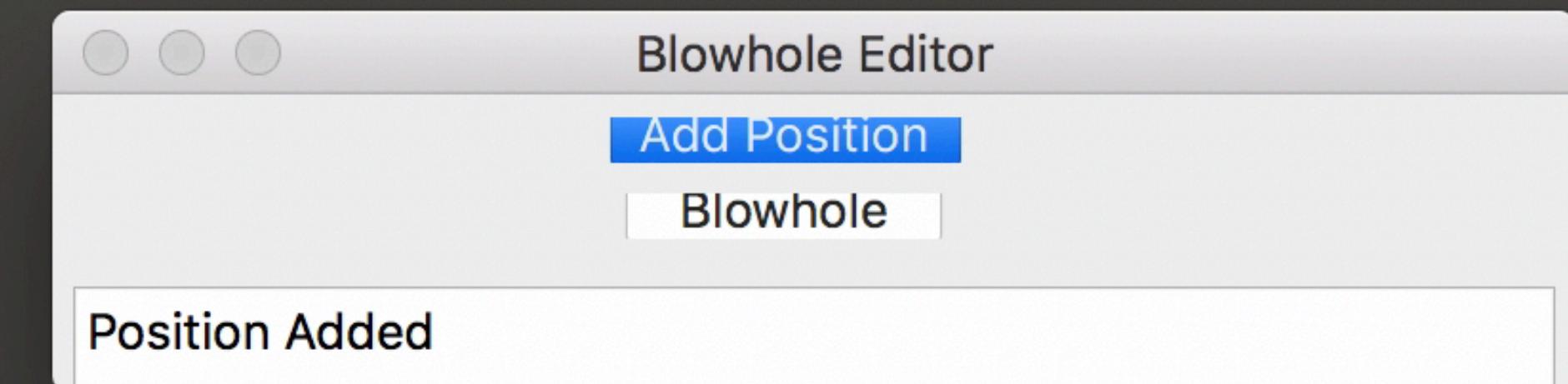
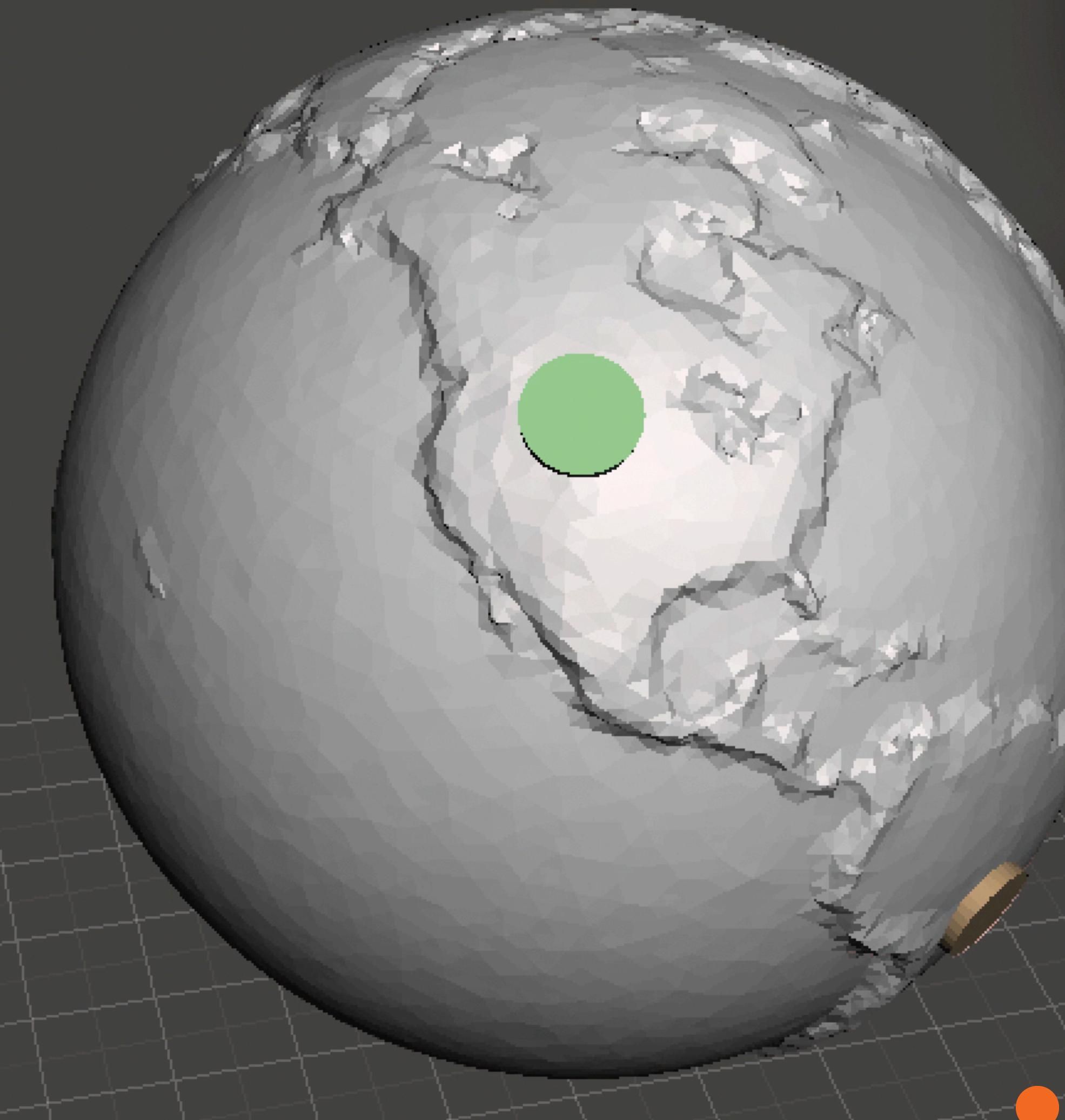


# Blowhole Characterization

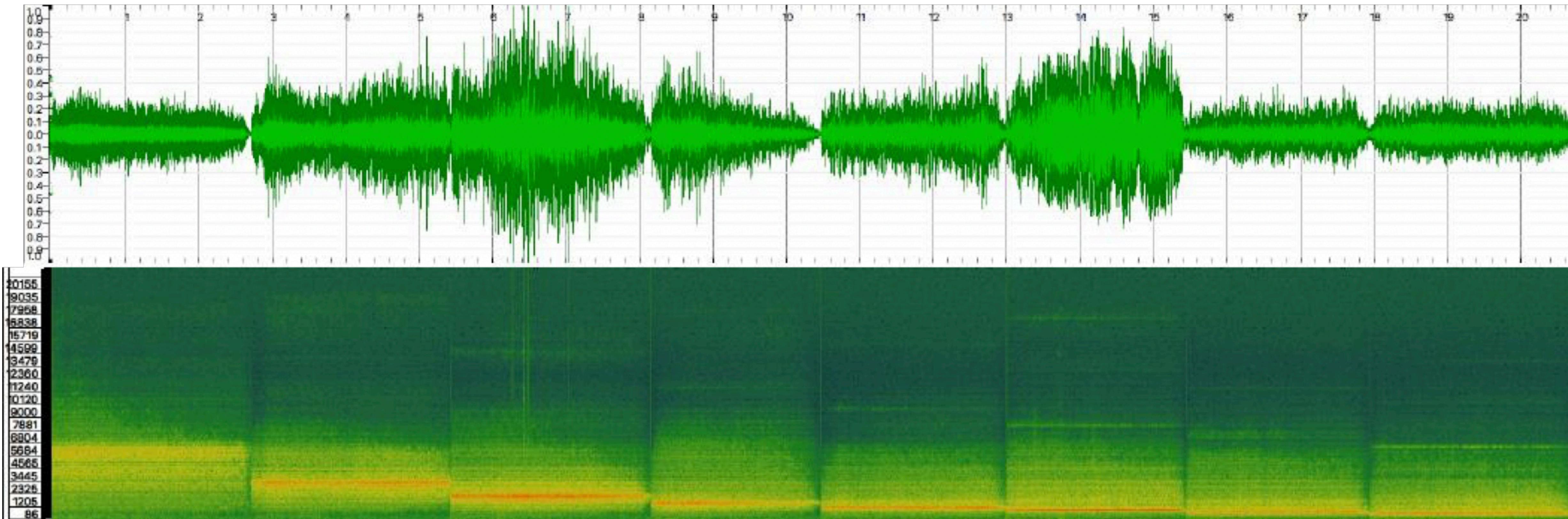
- 10 participants
  - Fundamental frequencies.



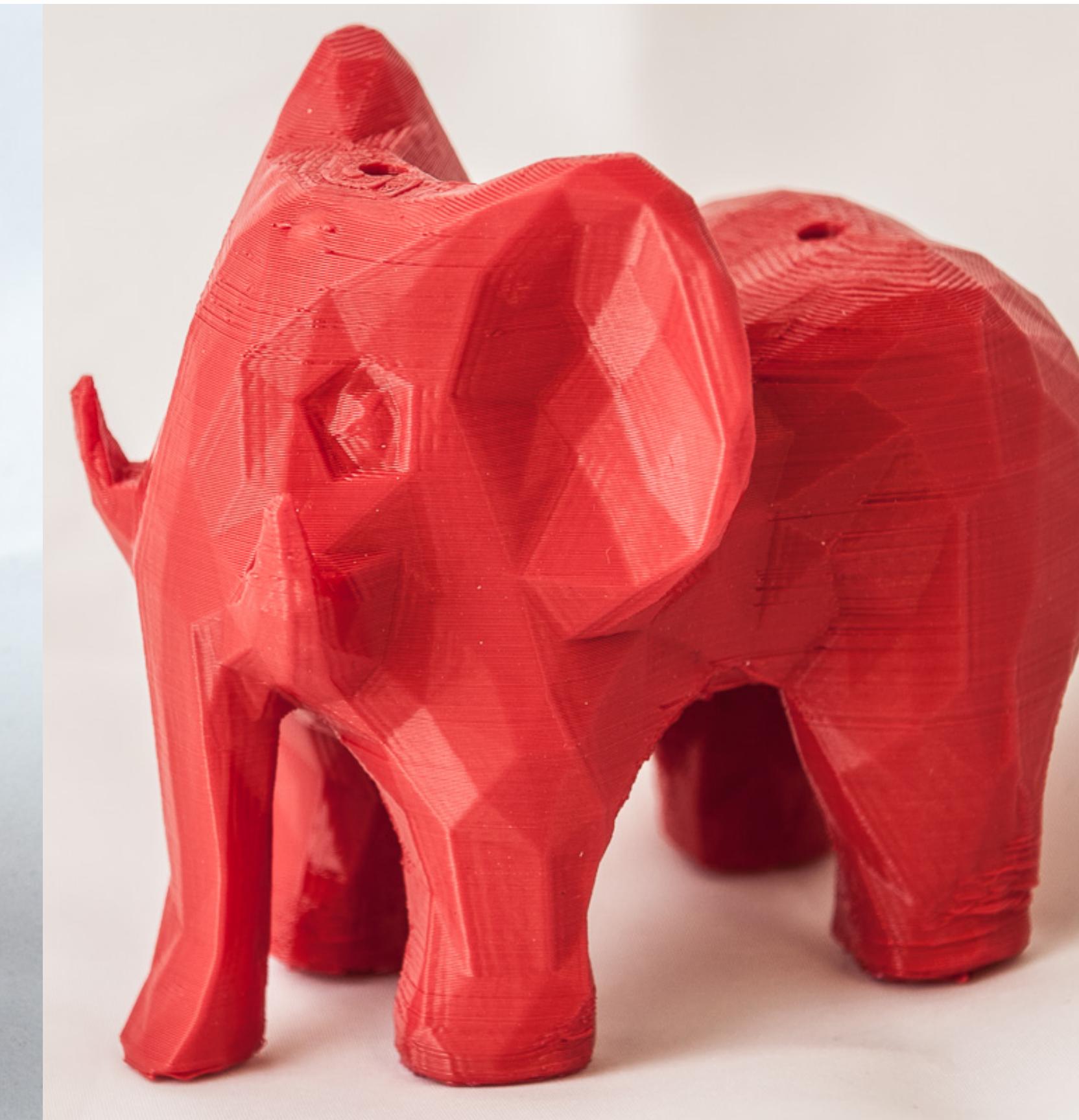
# System Implementation



# System Implementation



# System Implementation

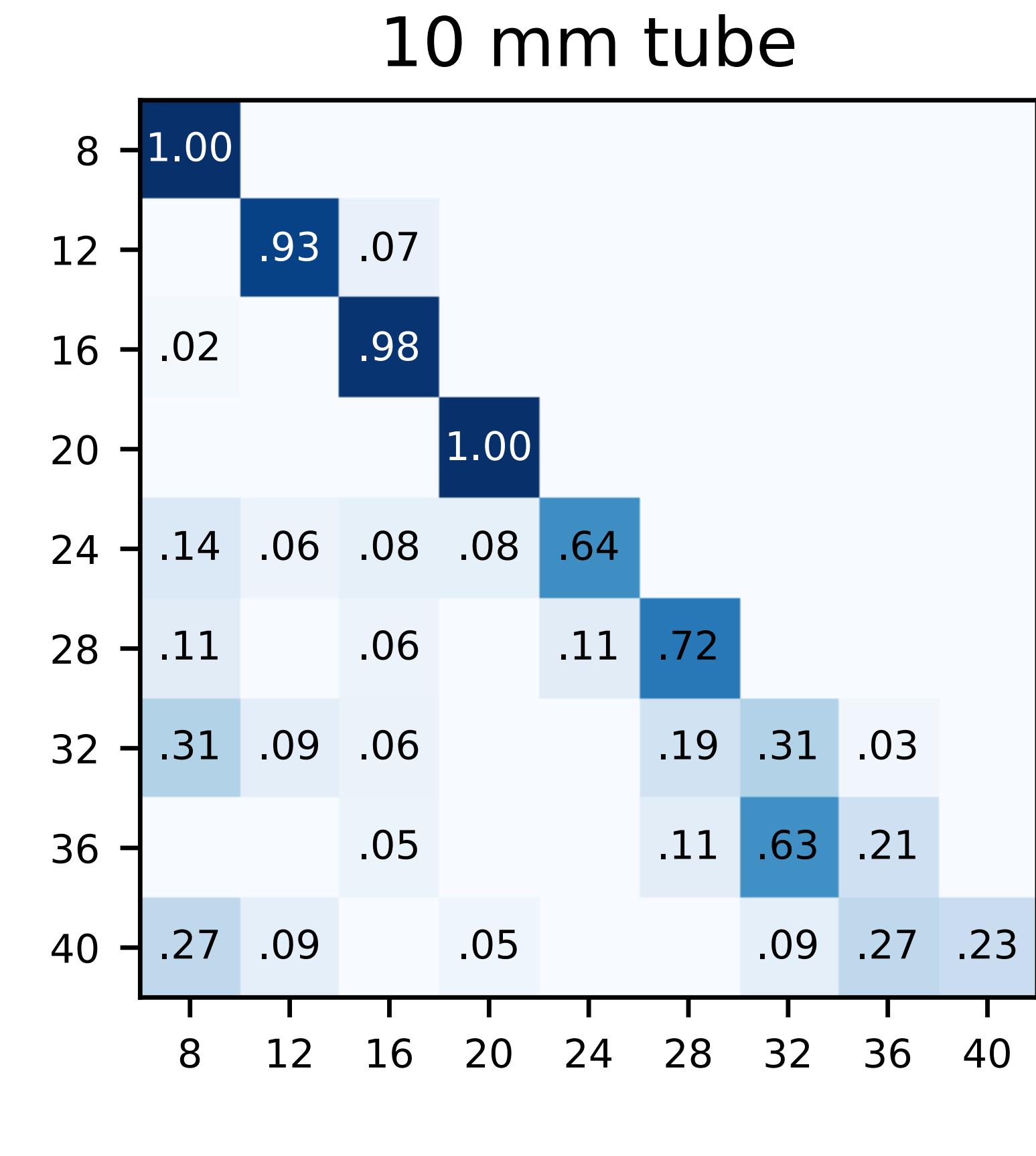
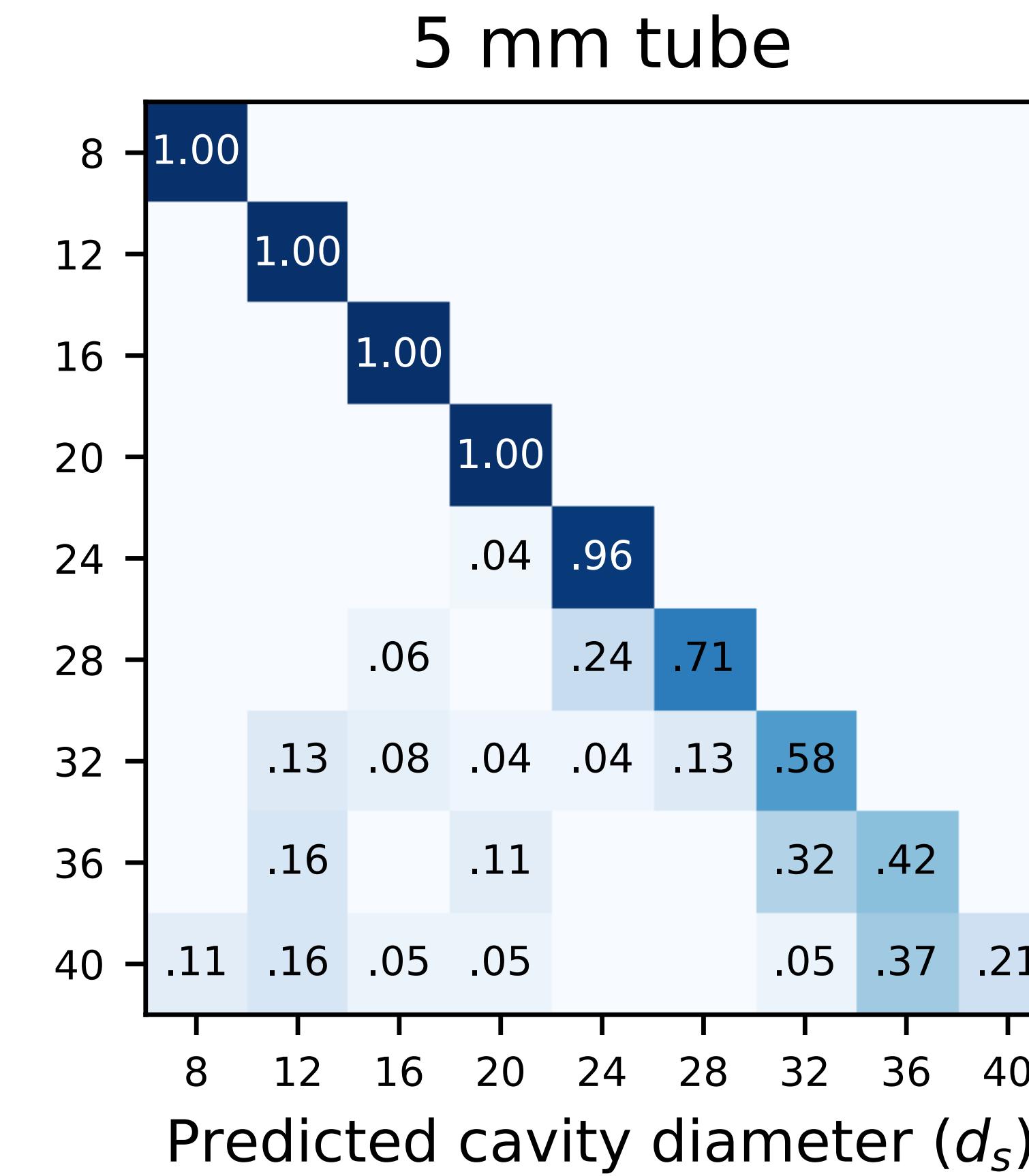
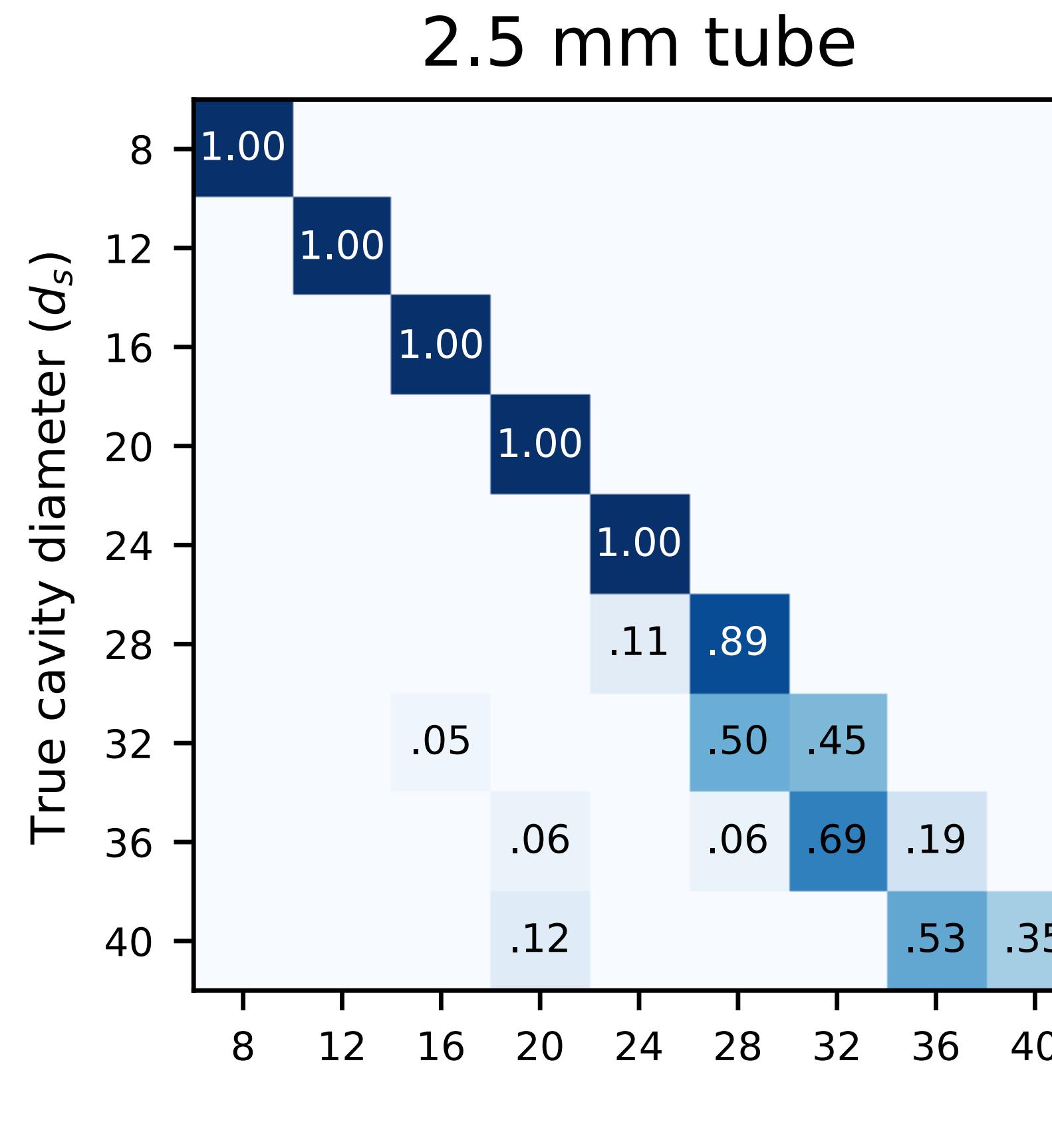


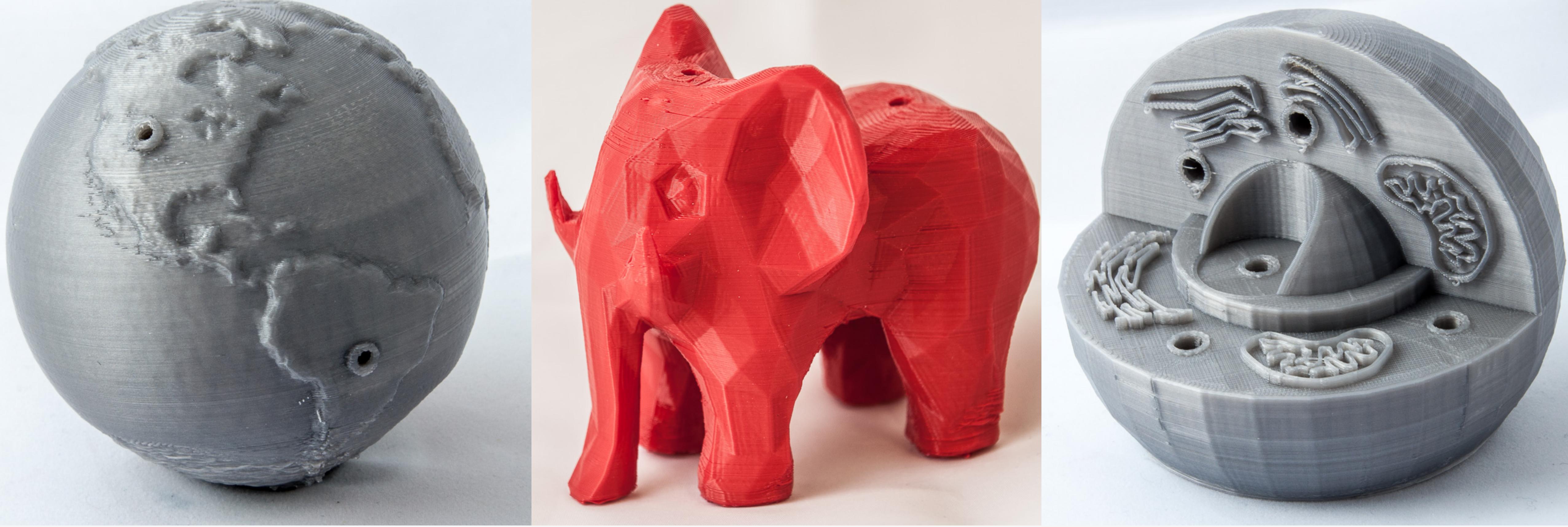
# Performance Testing

# Performance Testing

- Collected 830 blow segments.
- 10 participants.
- Tested both overall and per-user.

# Performance Testing





# Blowhole

Blowing-Activated Tags for Interactive 3D-Printed Models

# Limitations

**Sensitive to environmental noise**

Only 6 locations

CHI '20

# AirTouch

## 3D-printed Touch-Sensitive Objects Using Pneumatic Sensing

Carlos Tejada  
University of Copenhagen



Raf Ramakers  
Hasselt University

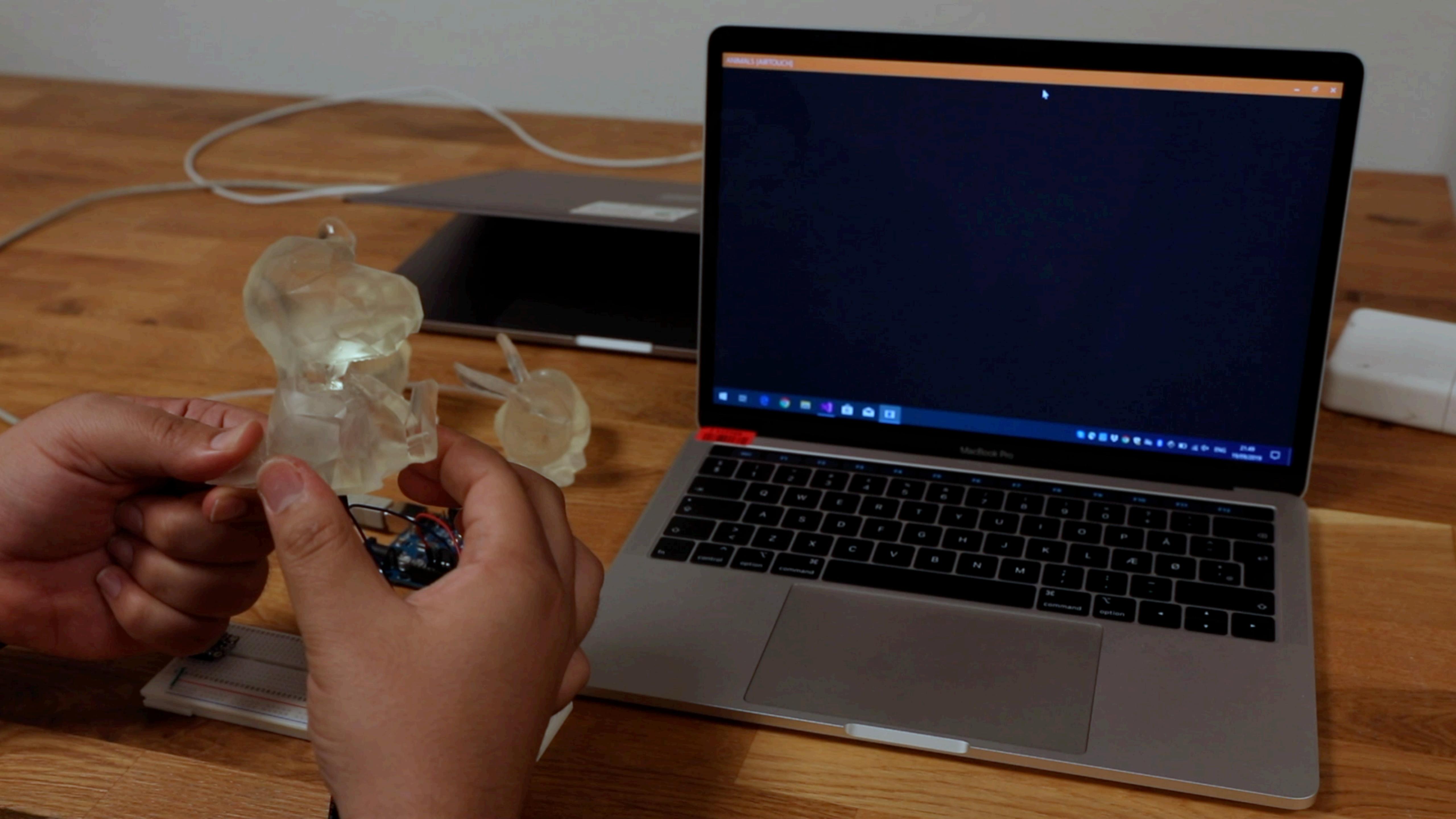


Sebastian Boring  
Aalborg University



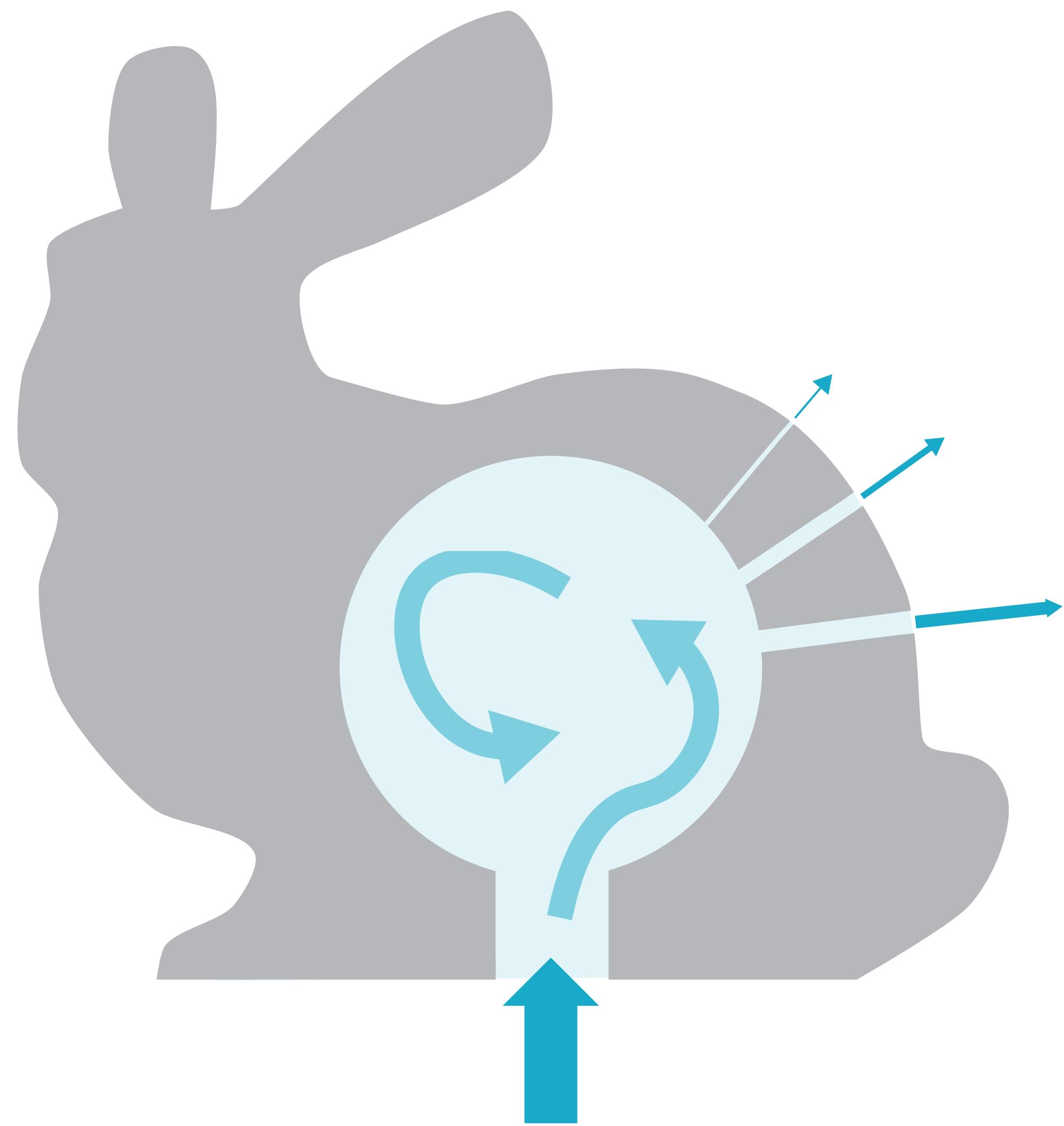
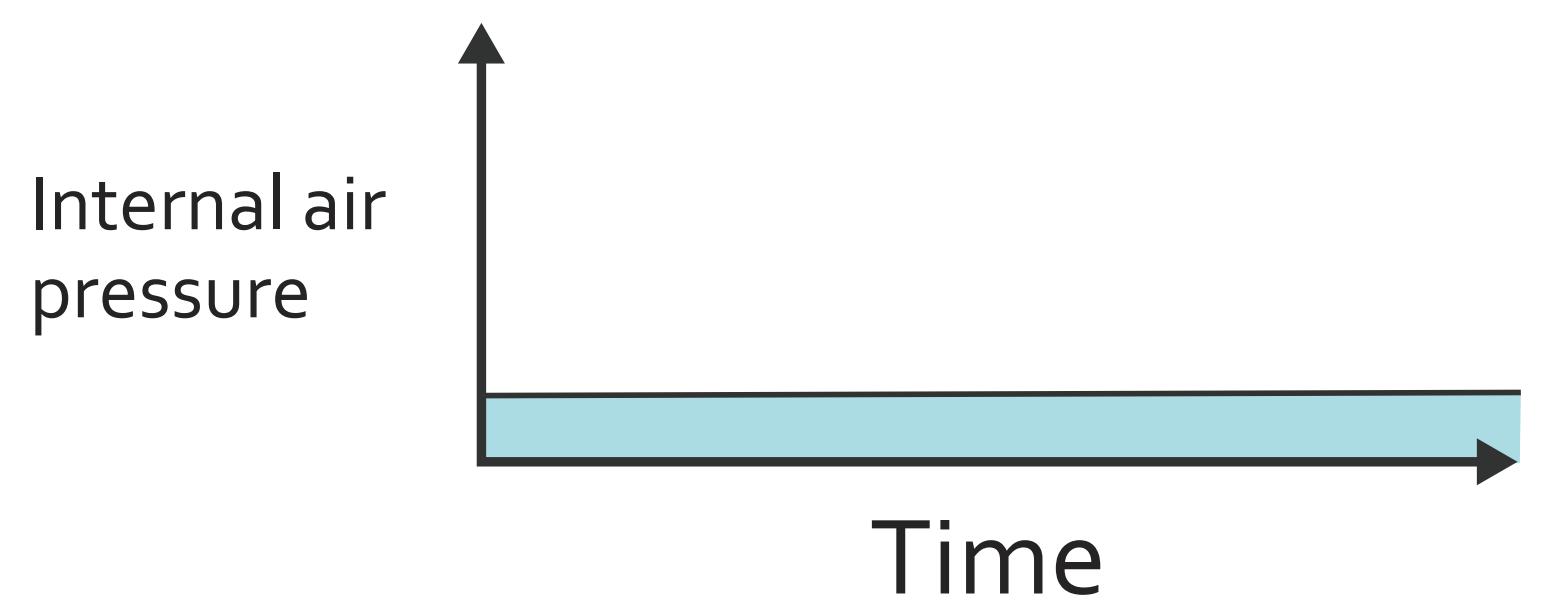
Daniel Ashbrook  
University of Copenhagen

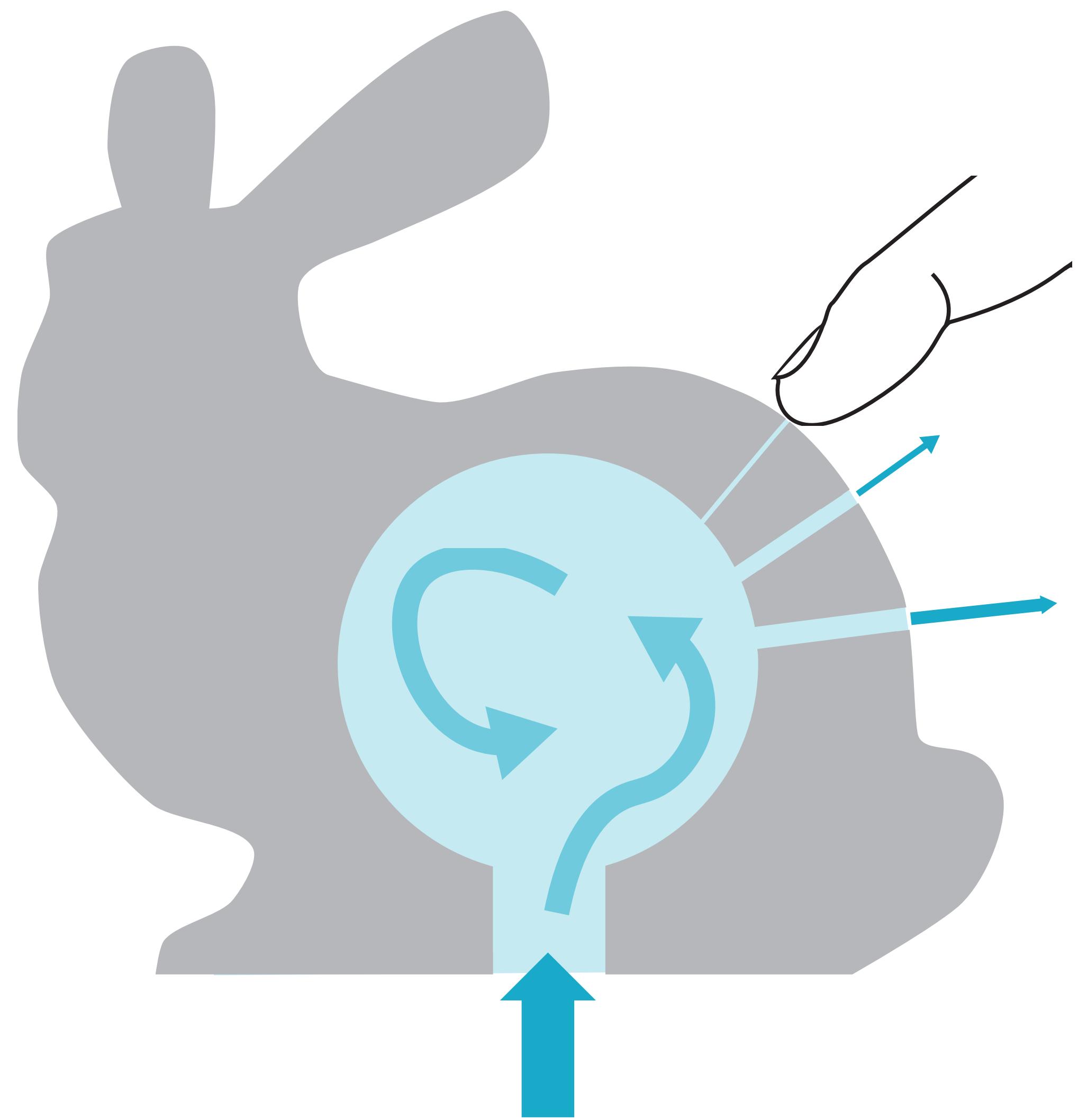
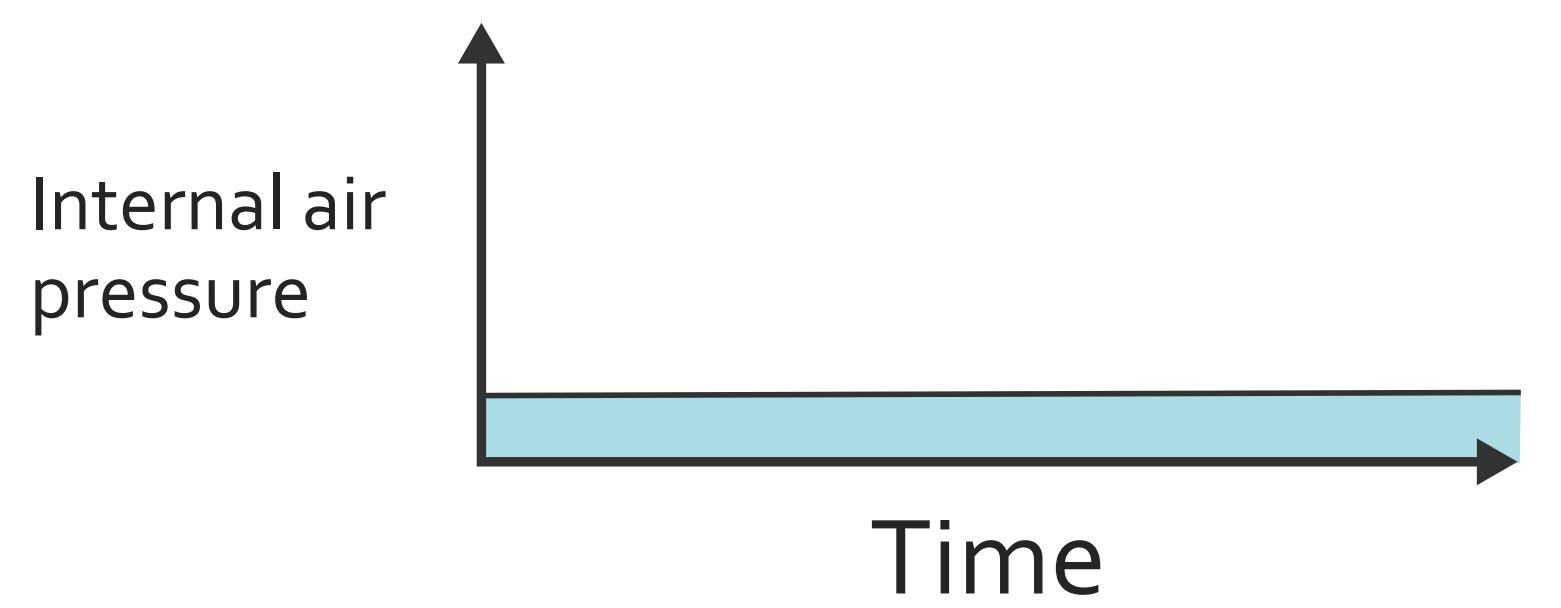


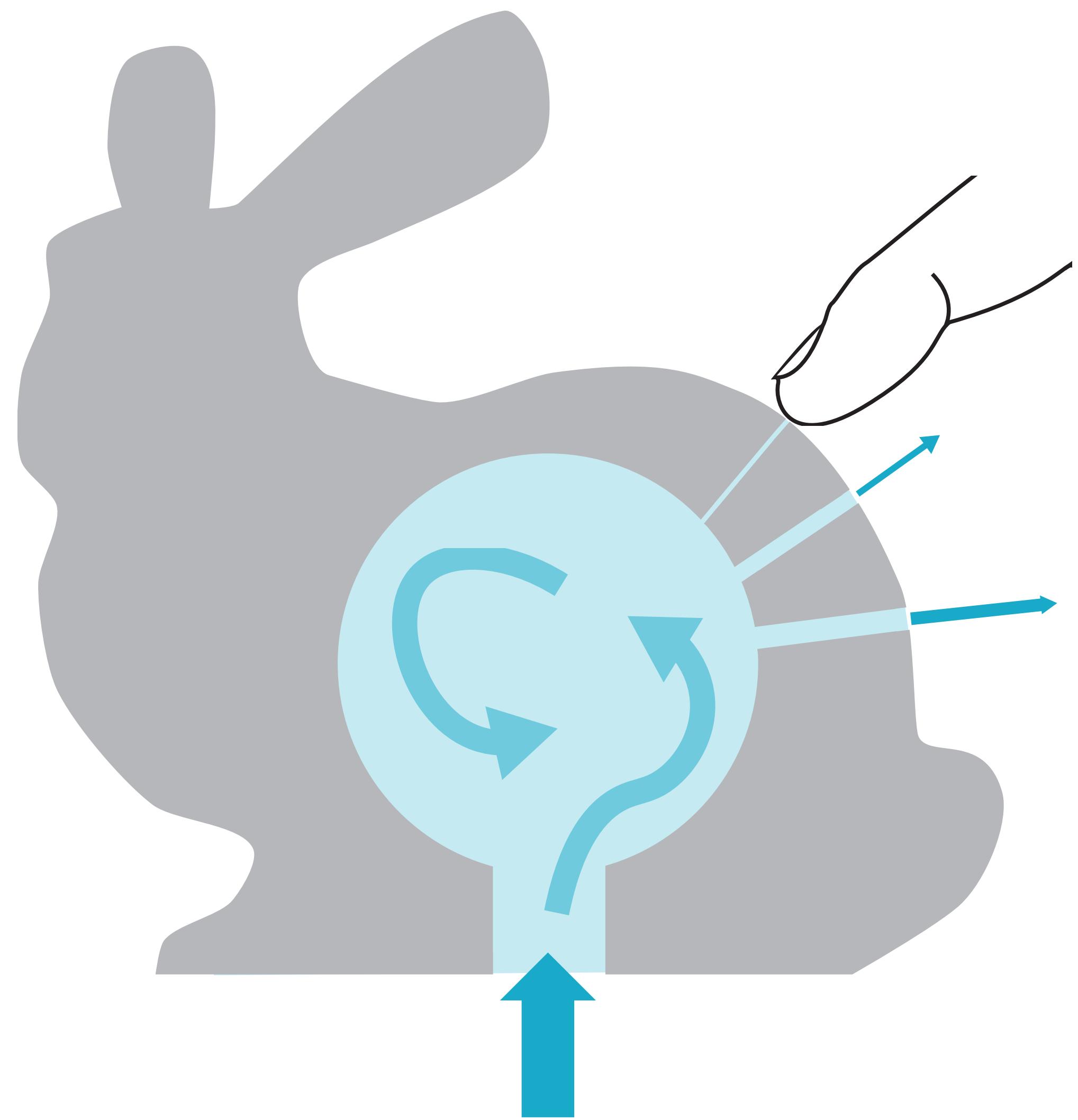
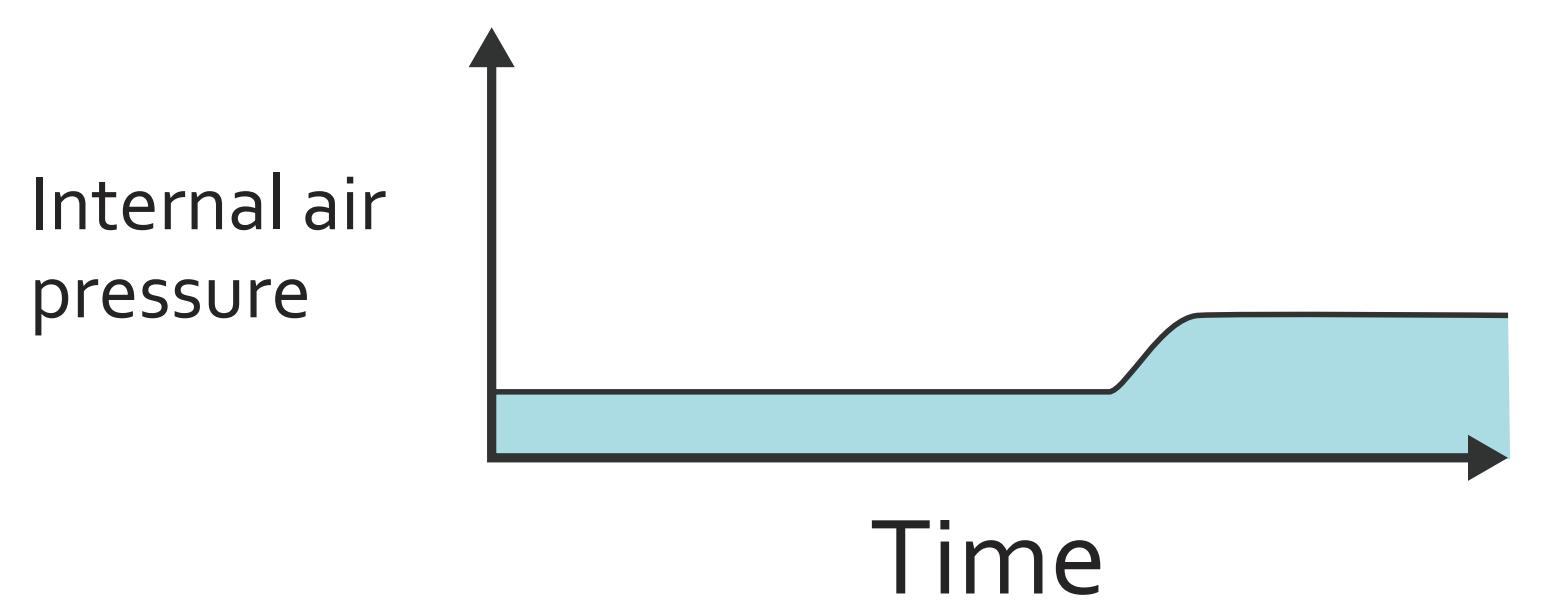


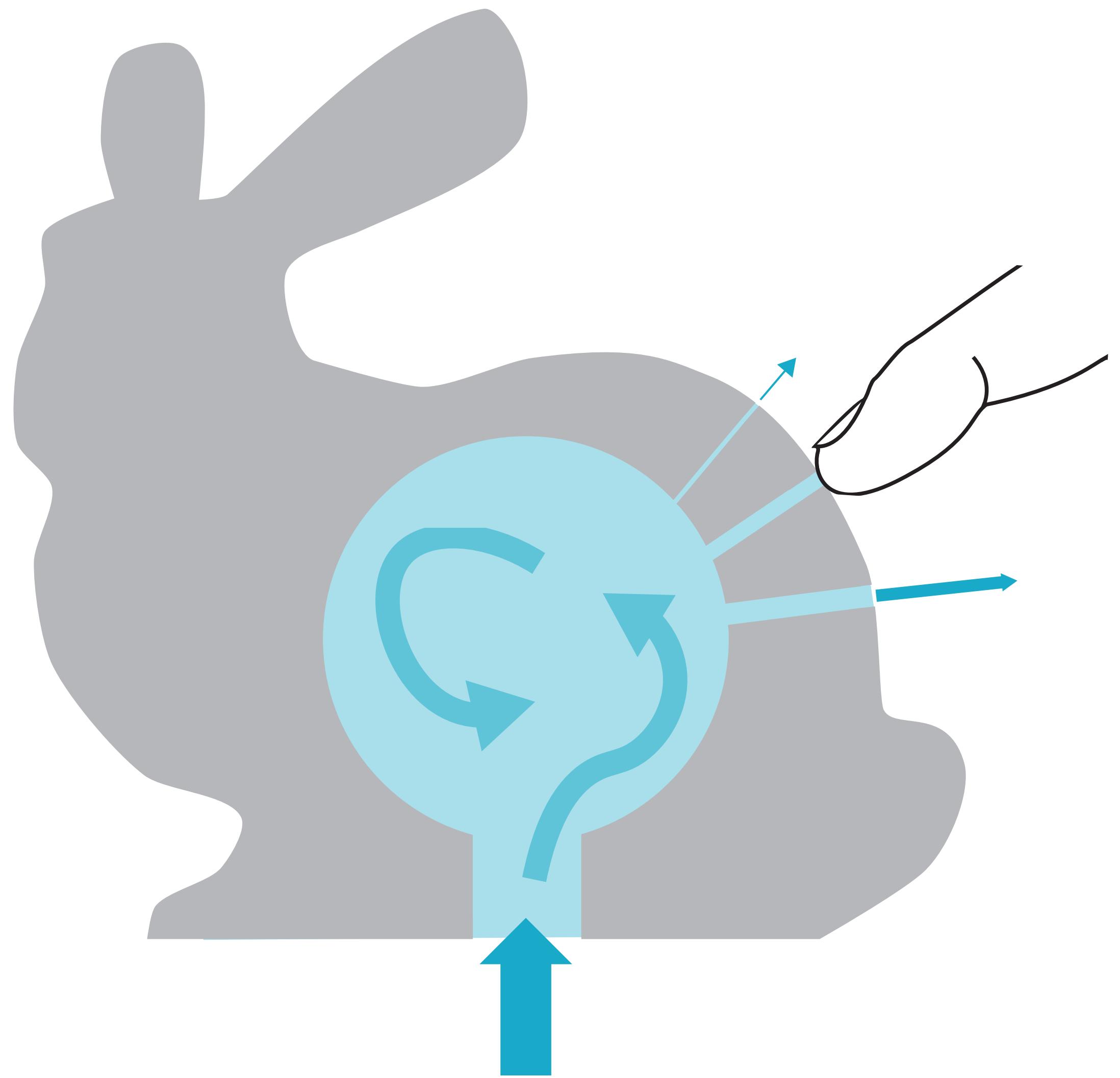
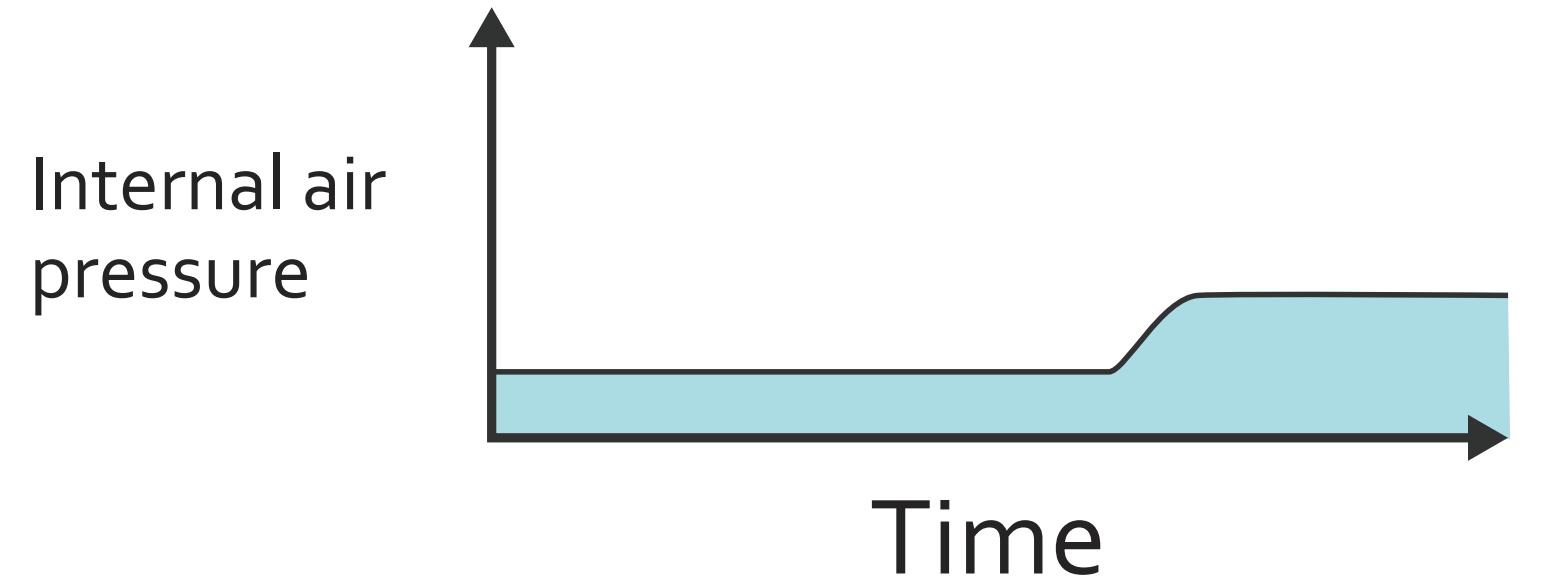
# How does it work?

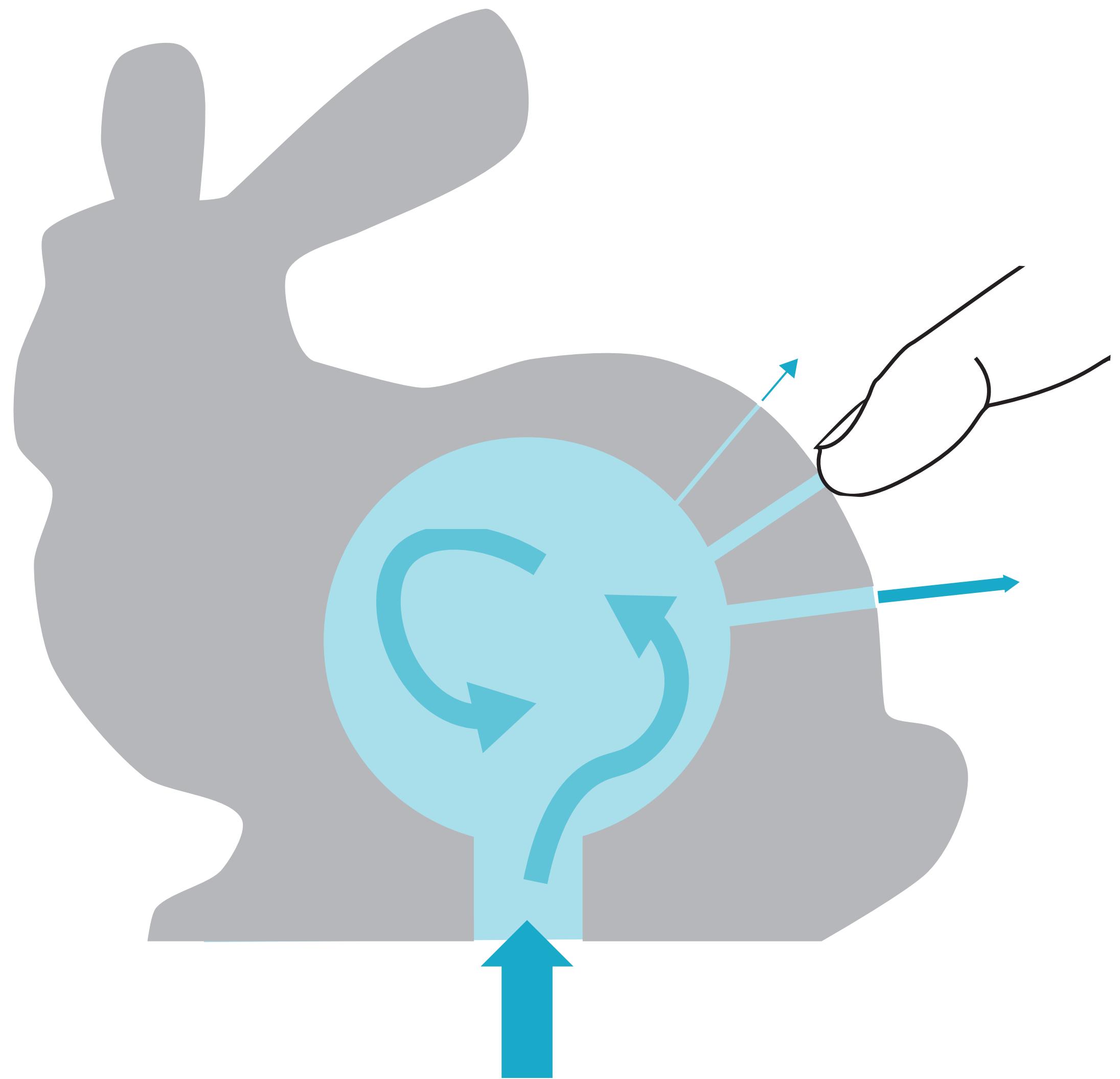
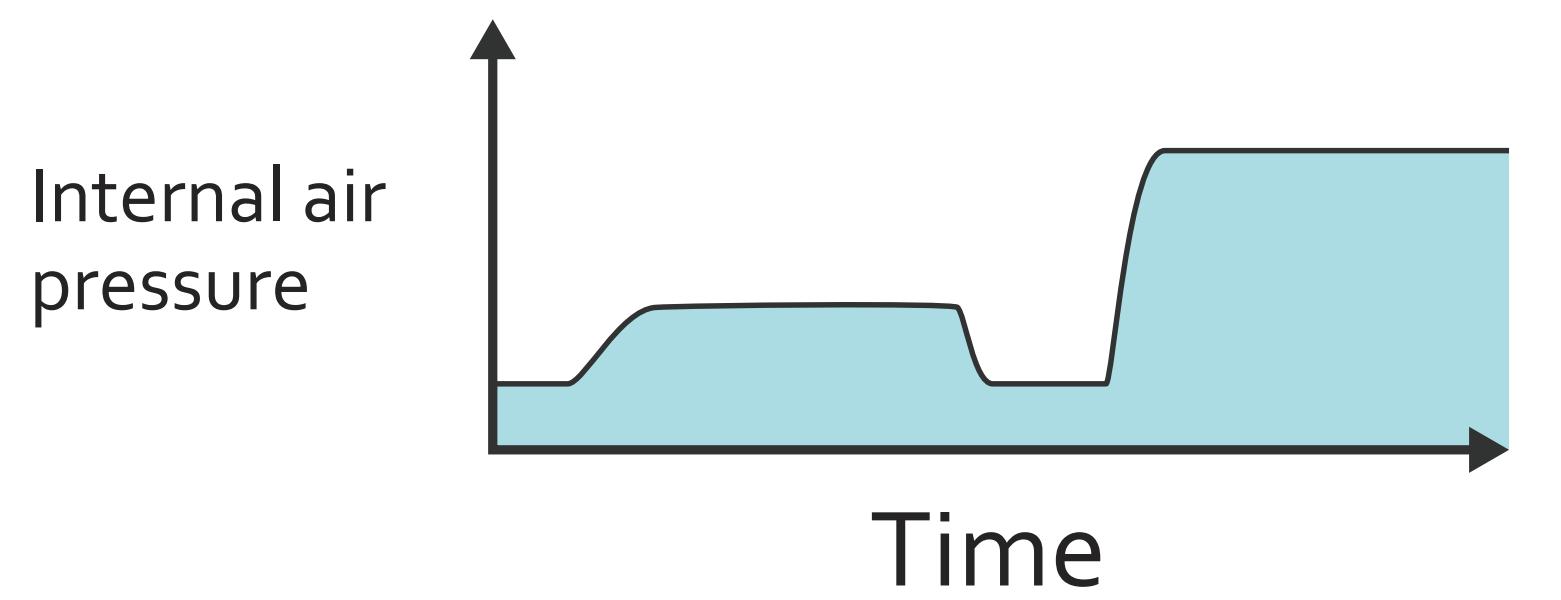












# How does it work?

- Principle of fluid continuity.
- Bernoulli's principle.

$$\Delta P_x = \frac{(\sum A_i)^2 \Delta P}{(\sum A_i - A_x)^2}$$

- Change in size of openings → Change in pressure.

# How does it work?

- Assumptions:
  - Incompressible fluids.
  - Perfectly shaped outlets and structures.
- Reality:
  - Air is compressible.
  - 3D-printed objects are not perfect.
  - Complex internal geometries.

# AirTouch



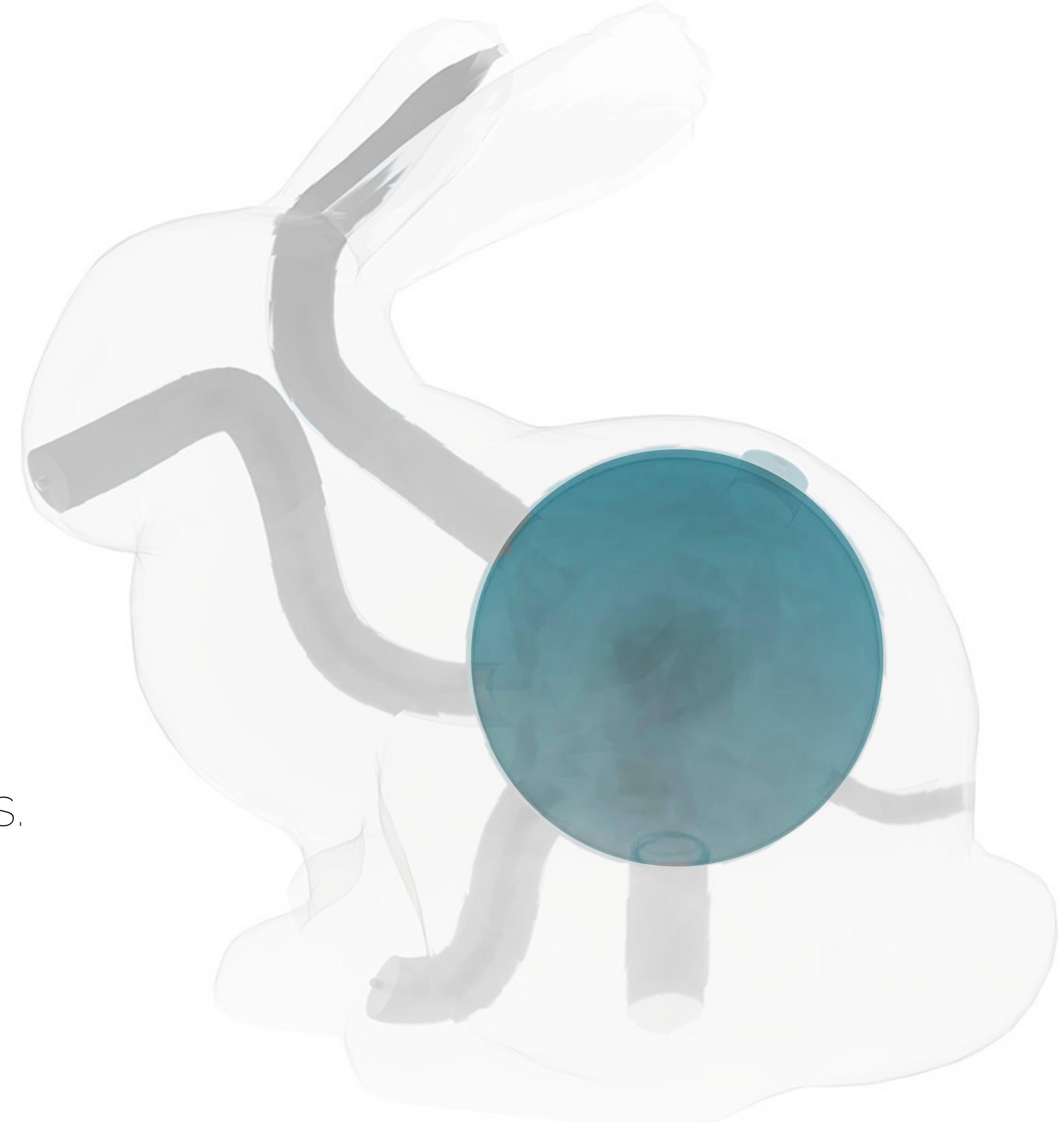
# AirTouch

- Cavity
- Tubes
- Outlets



# Cavity

- Spherical cavities.
- 30 mm in diameter.
- Shared cavity size between all objects.
  - Shared machine learning model.



# Tubes

- Cylindrical tubes.
- 5mm in diameter.
- Compromise between printability and size.

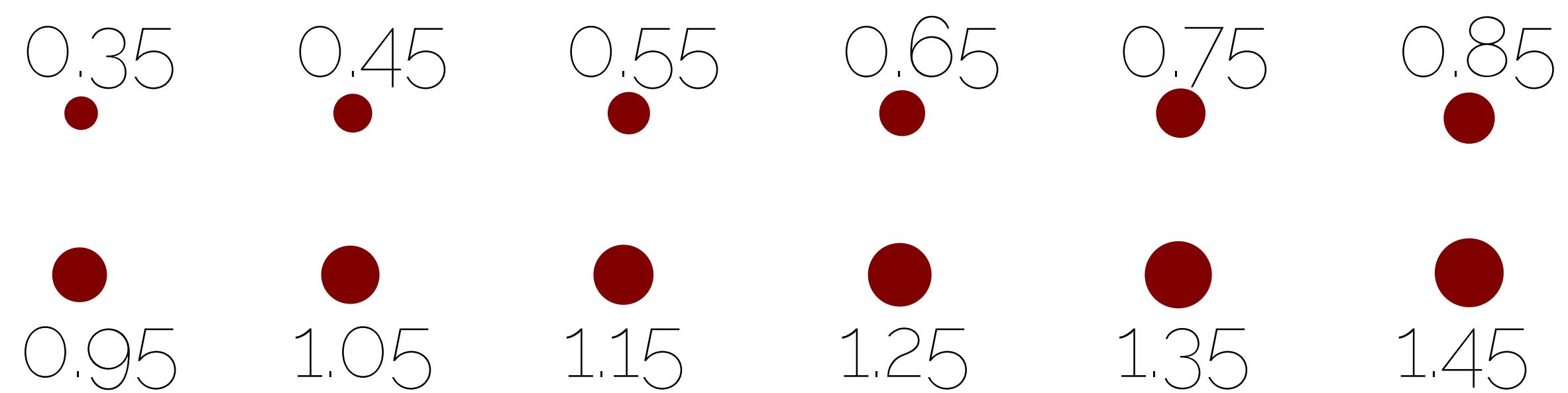


# Outlets

- Outlets are placed on touch locations.
- Very small.
- Pressure increase depends on the area of outlet.

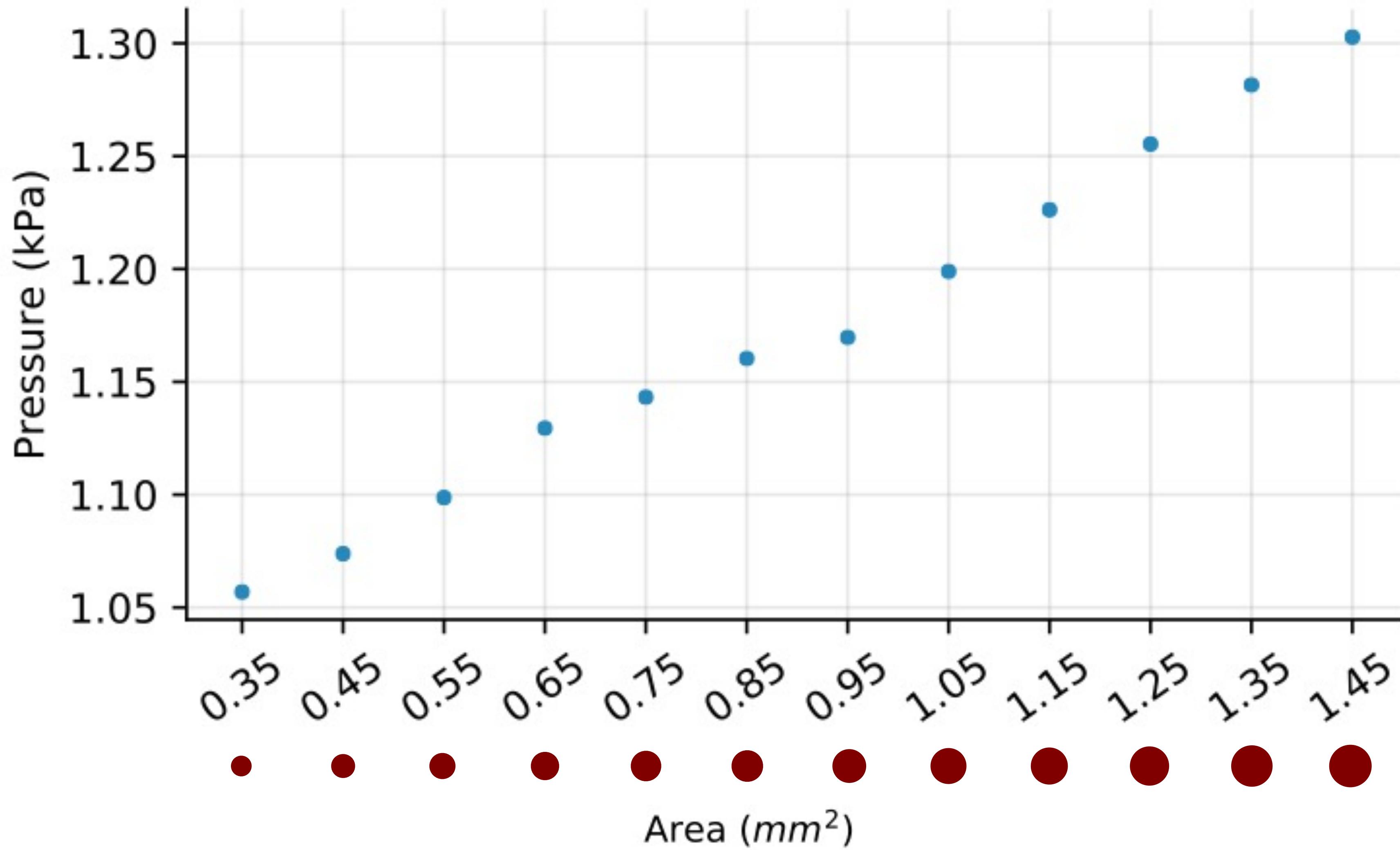


# Final outlet dimensions



Outlet area, in mm<sup>2</sup>

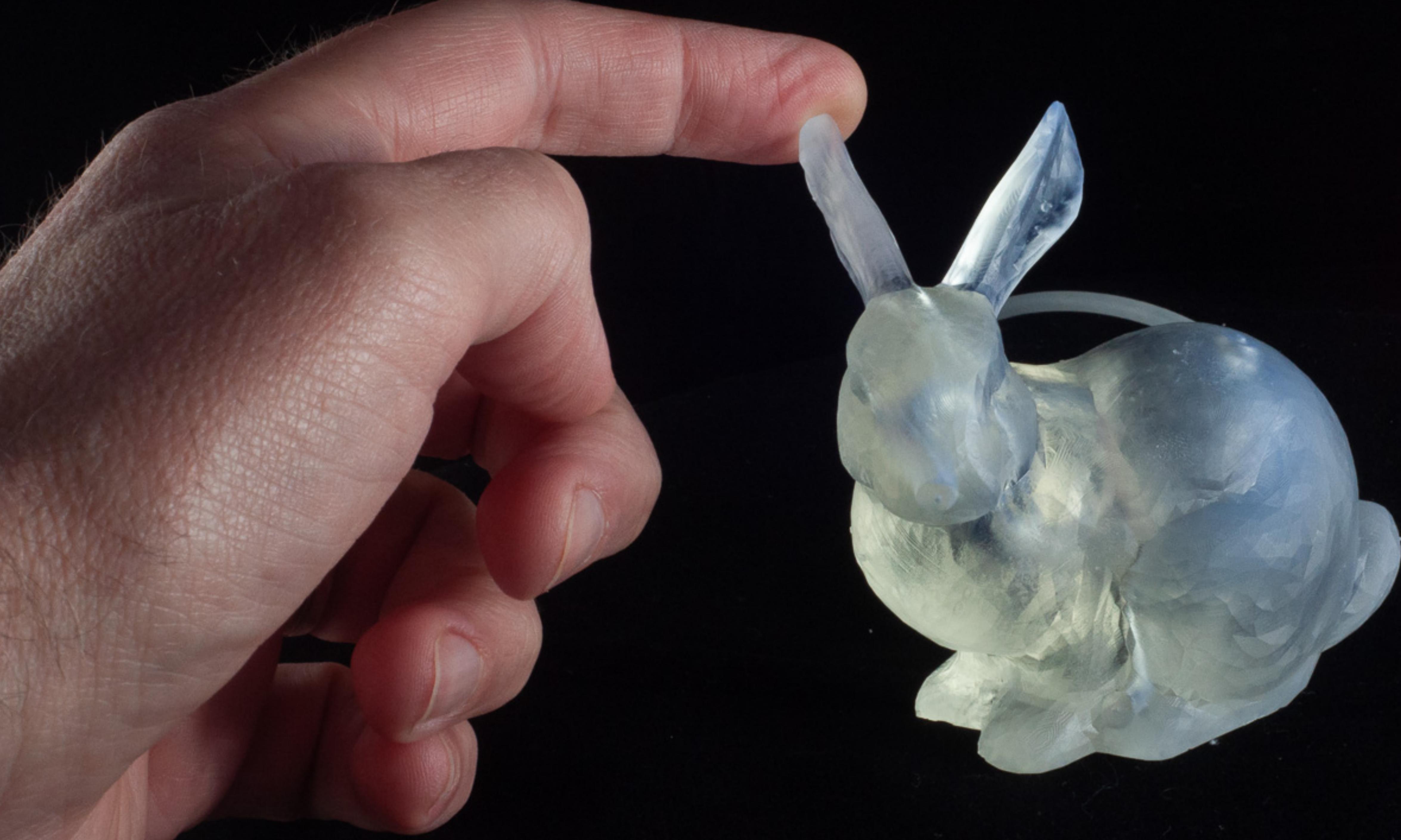


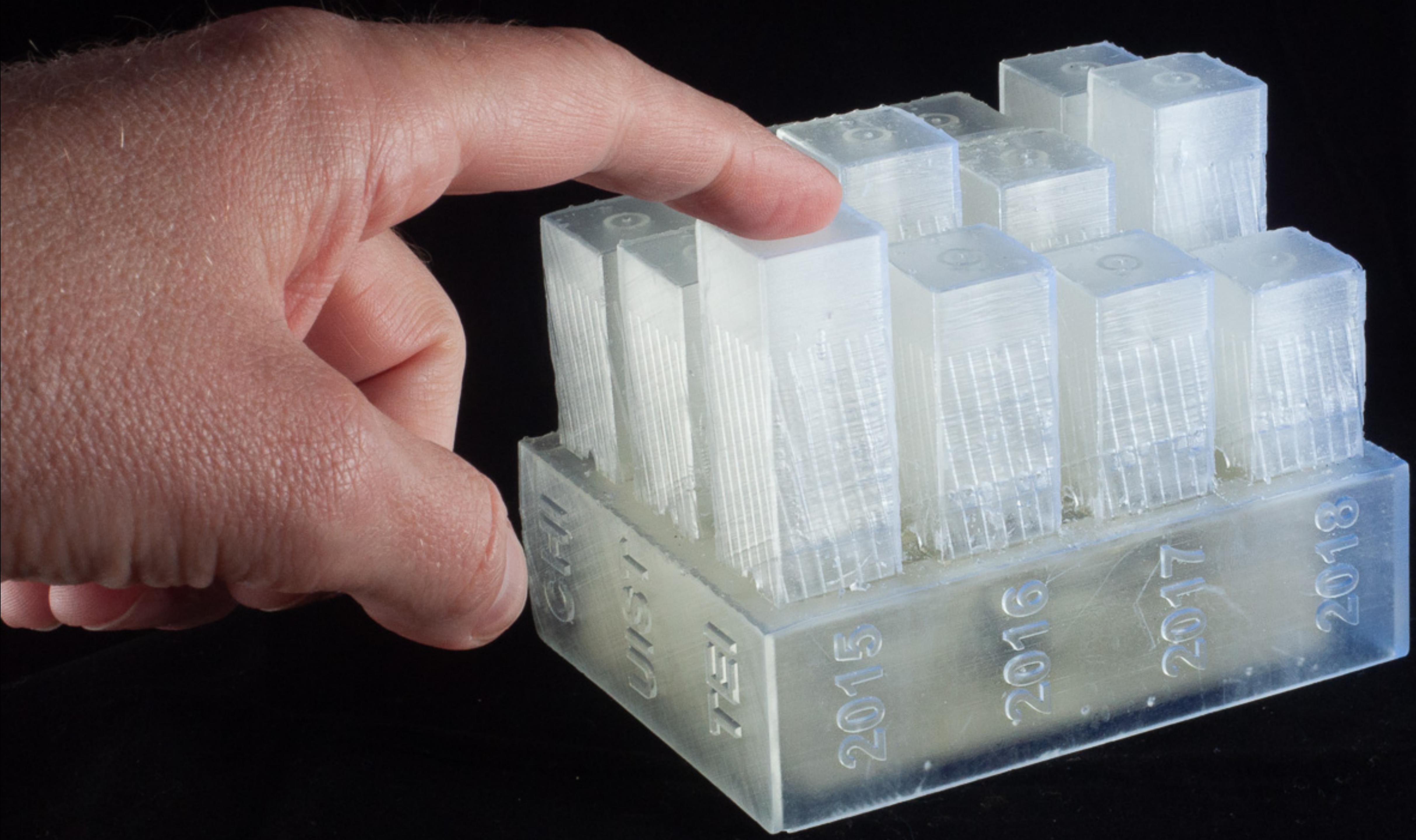


# Performance Testing

# Performance Testing

- Printed four objects.
- Pre-trained a machine learning model.
  - One instance per touch.
- Cycled through all touch locations.
- Repeated four times per object.

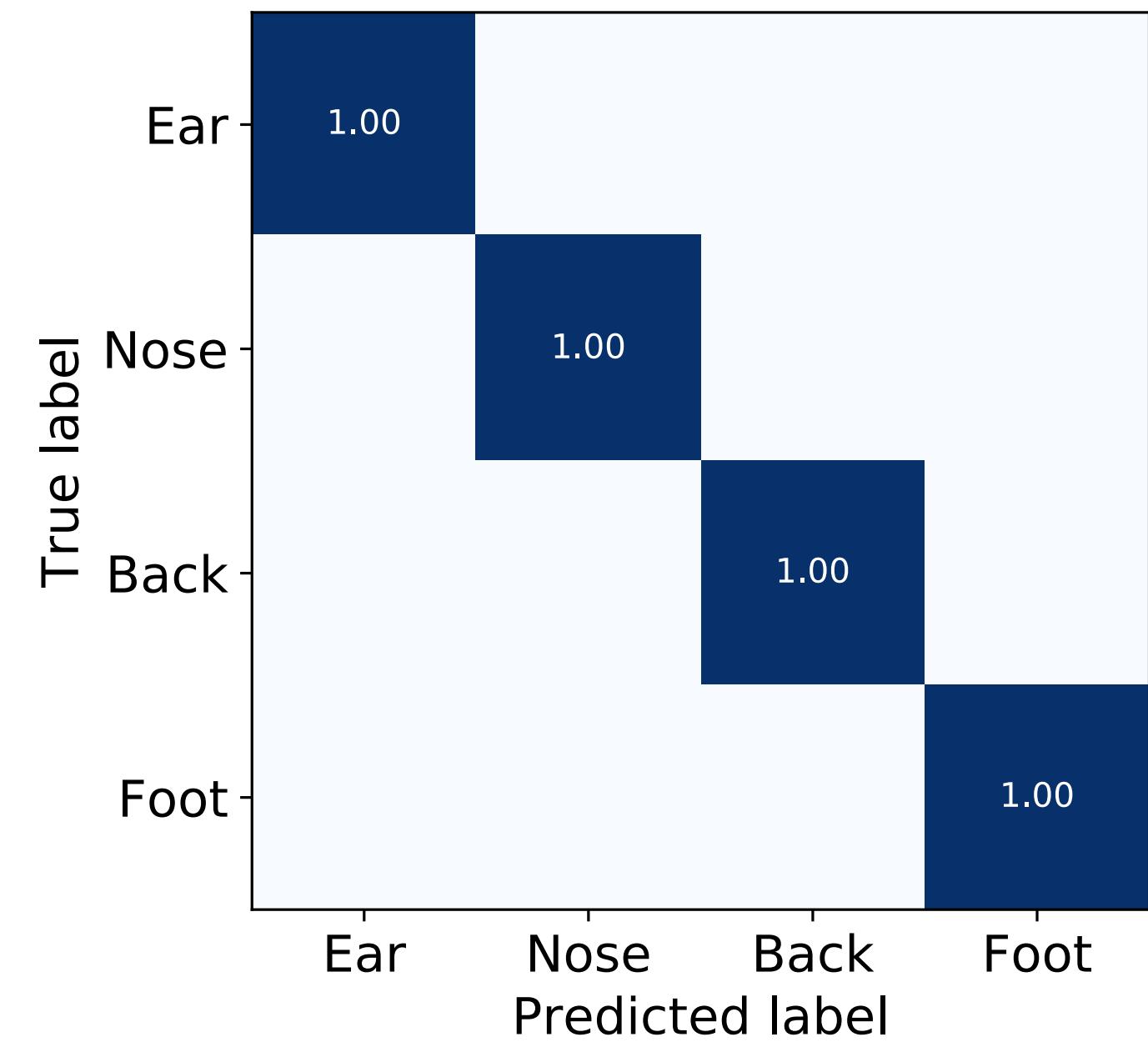






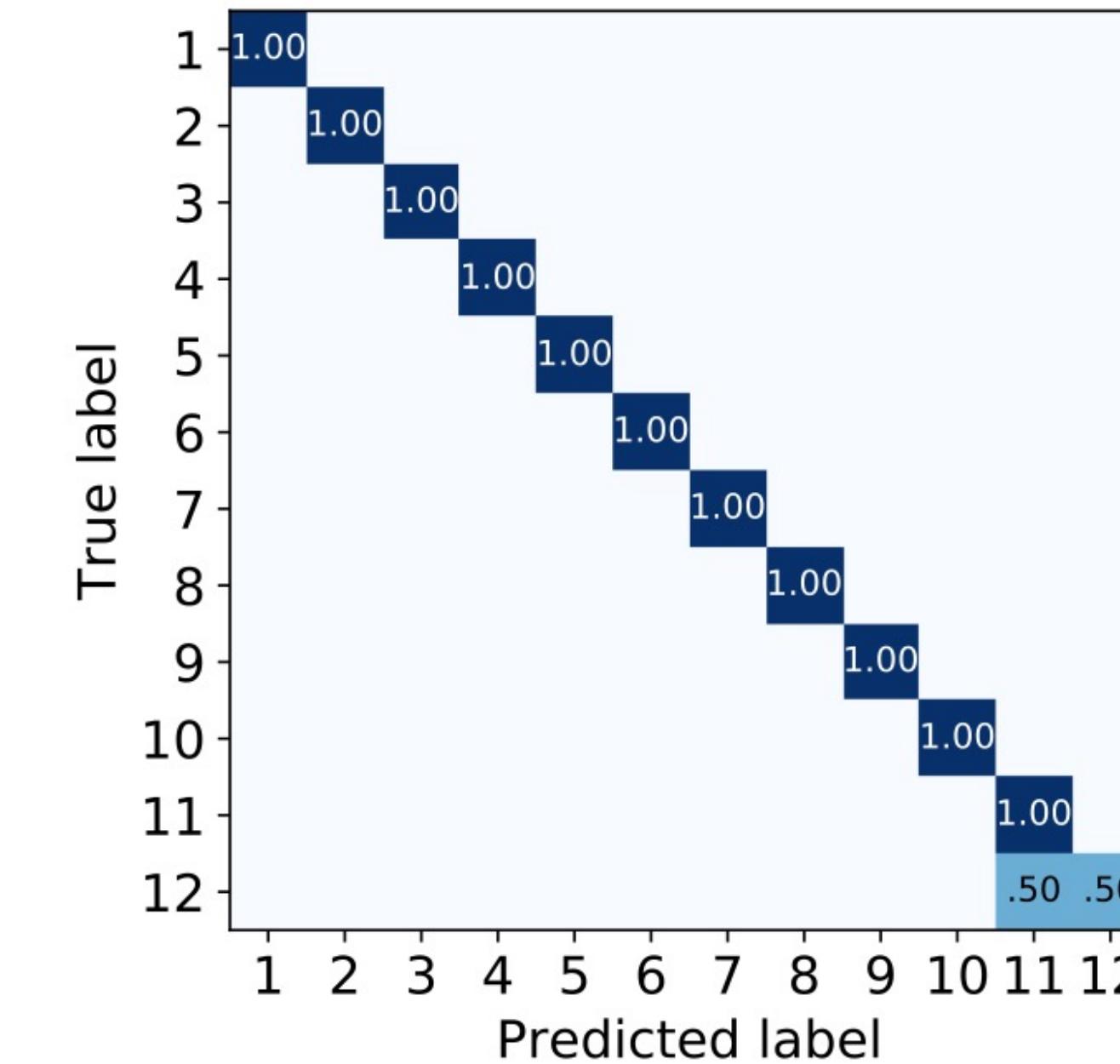


# Stanford Bunny



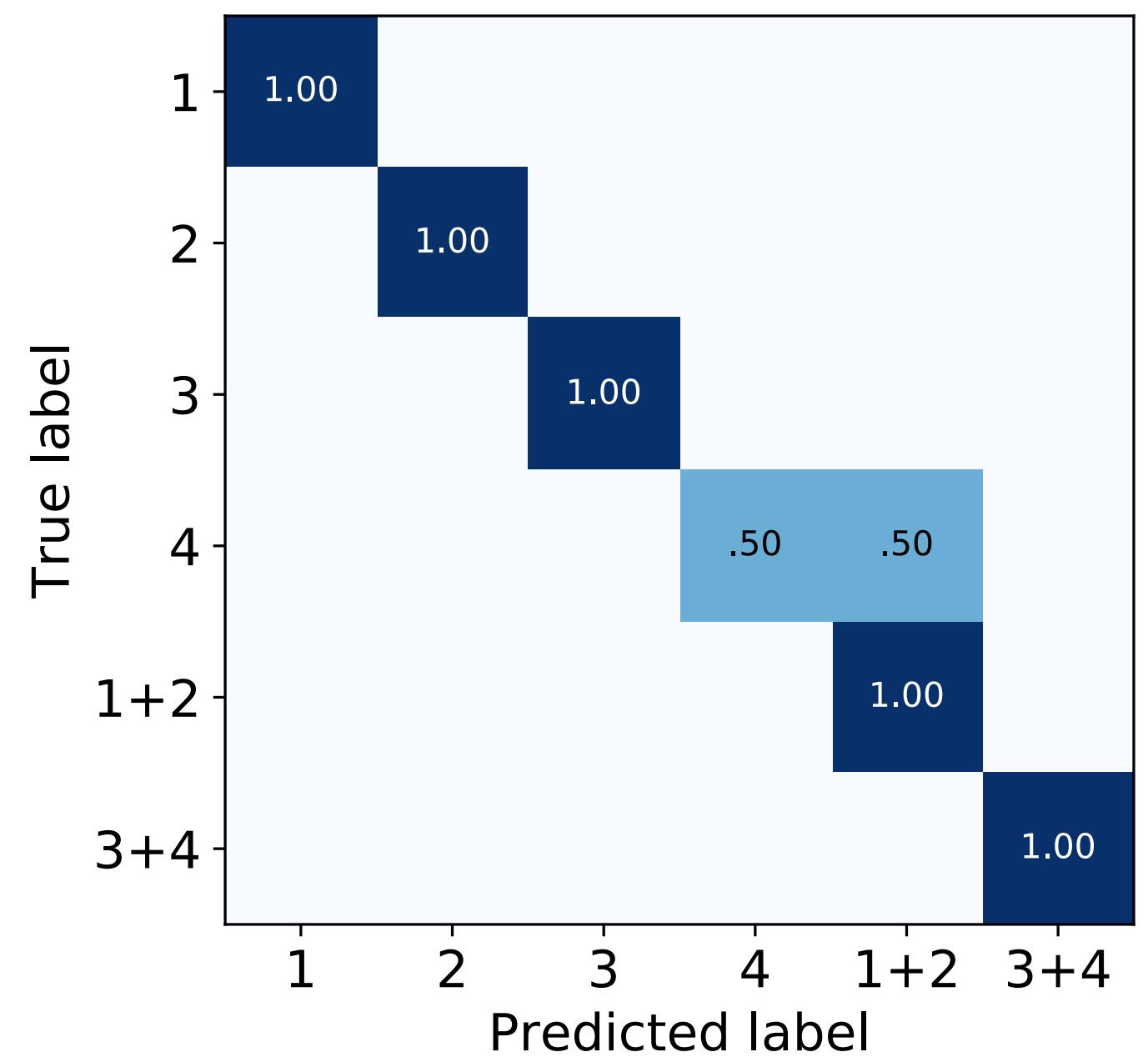
100%

# Interactive Bar Chart



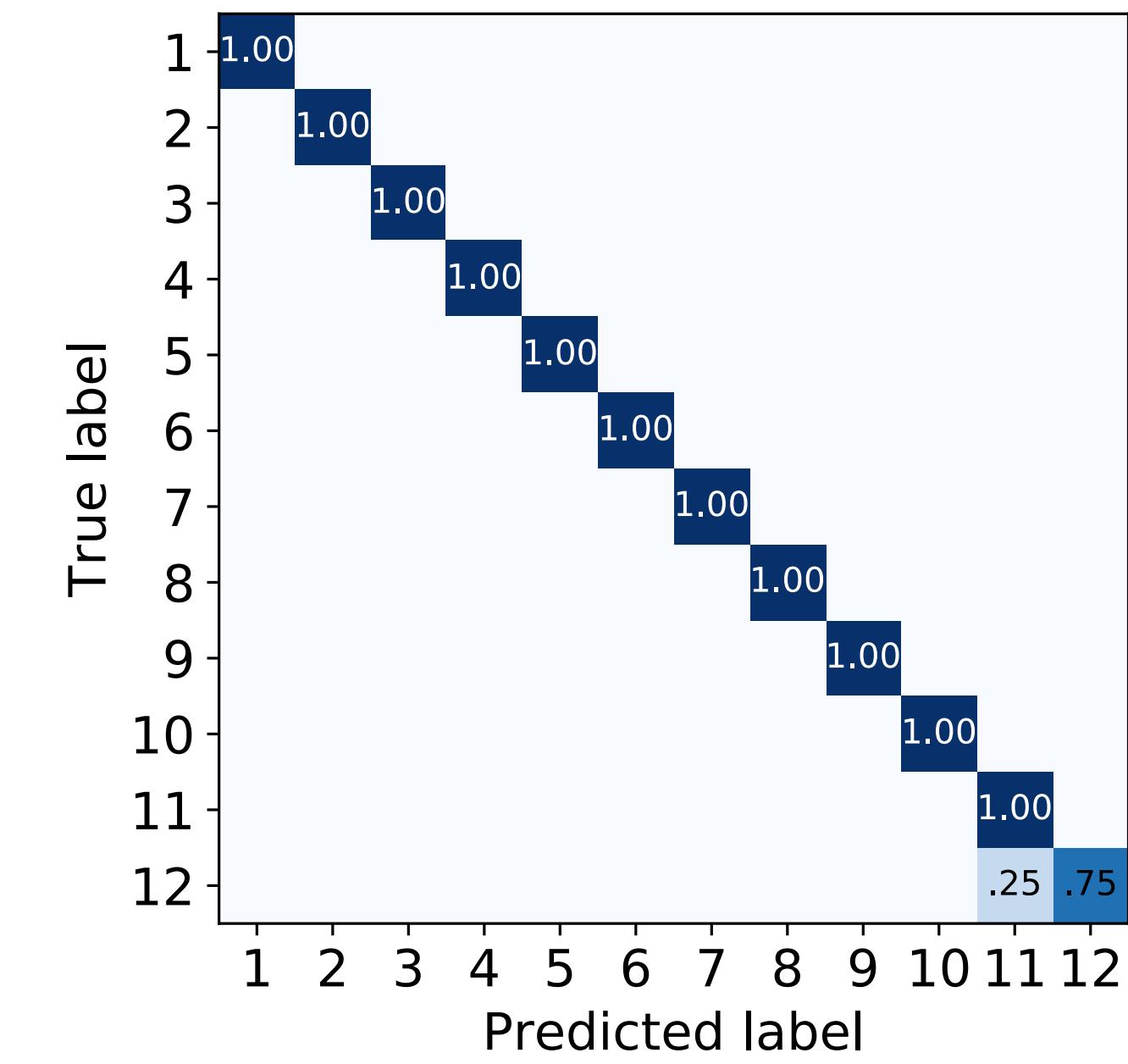
95.50%

# Grasping Sphere



91.60%

# Color Hue Selector



97.75%

# Limitations





# Atmospheric Pressure Changes

CHI '20

# AirTouch

3D-printed Touch-Sensitive Objects Using Pneumatic Sensing



Sensors, not artifacts

How to fabricate stand-alone interactive devices?

# Microcontrollers + sensors?

Fabricate object with computation  
embedded into it

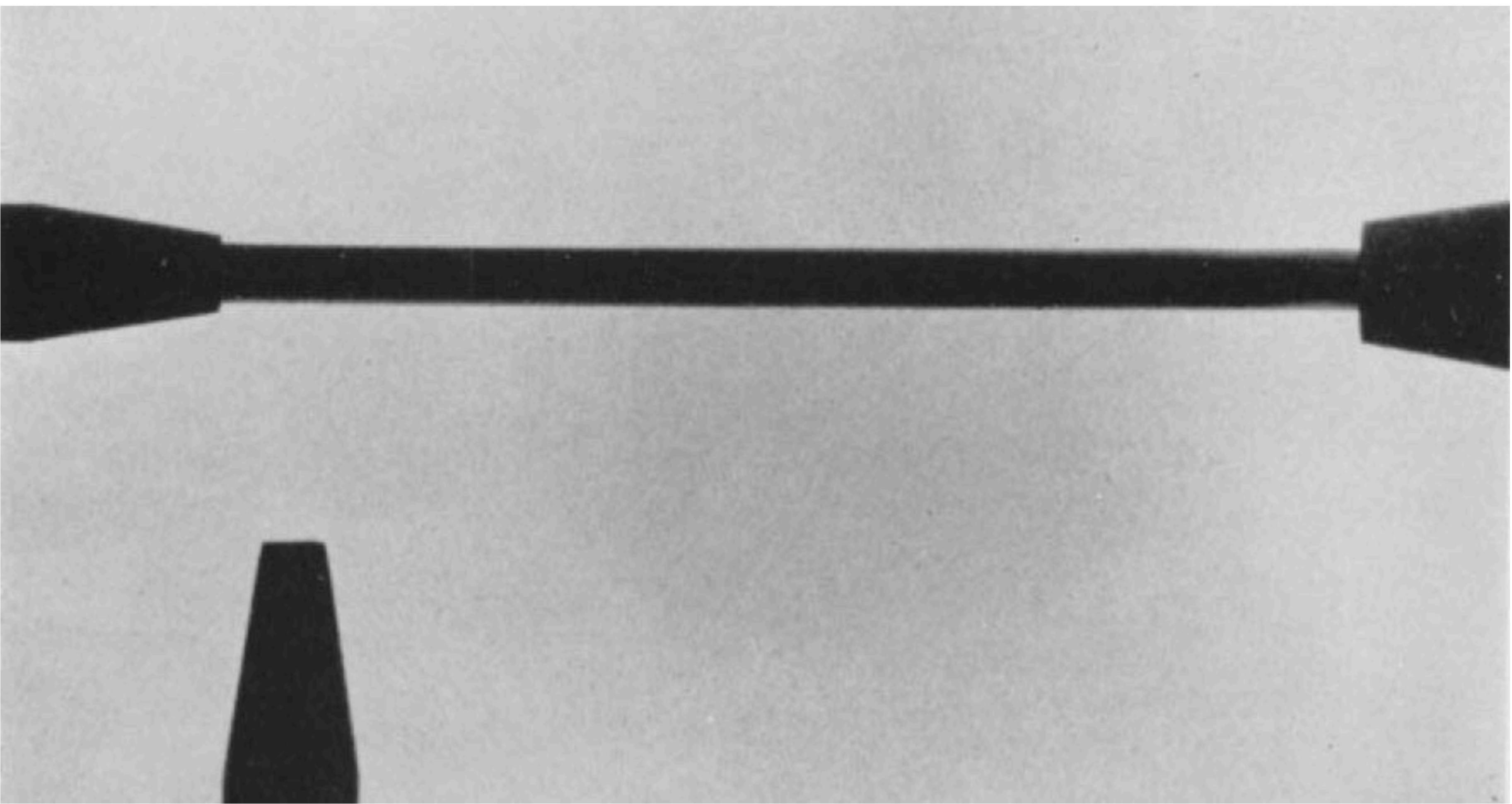
# 3D-printed Logic

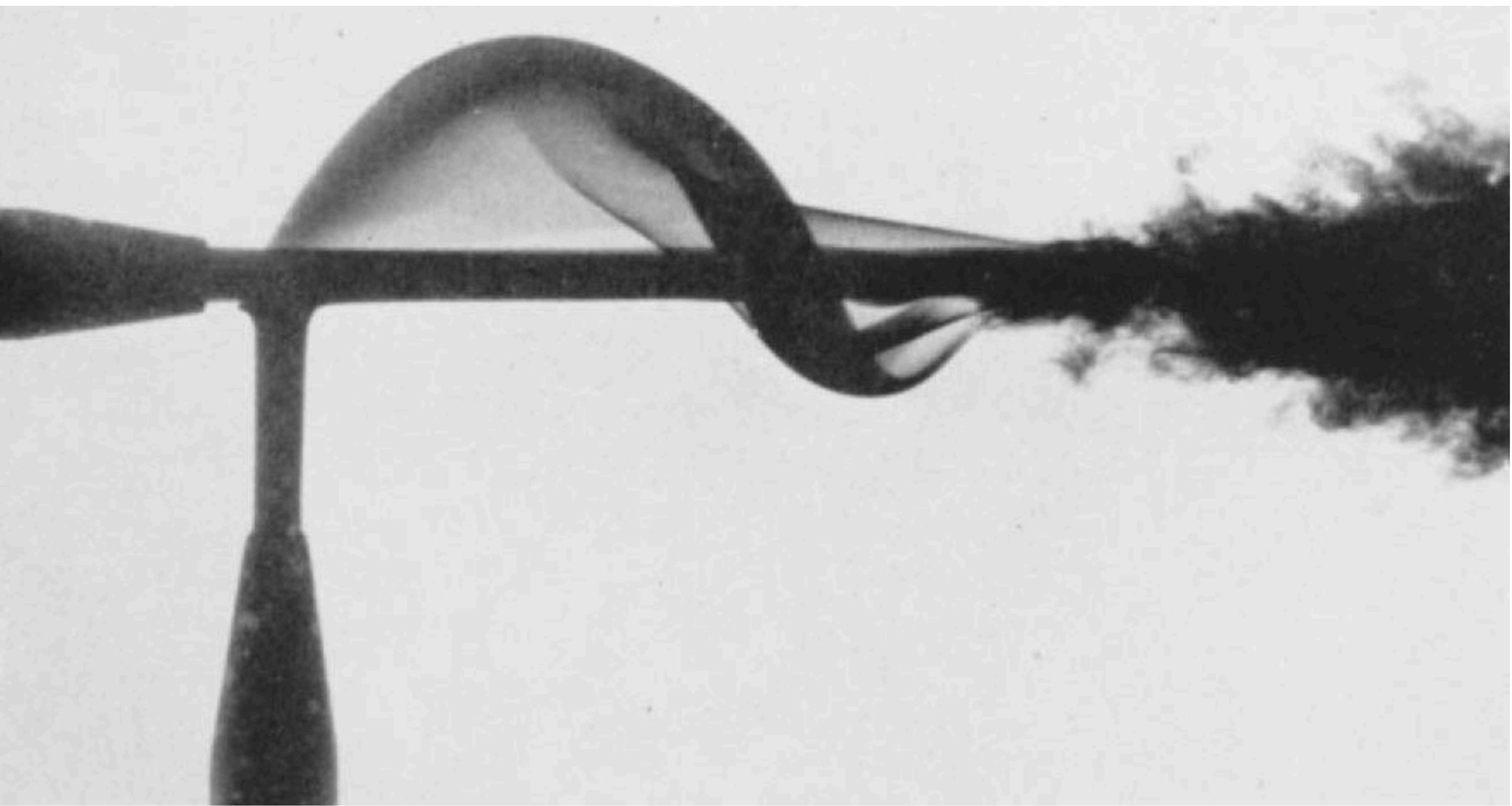
# Logic gates

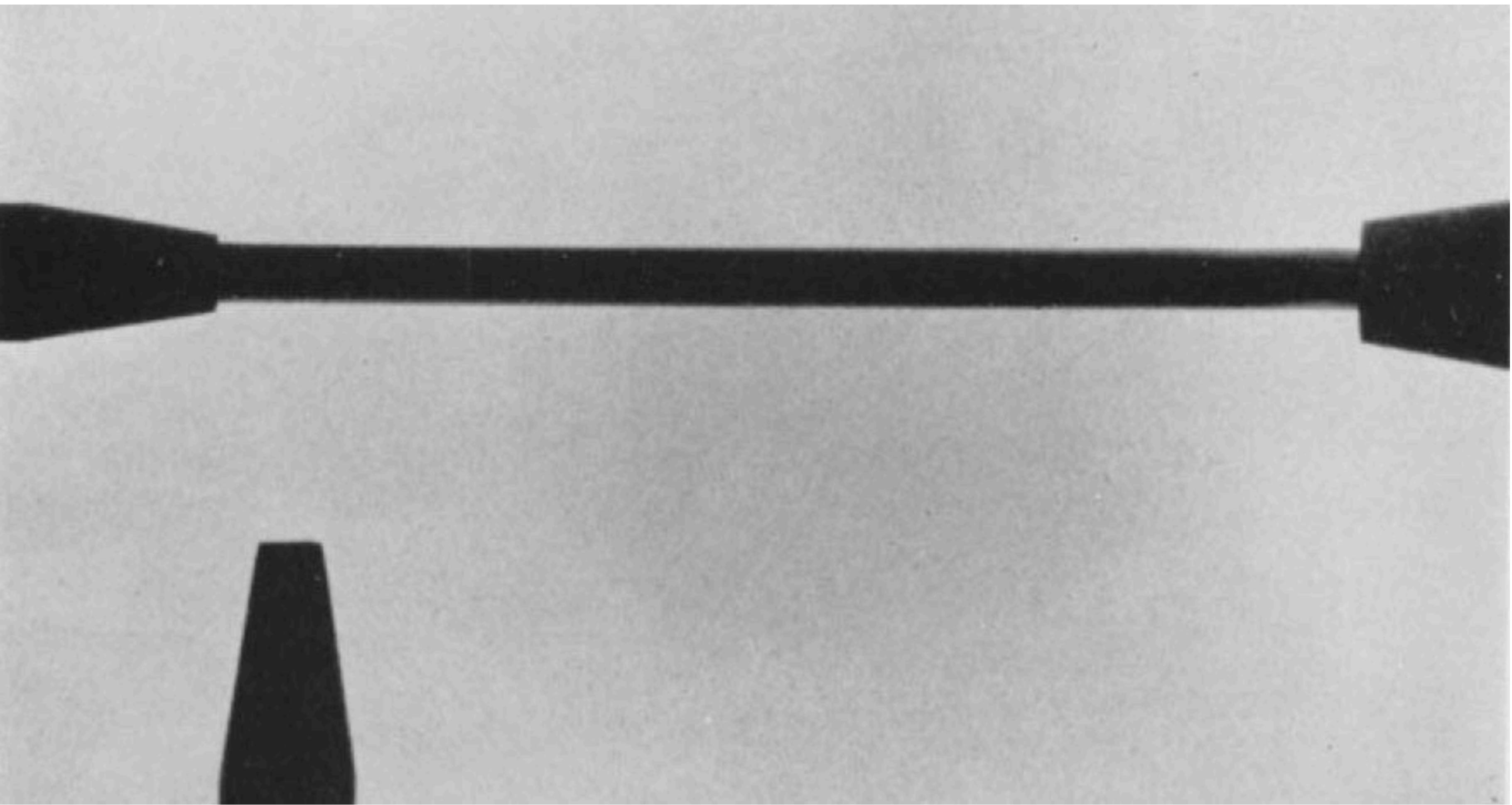
# Fluidics

# Fluidics

- Technique of using small interacting flows and fluid jets for functions usually performed by electronic devices.
- Require no moving parts or electricity.

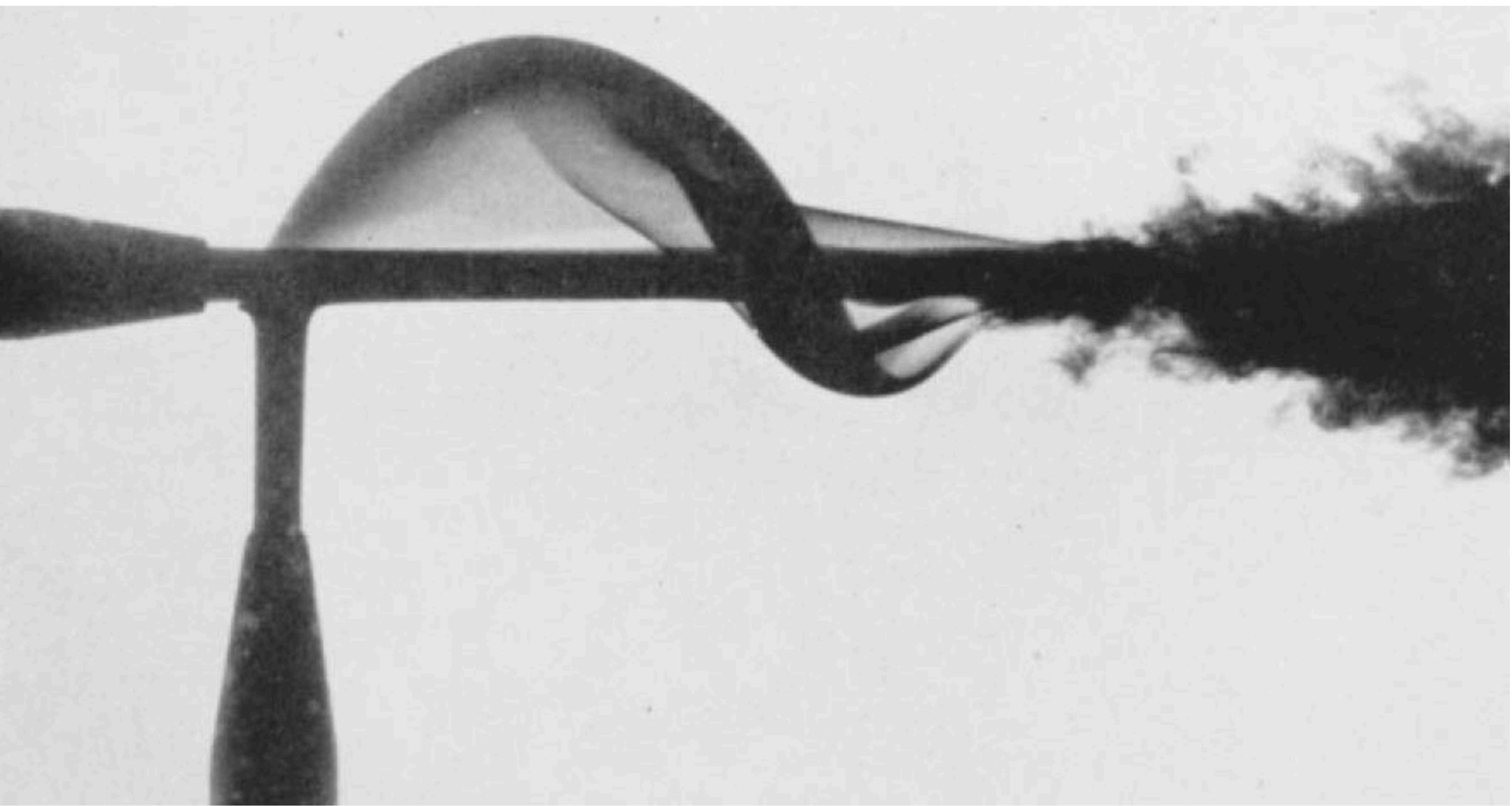






1

0

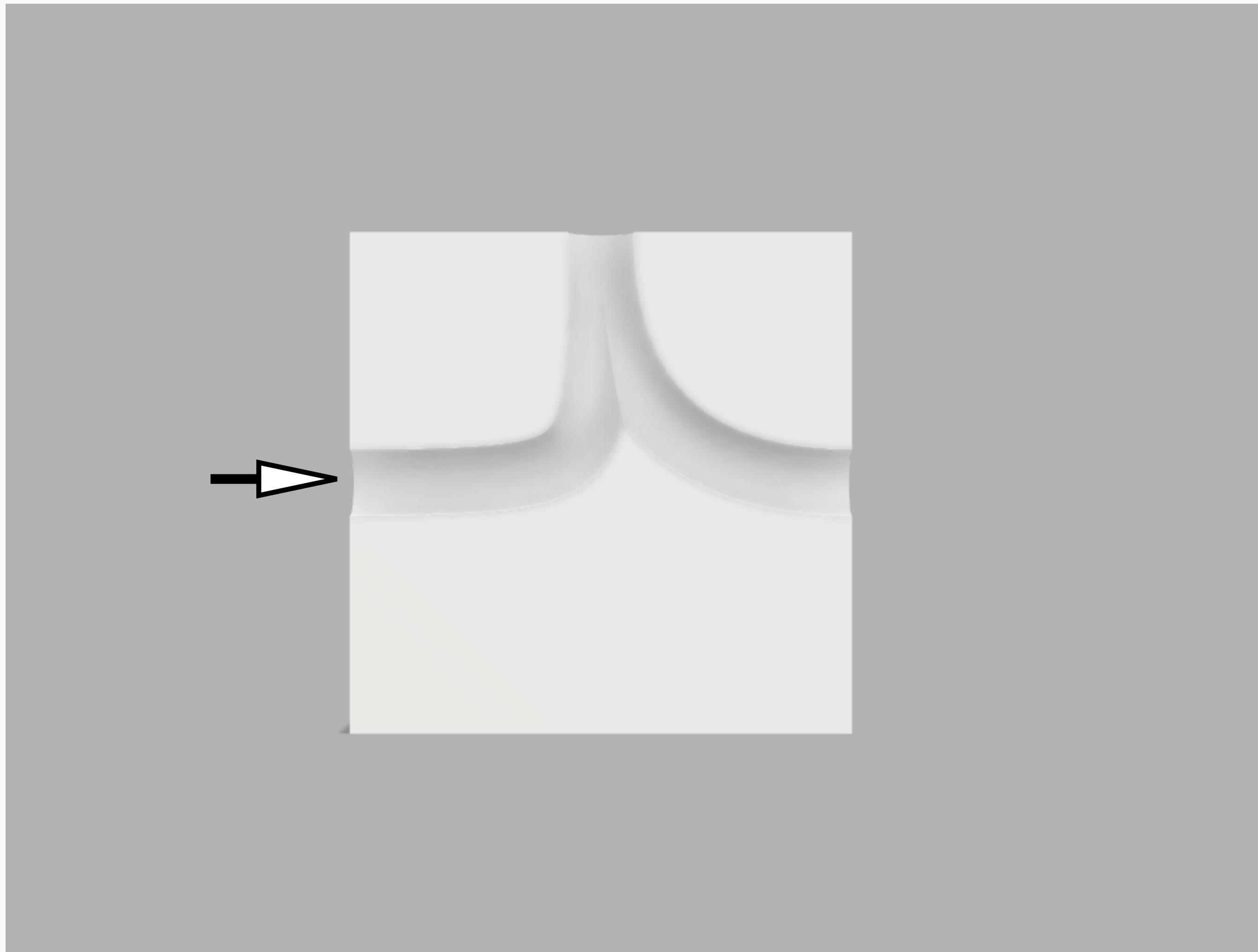


**Previous work is unaccessible**

# 3D-printed Logic Toolkit

# Components

# Input



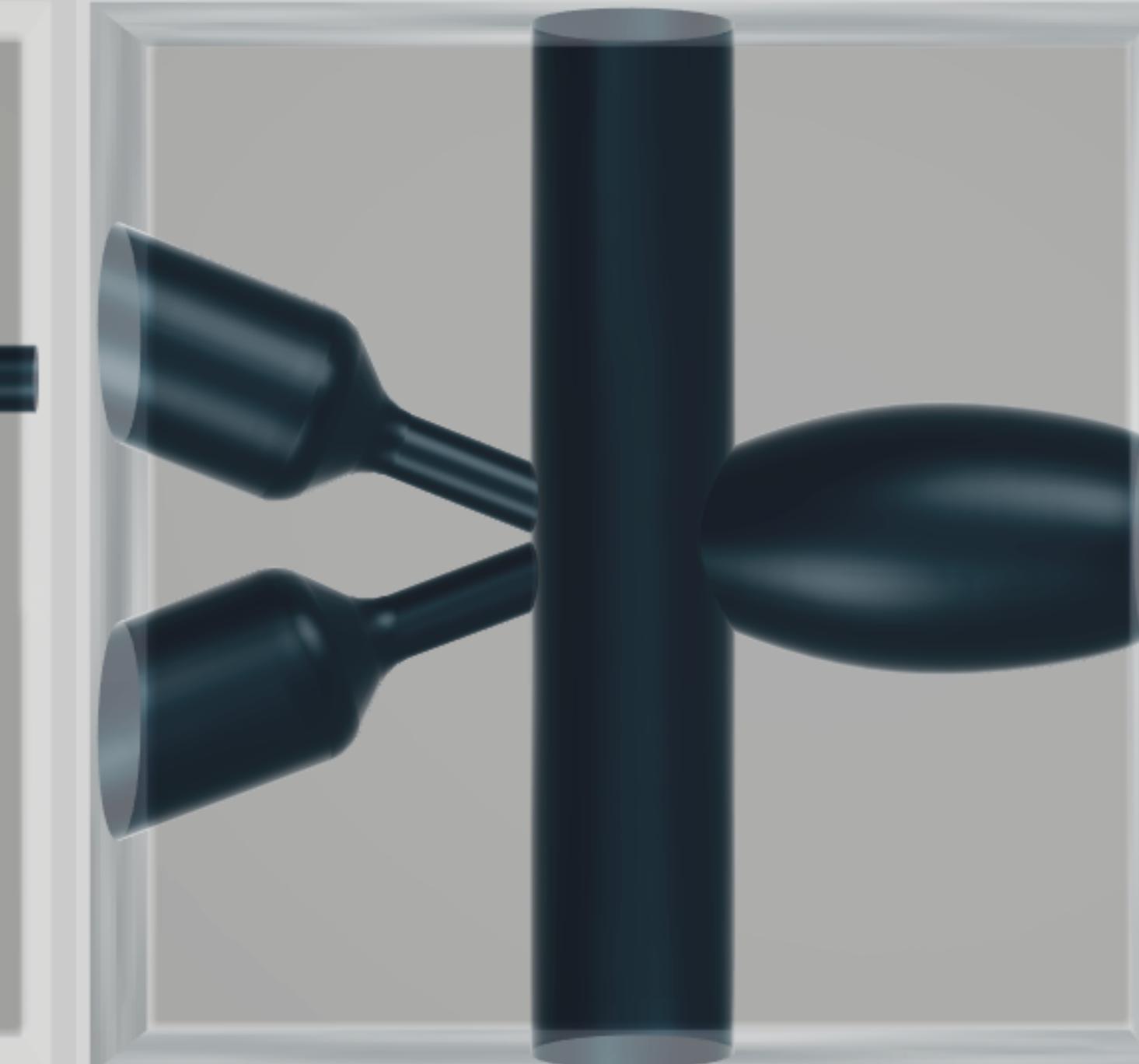
Touch

# Logic

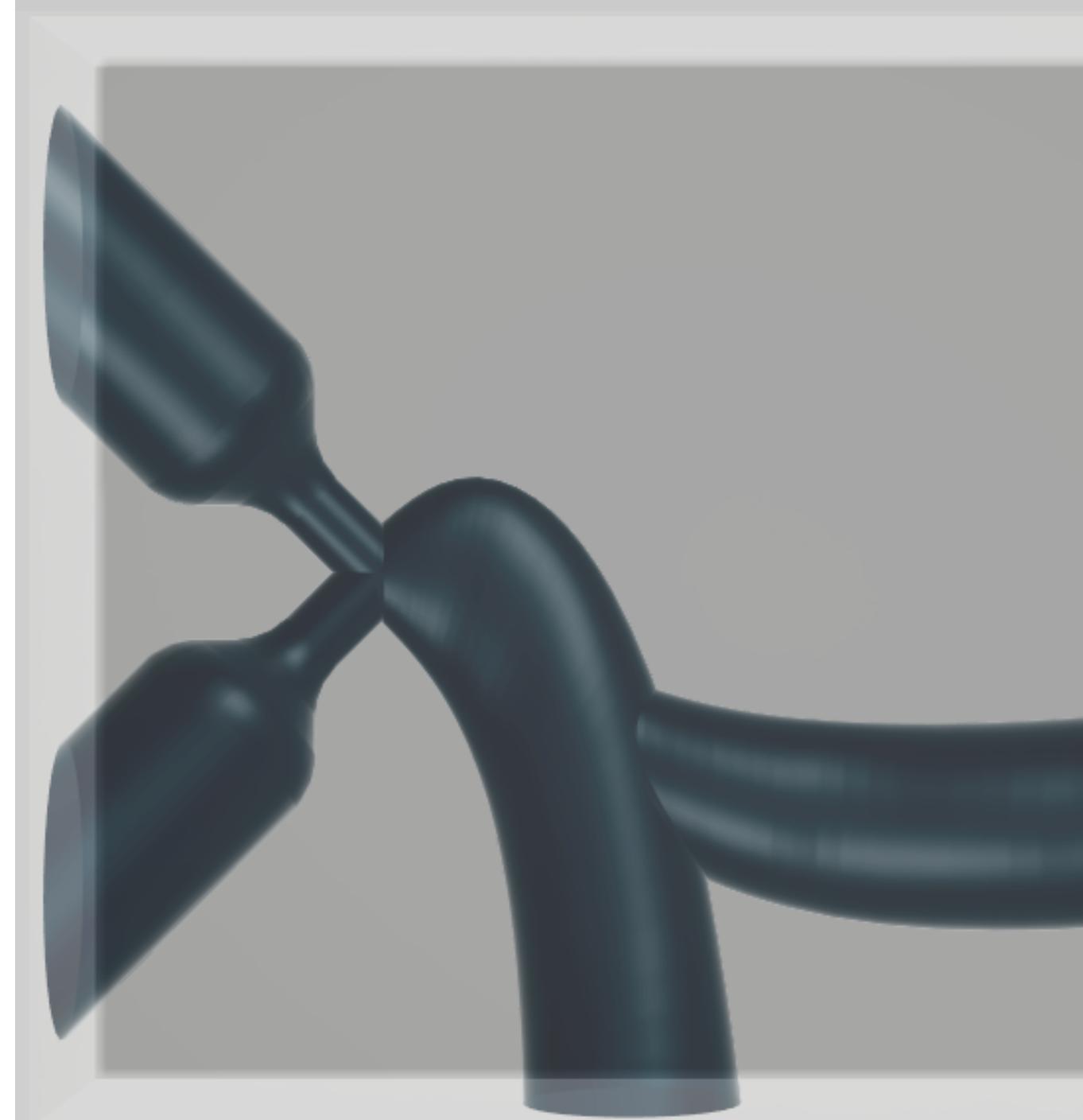
NOR



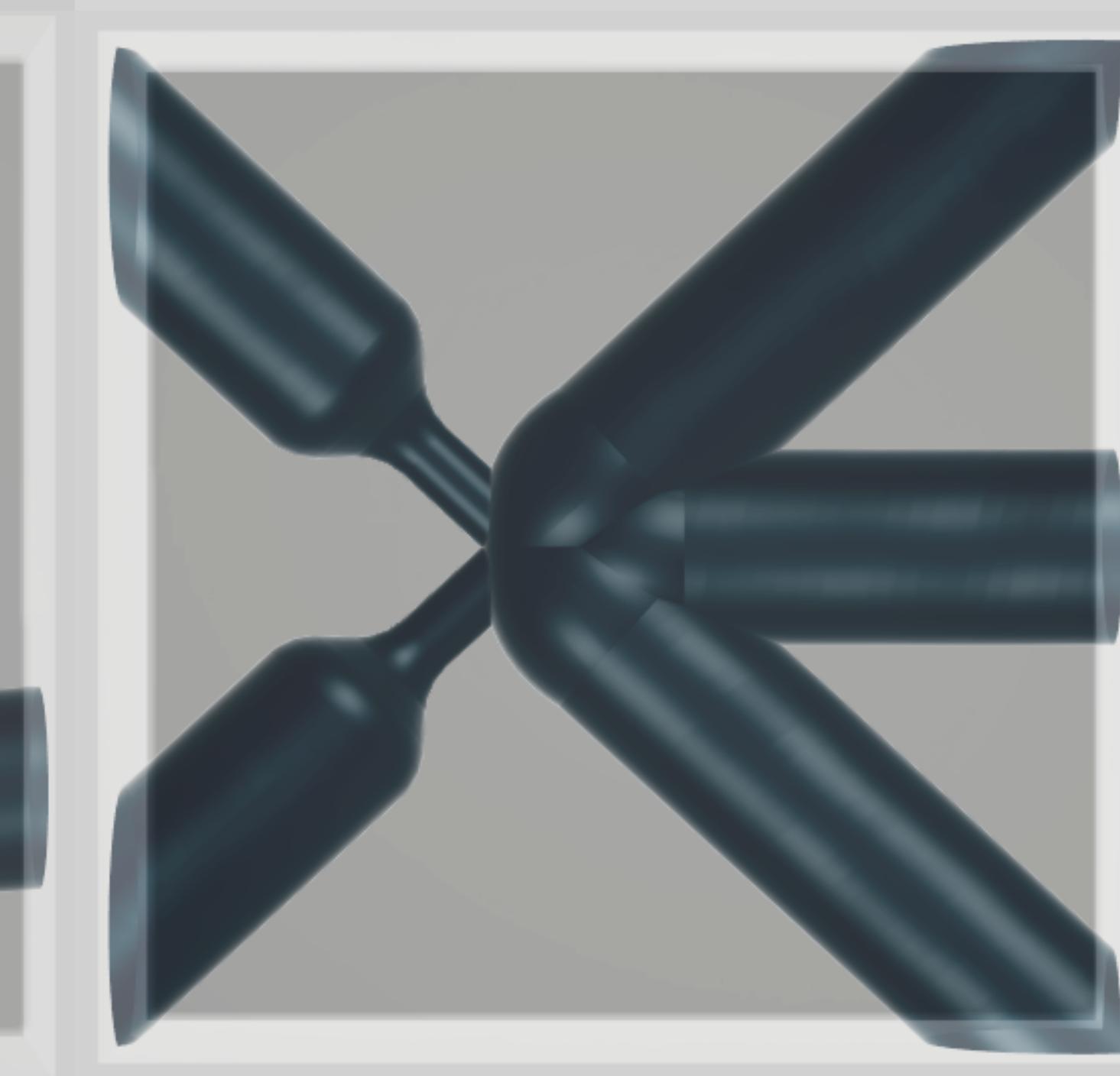
OR



XOR

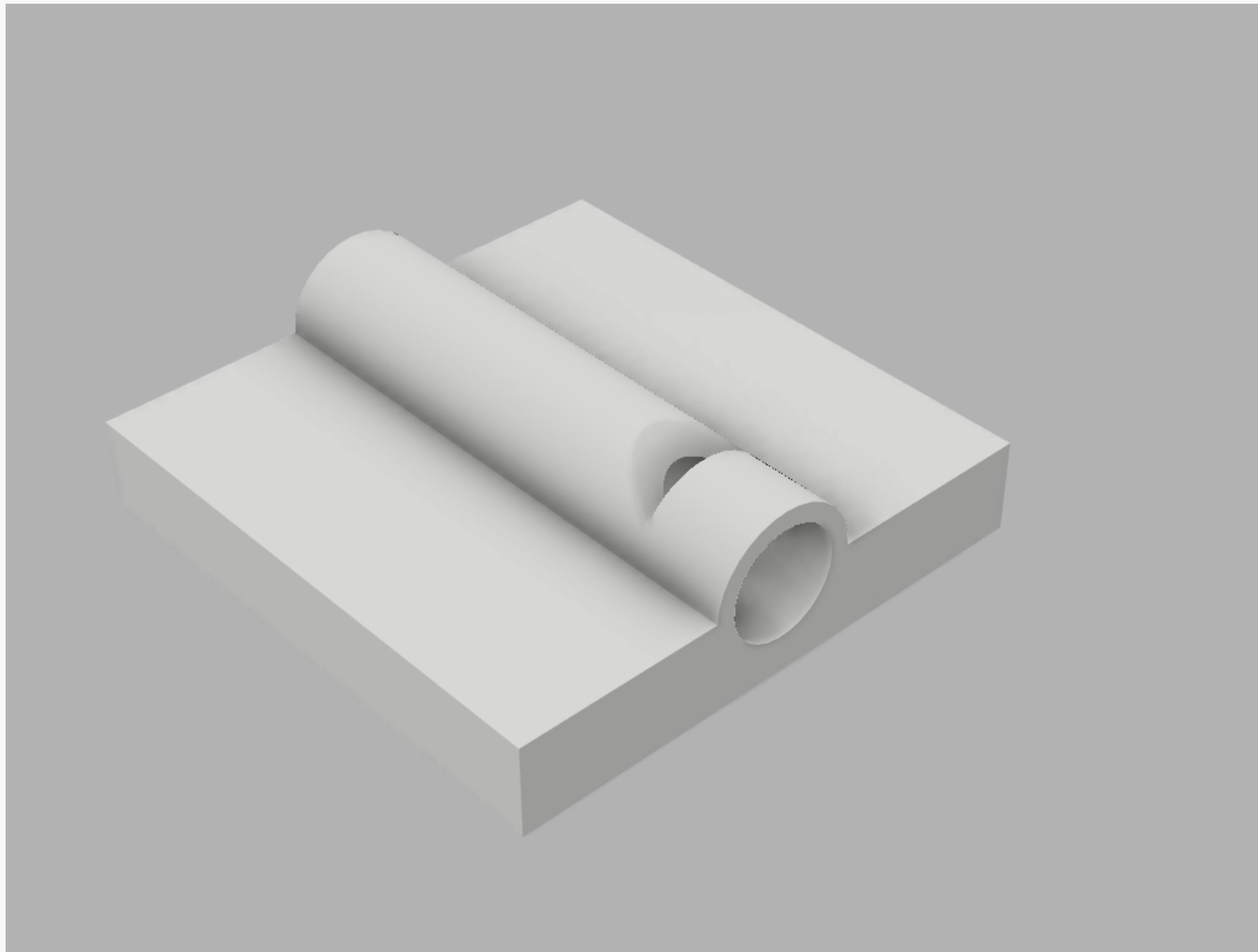


AND





# Output



Whistle

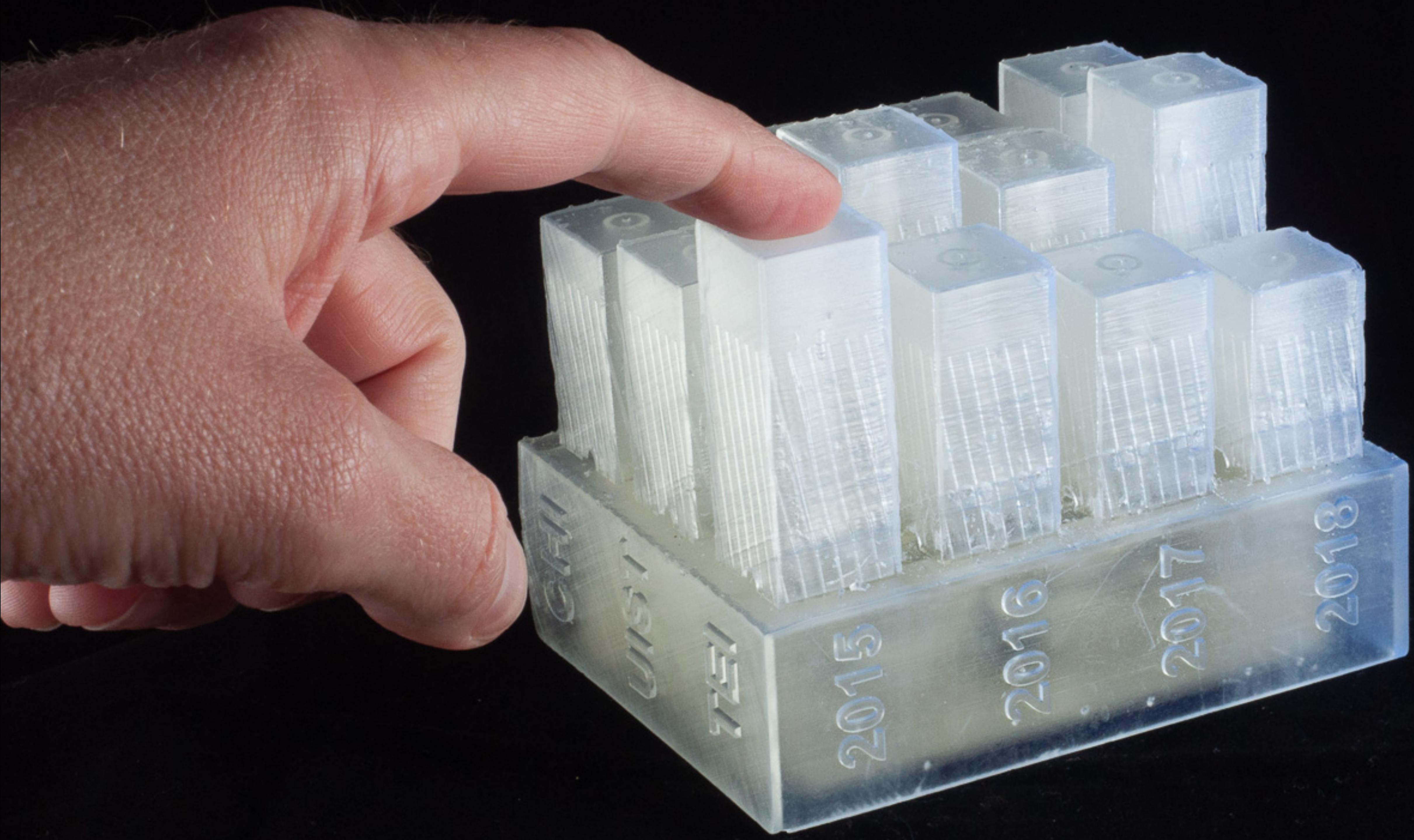
Translate components to 3D-model using  
design tool

# Research Agenda

Non-experts can create interactive  
artifacts in the physical world

# Sensing techniques

# Haptic Feedback



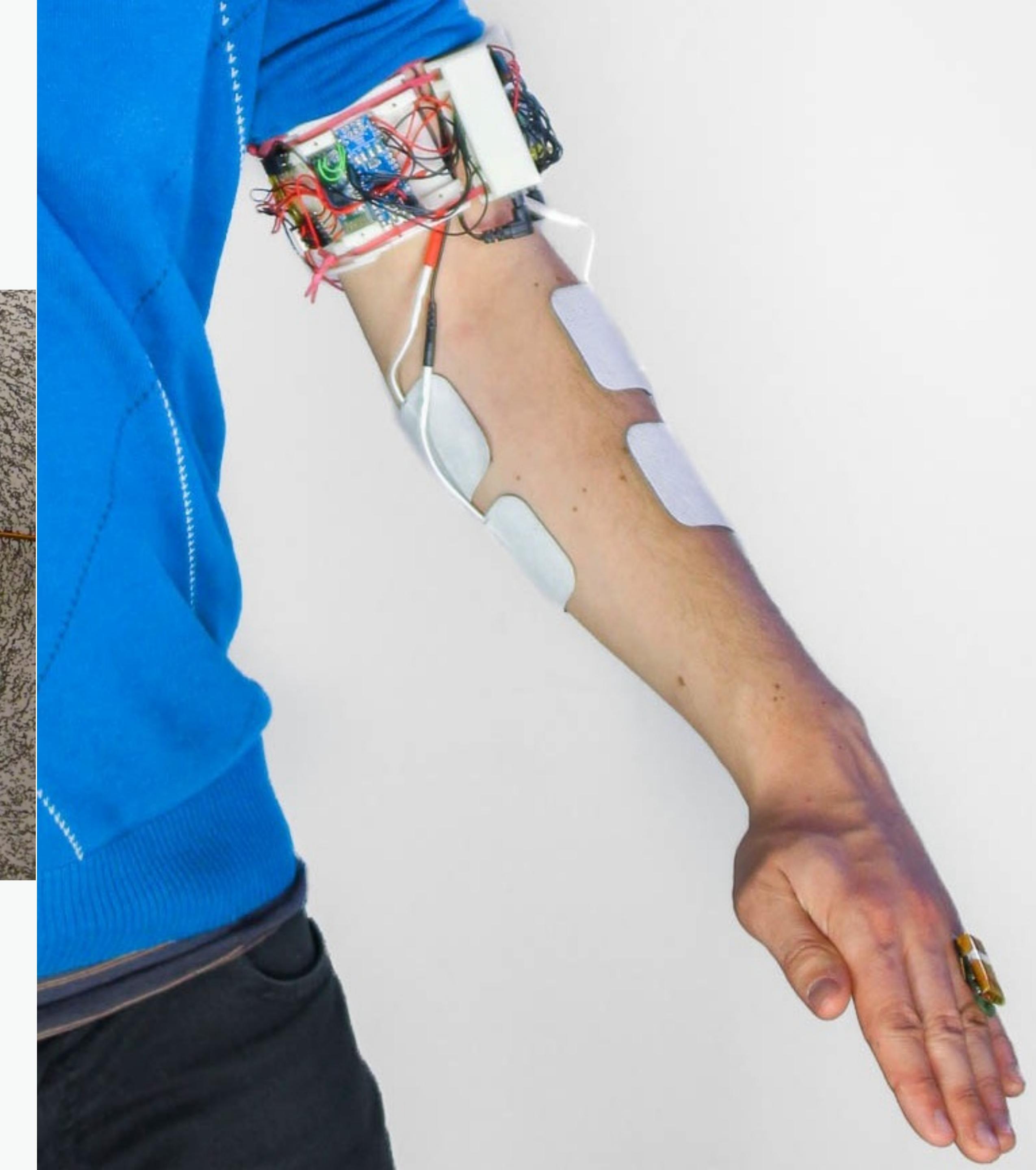
2015

2016

2017

2018







- Fabricate interactive objects using both conductive filament and regular plastic.
- Coil the conductive filament in locations of interest in the object.
- Instrument user with magnet.
- Sense changes in current generated by the interaction.
- Actuate magnet by inducing a magnetic field with the coil.

- Simulate haptic feedback by using electronic muscle stimulation.



# **Enabling non-experts to author tangible interactions**

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