

Xspine: Integrating Motion Sensing Capability into Dynamic Structures Using Multi-material FDM 3D Printing



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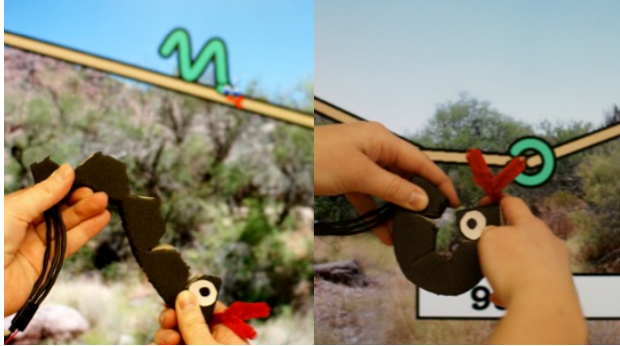
jiaji@mit.edu



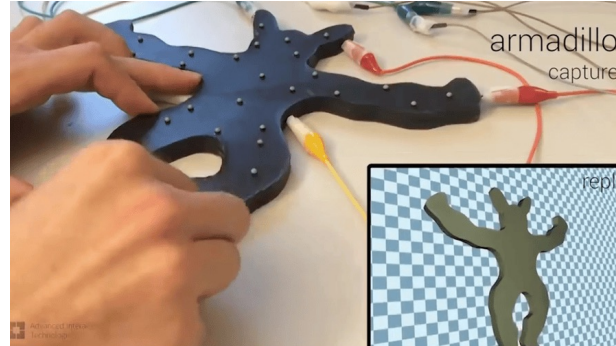
Bridge the physical and digital world



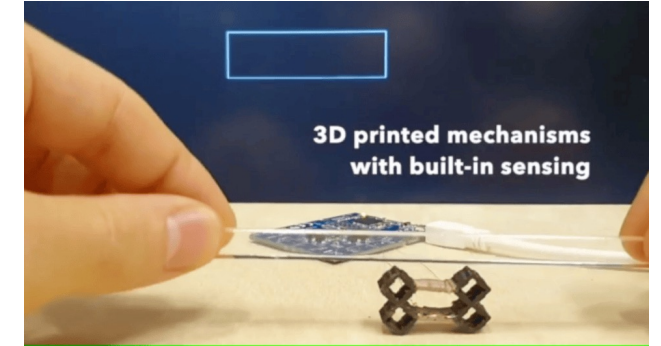
Related Works



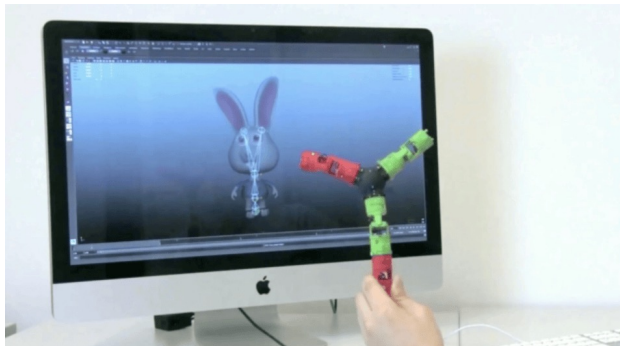
Sensing through Structure
Slyper et al. TEI'11



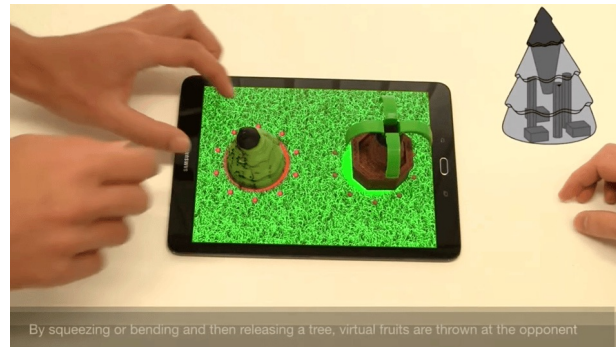
DefSense
Bächer et al. CHI'16



MetaSense
Gong et al. UIST'21



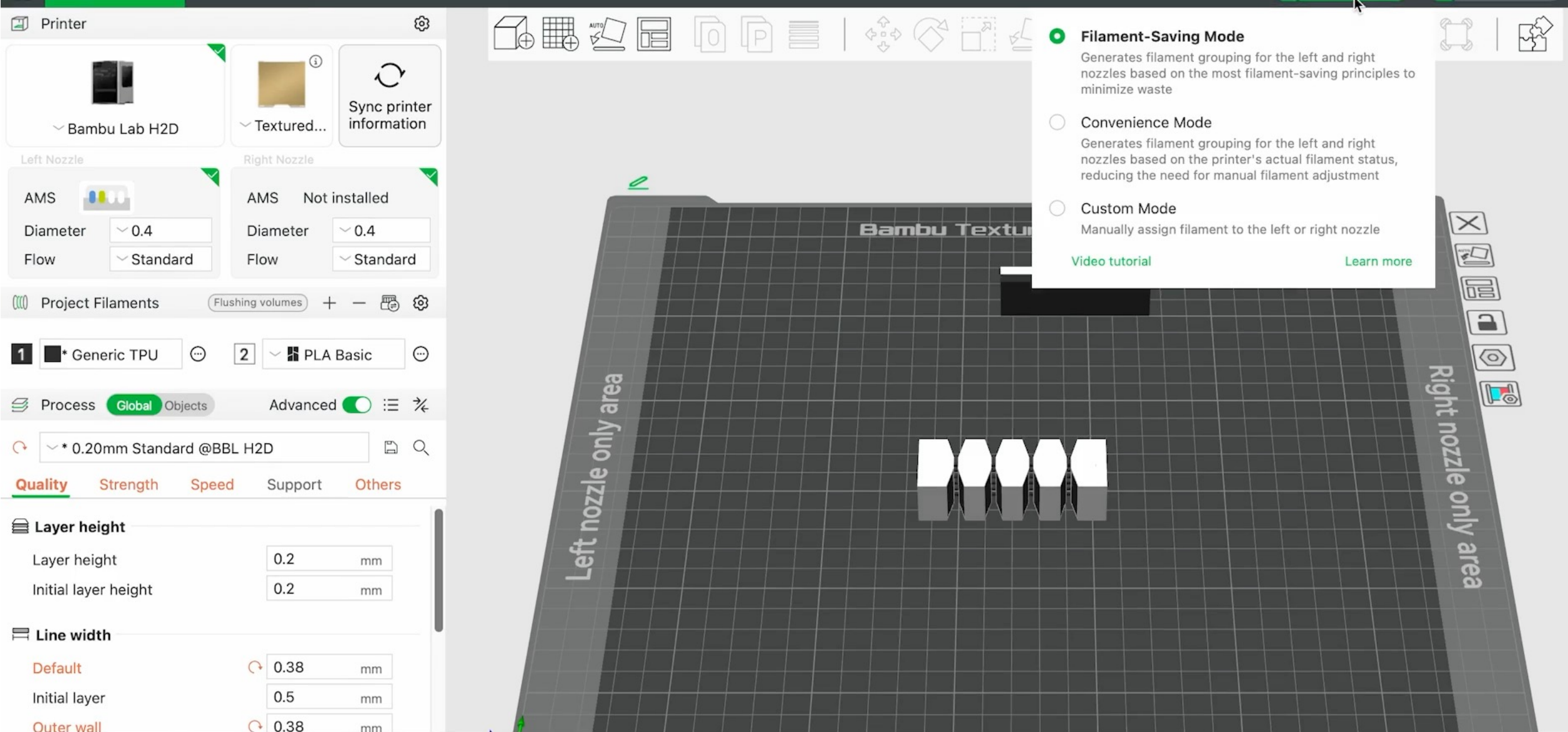
Rig animation
Glauser et al. TOG'16



Flexibles
Schmitz et al. CHI'17

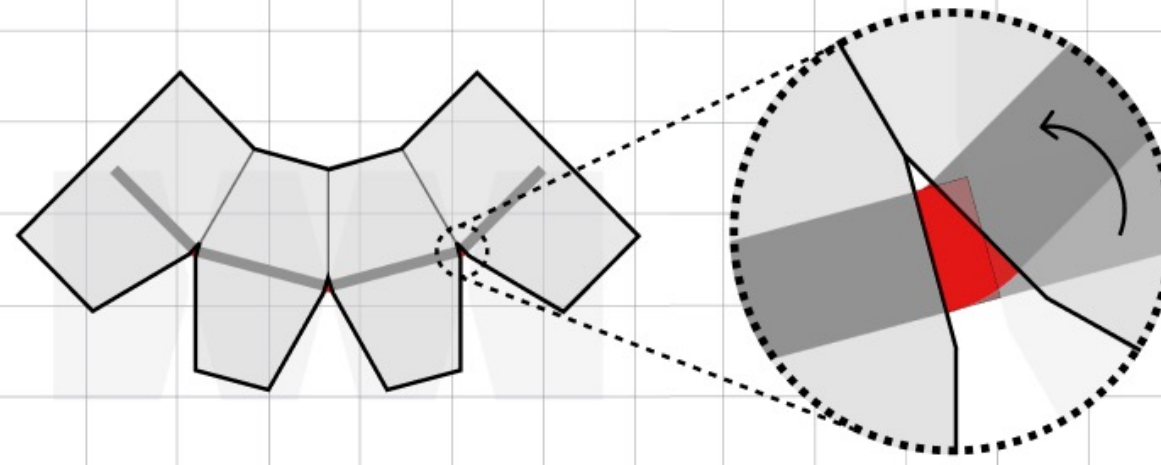
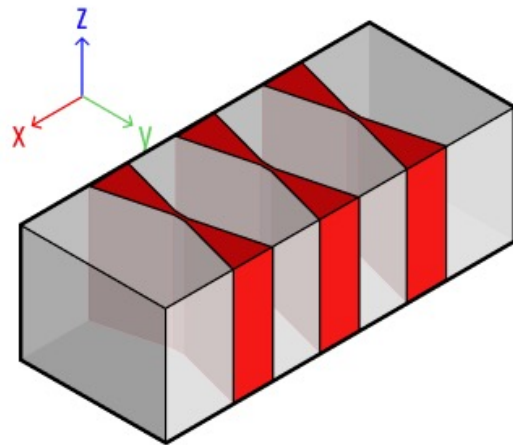
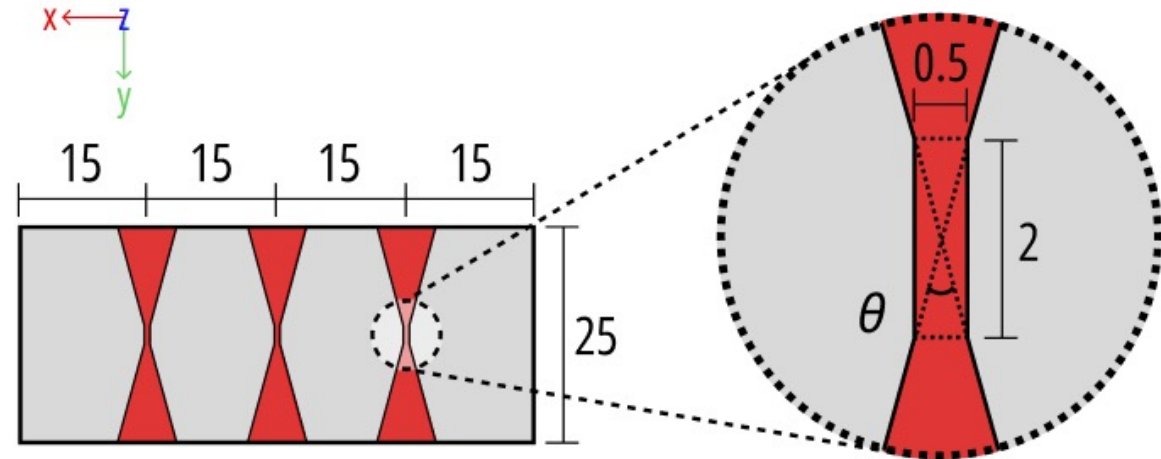
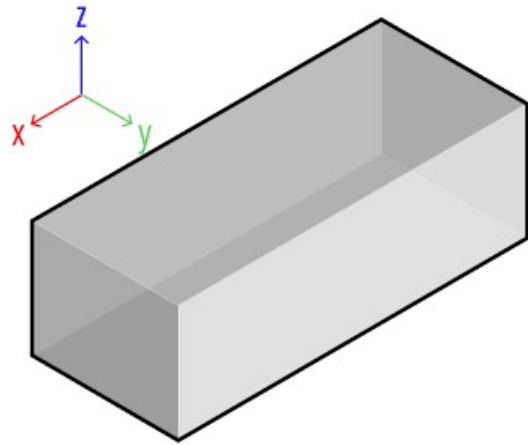


LattiSense
Sakura et al. SCF'23



We present **Xspine**, a design and fabrication method for creating **motion-capable, self-sensing** structures using multi-material FDM 3D printing with **conductive filaments**.

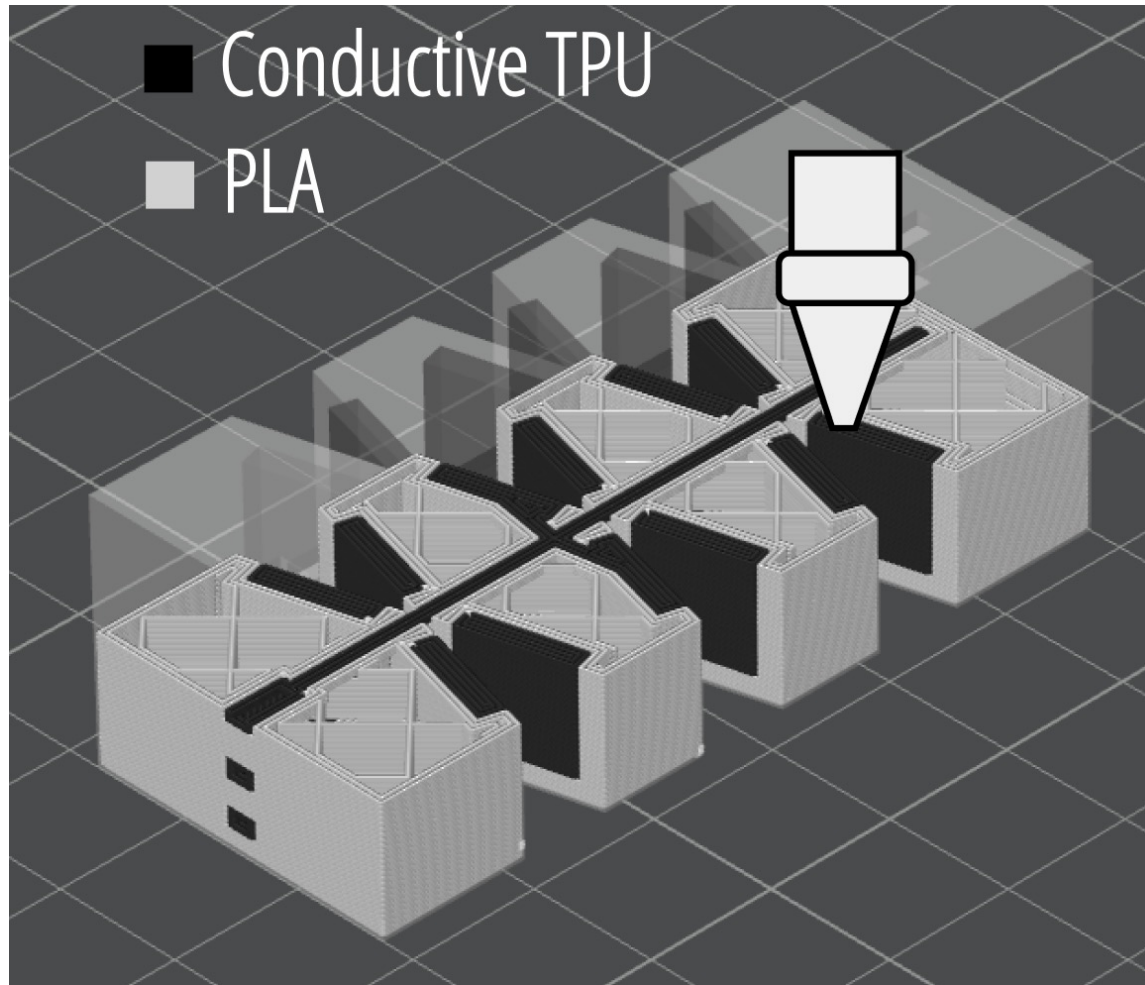
Generate Deformable Object



Adding Cut-outs for Contact

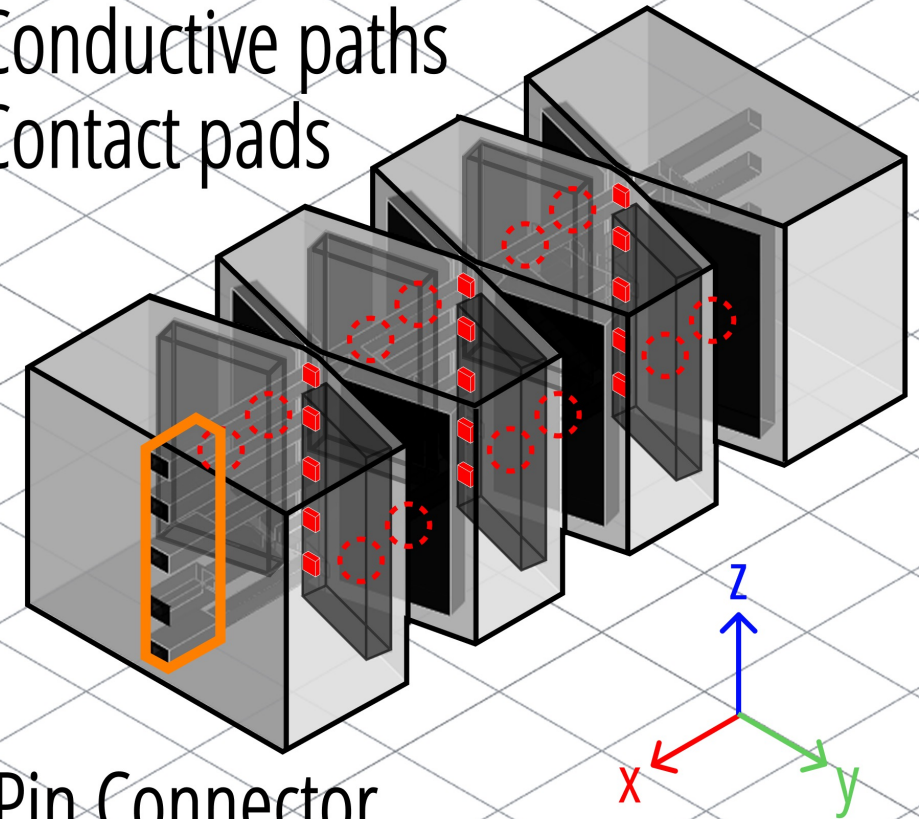
Adding Compliant Mechanism-Bridges

Circuit Design

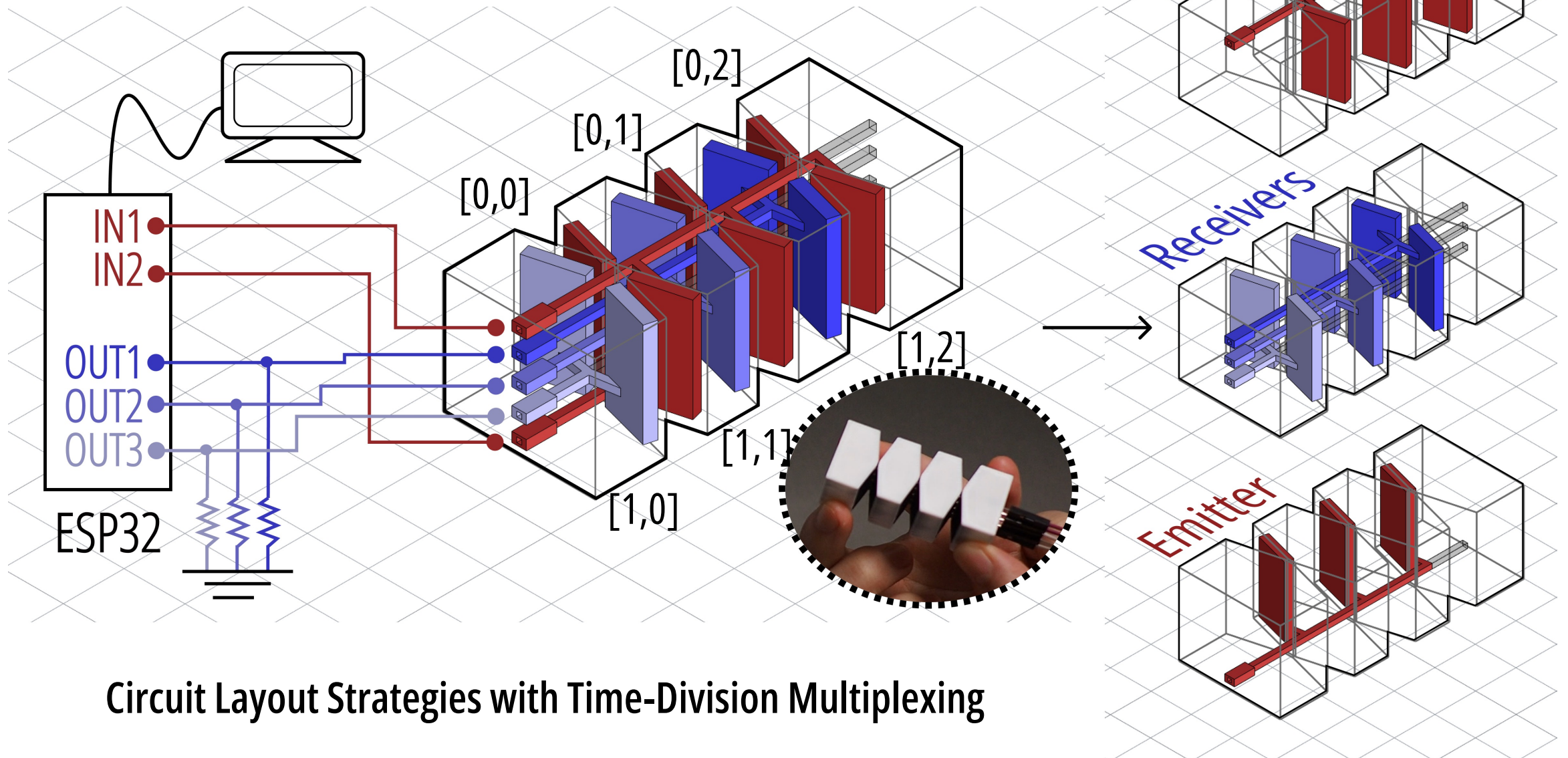


- Compliant bridges
- Conductive paths
- Contact pads

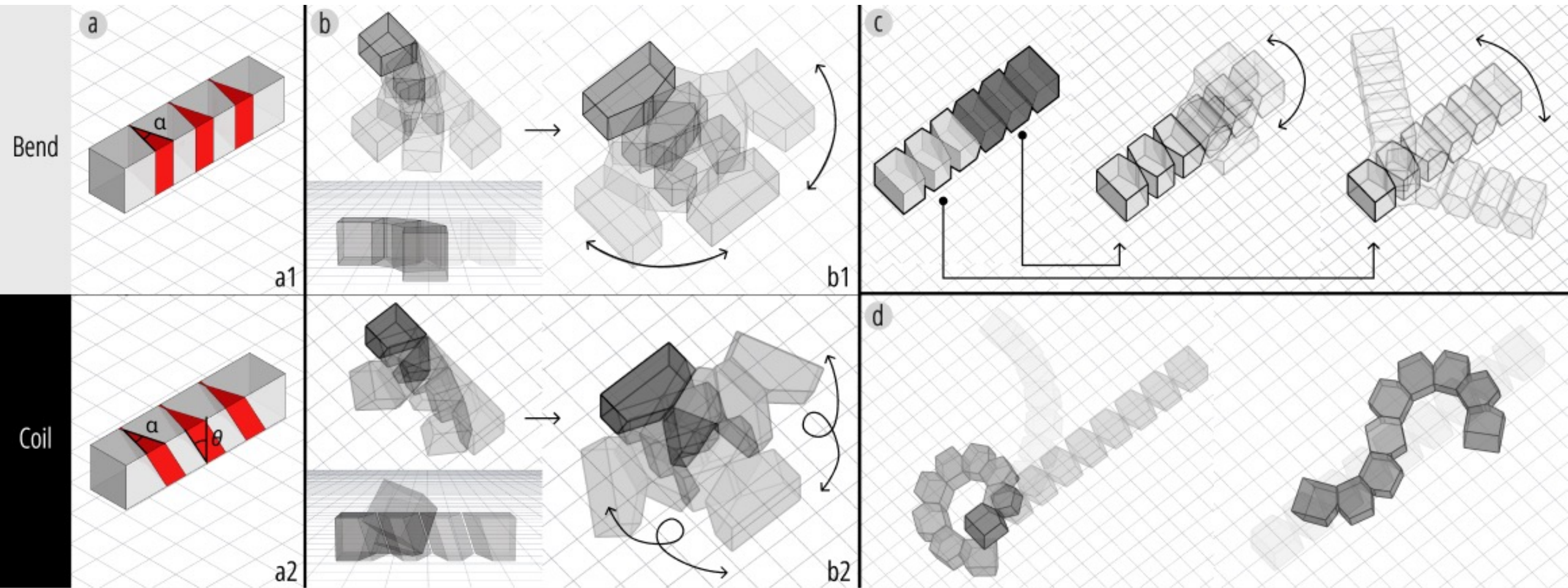
□ Pin Connector



Circuit Design

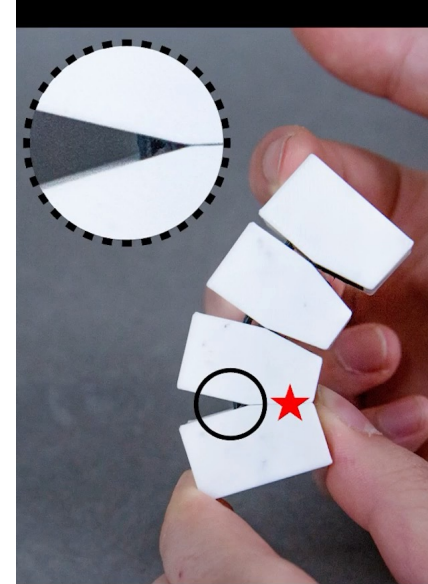
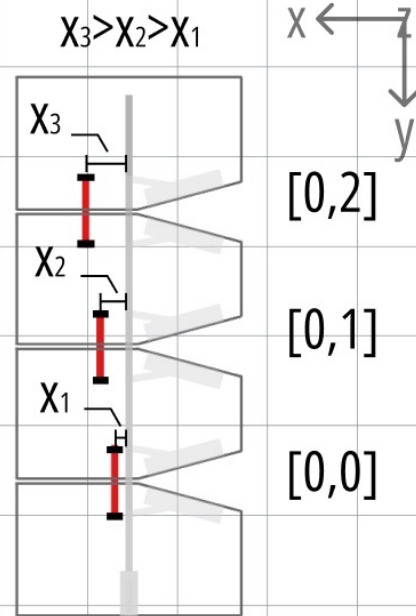
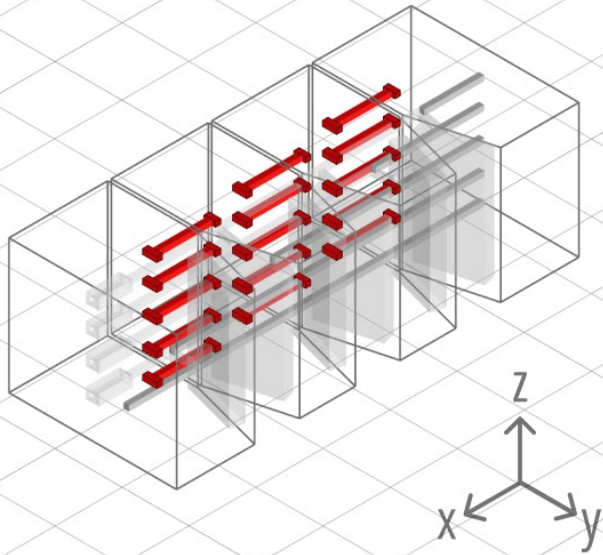


Motion Primitives



Physical Augmentation Strategies

— auxiliary cables

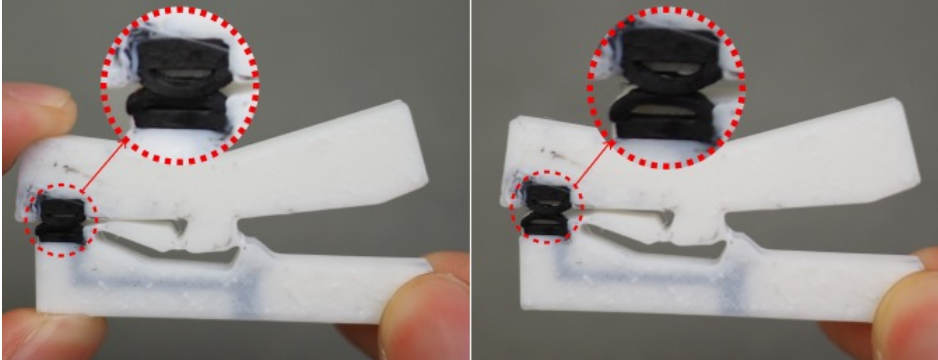
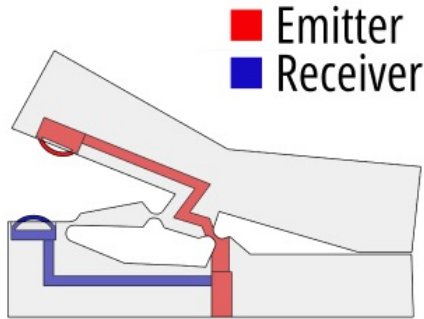


Force feedback customization uses **auxiliary cables** to control the effort required for interaction. This generates temporally graded signals, where the system **detects contact events in order** as force rises.

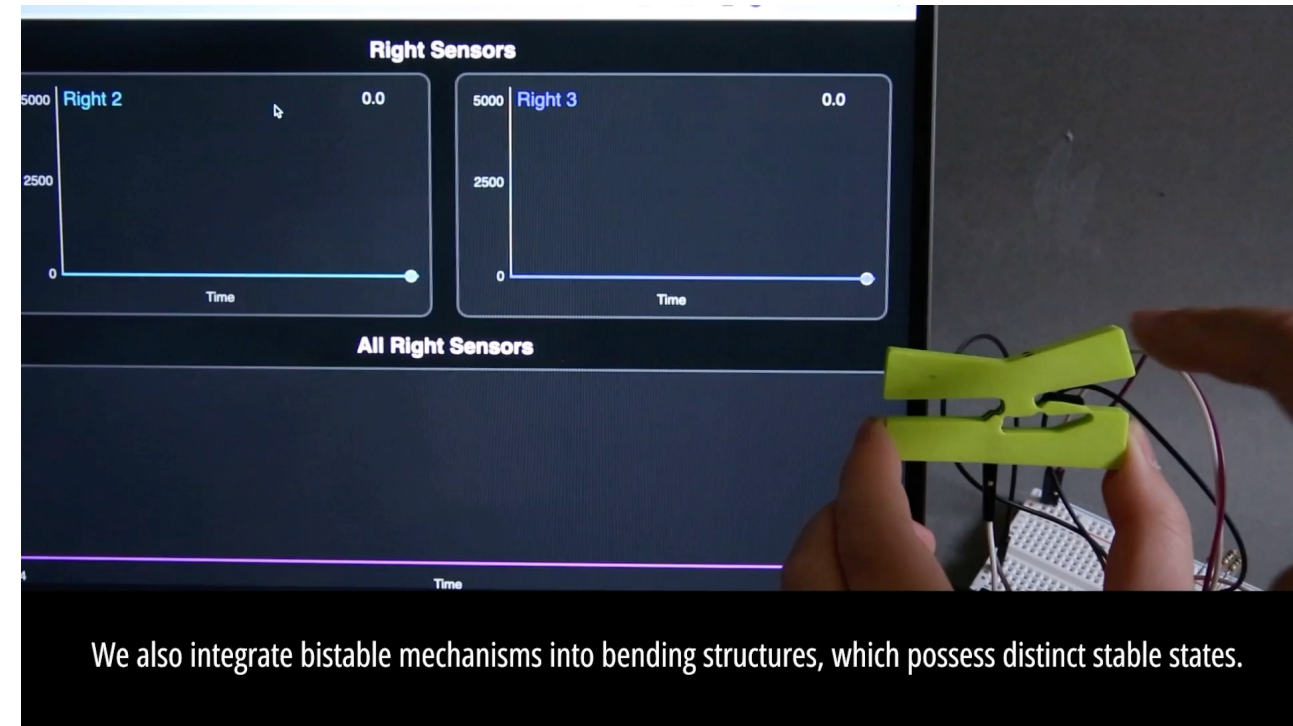
Auxiliary Cables

Signal Performance

Physical Augmentation Strategies

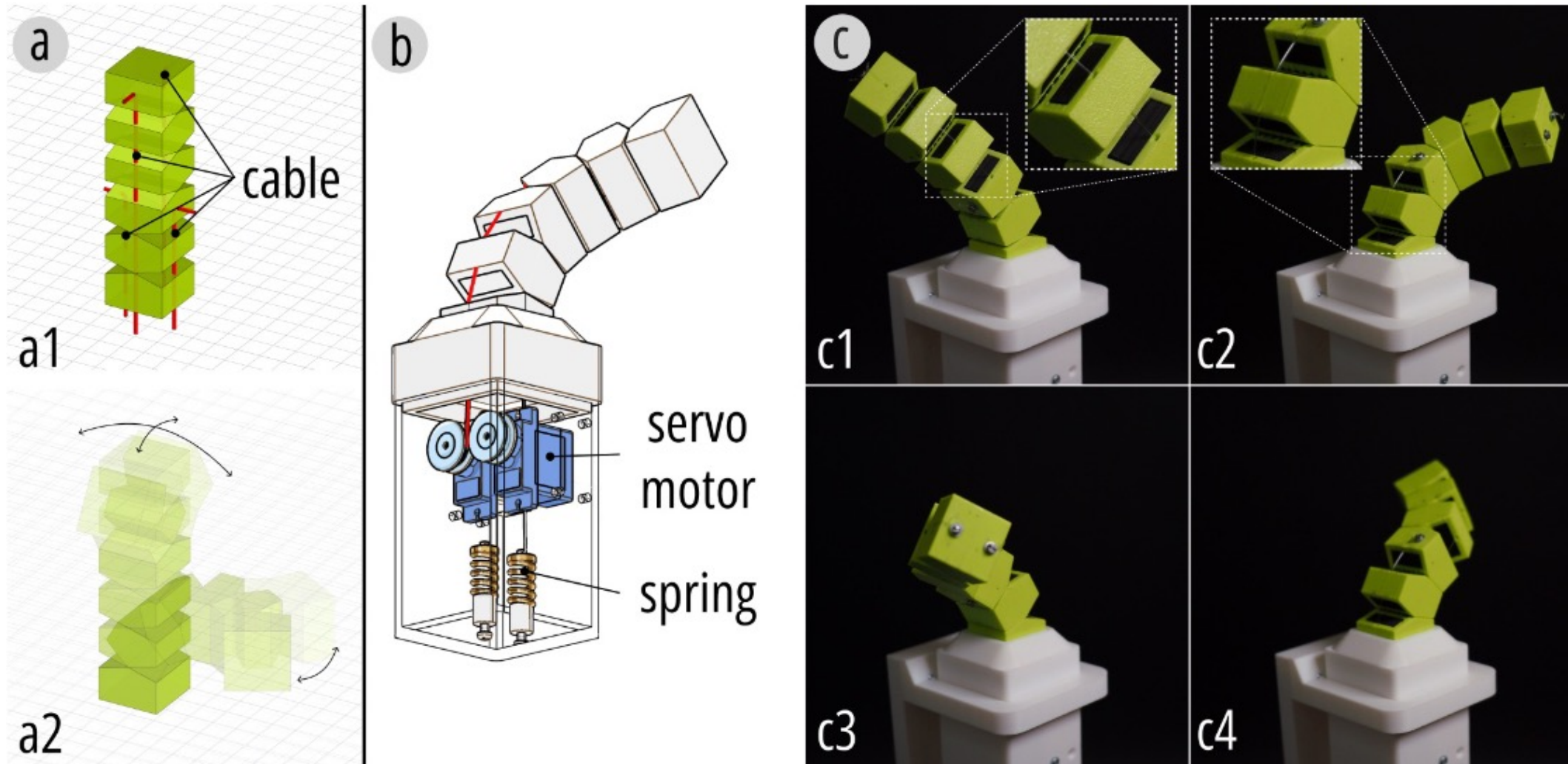


Bistable Design



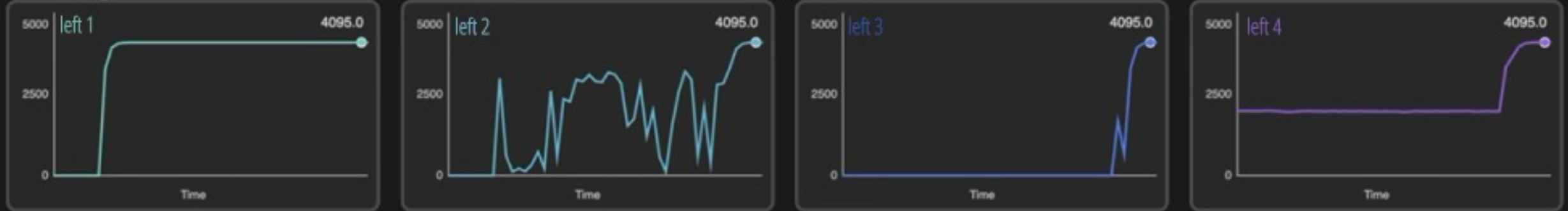
Signal Performance

Physical Augmentation Strategies

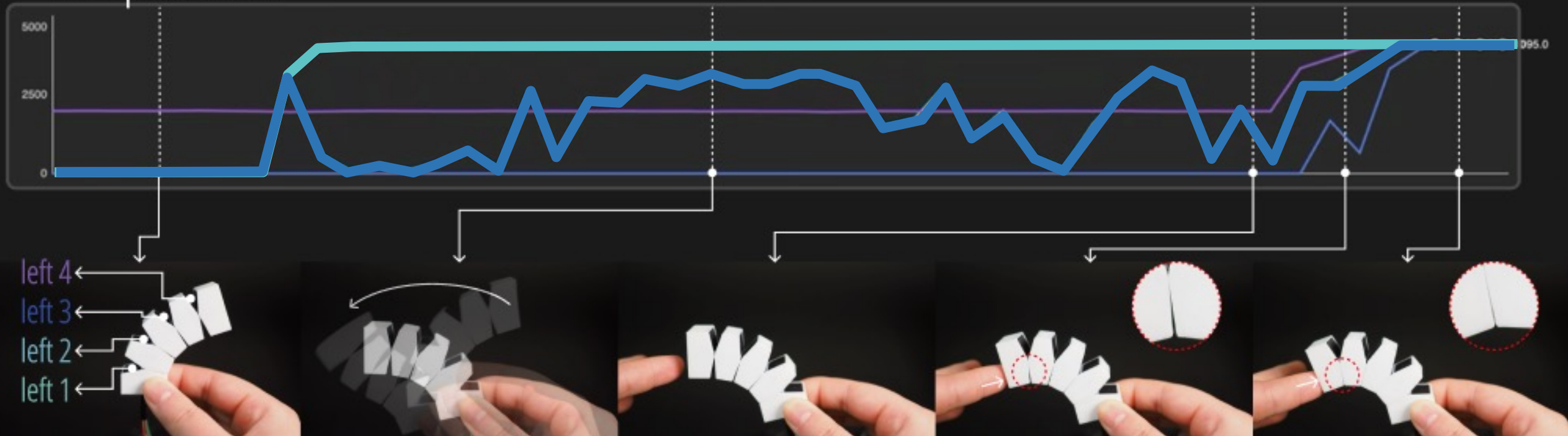


Digital Augmentation Strategies

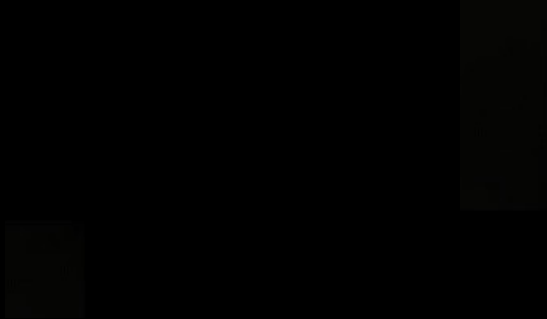
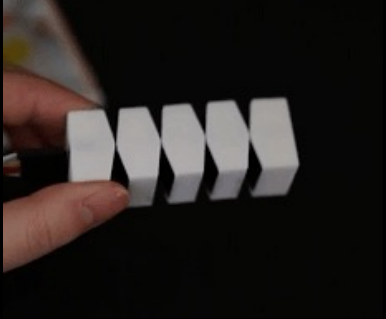
Single Sensors



Multiple Sensors



Digital Augmentation Strategies



Motion Setup

Number of Motions:

5

Trials per Motion:

20

Recording Duration (s):

3

Setup Recording

Start Recording Stop Recording Reset Session

Motion Setup

Recording Process

Progress: 0/100 recordings completed

Motion2 Motion1 Motion5 Motion2 Motion3 Motion2

Motion1 Motion4 Motion3 Motion3 Motion2 Motion5

Motion1 Motion4 Motion3 Motion3 Motion2 Motion5

Motion Data

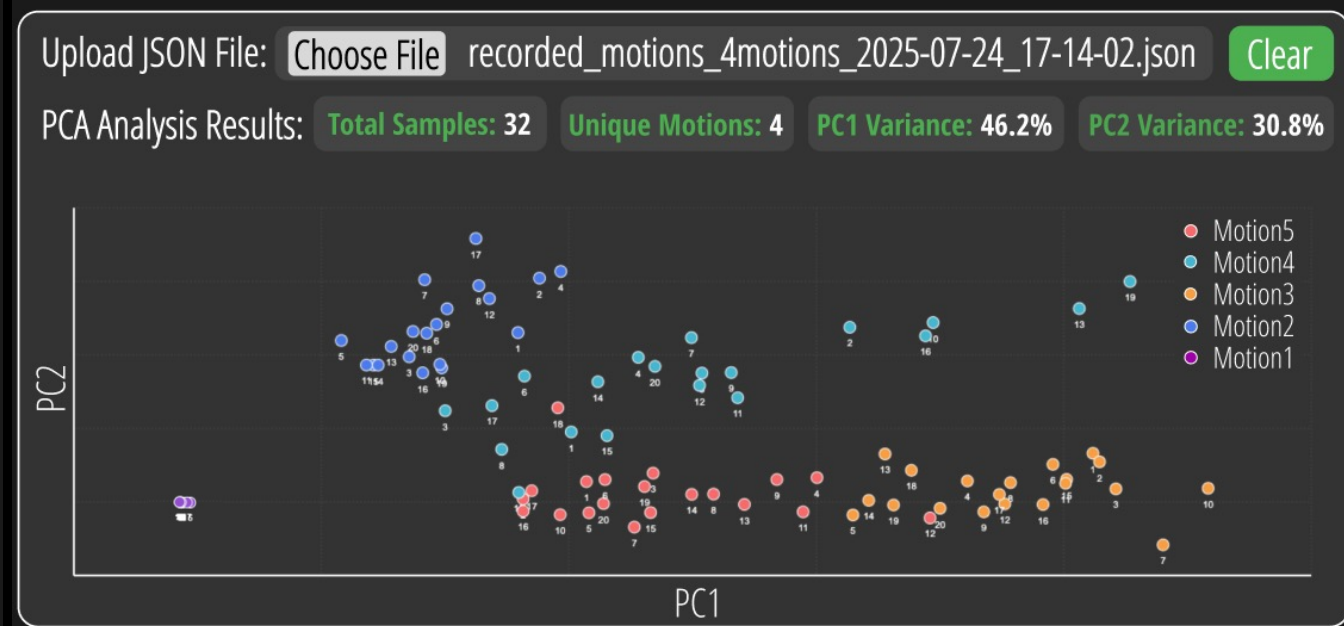
Motion 1

2

Get Ready!

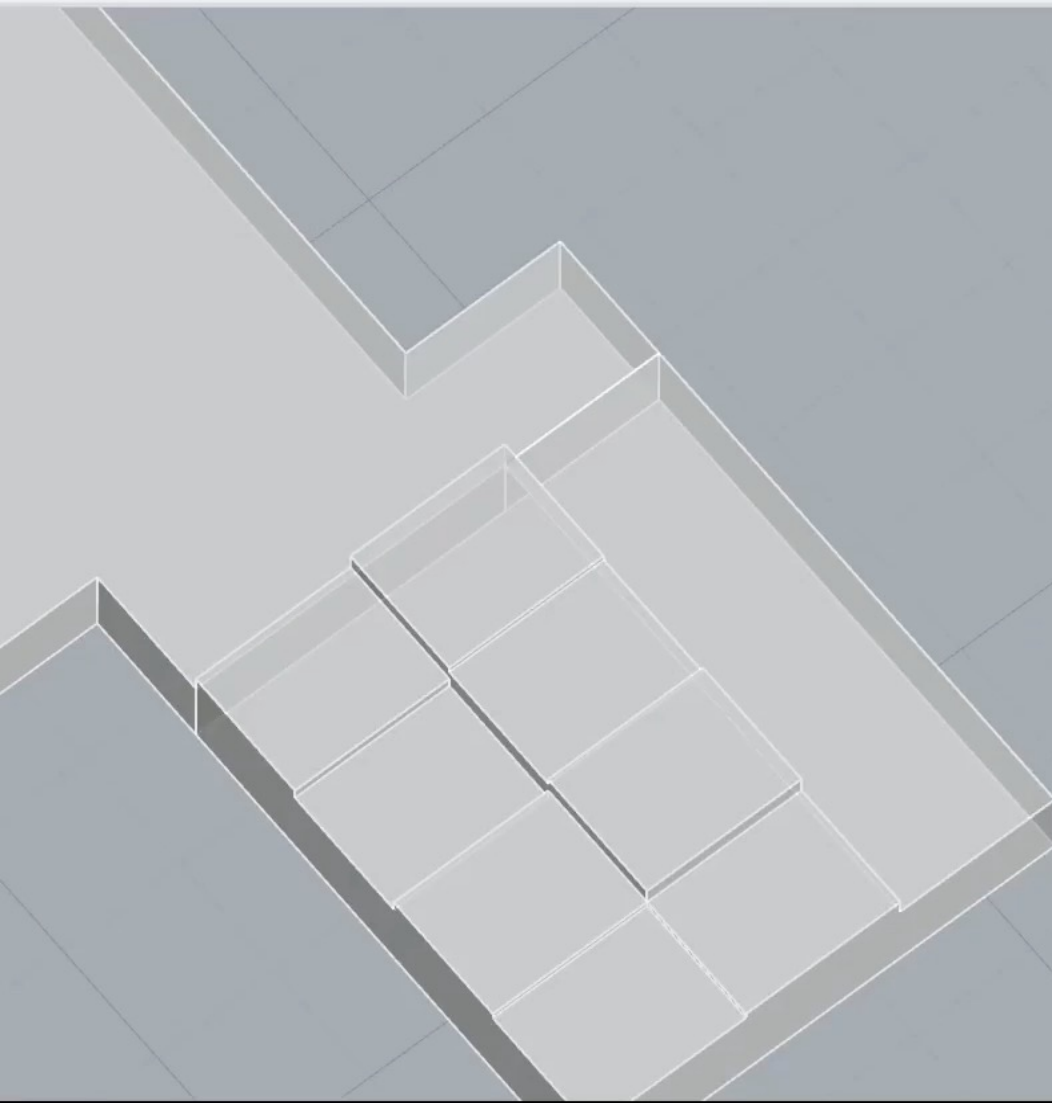
Left 1 Left 2 Left 3 Left 4 Right 1 Right 2 Right 3 Right 4

Record Data



Preview Data

Design Tool



We develop an **interactive design tool** that allows users to configure motion behaviors, preview structural responses, and generate printable circuits.

Customizable Game Controller

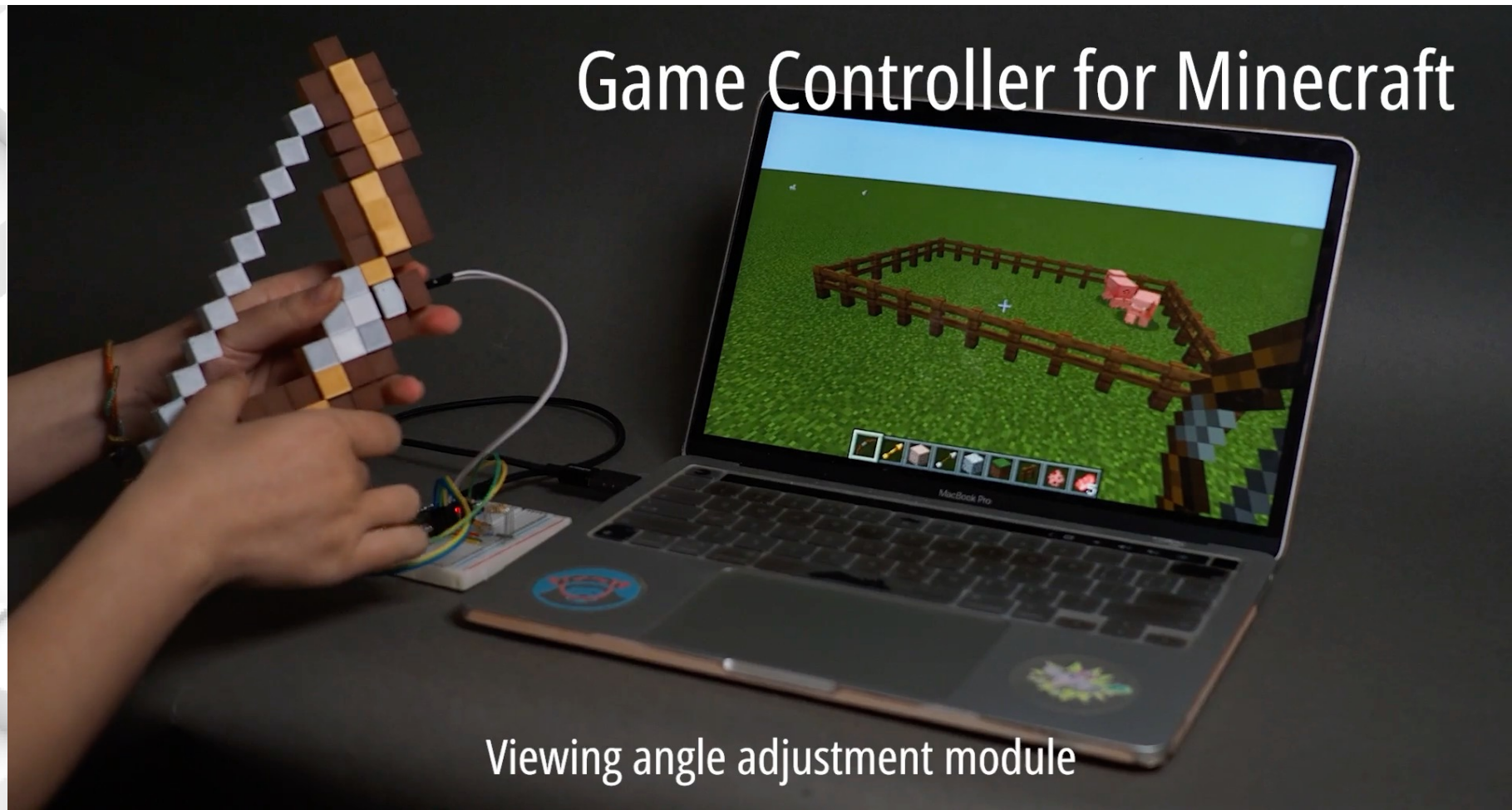
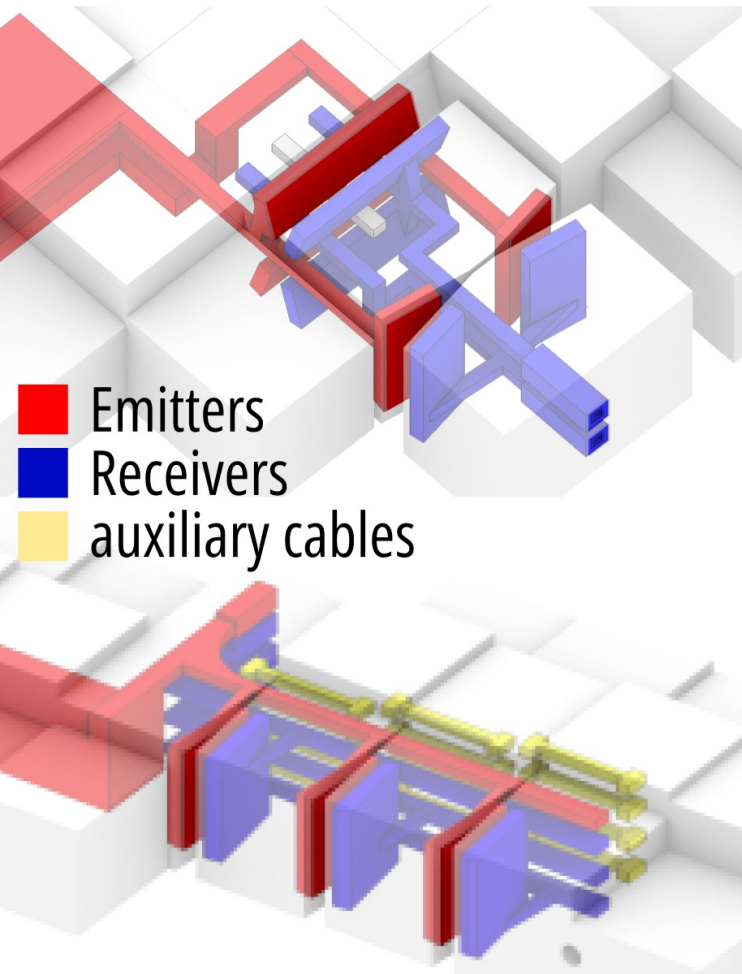
We demonstrate several **example applications** that showcase the flexibility and interactive potential of our method.

Applications

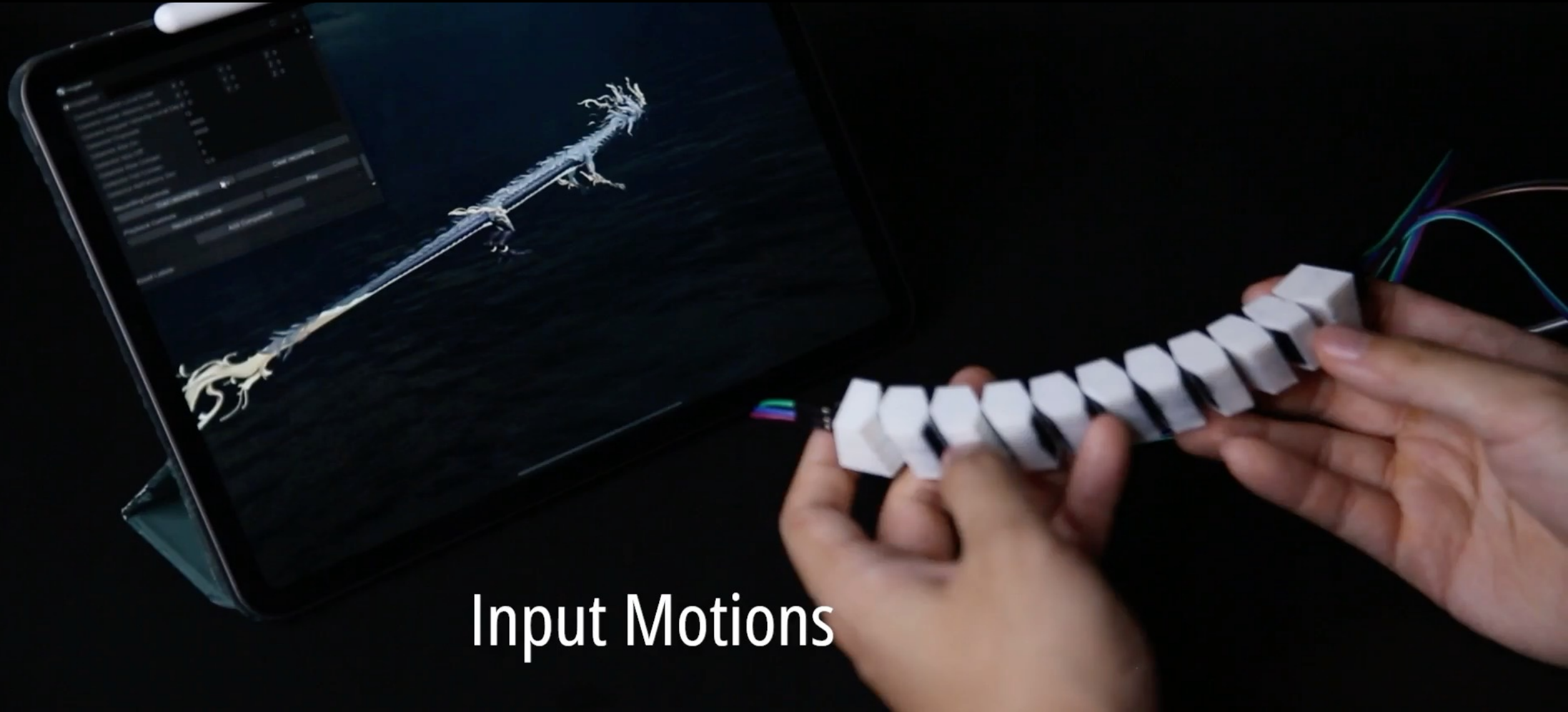
Bistable Lamp



Applications



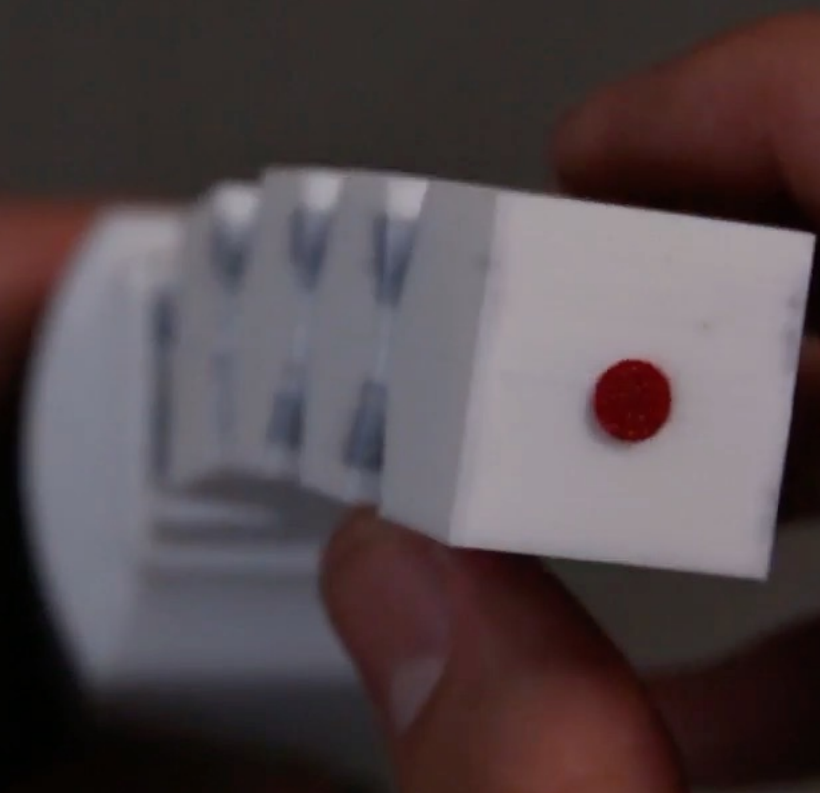
Applications



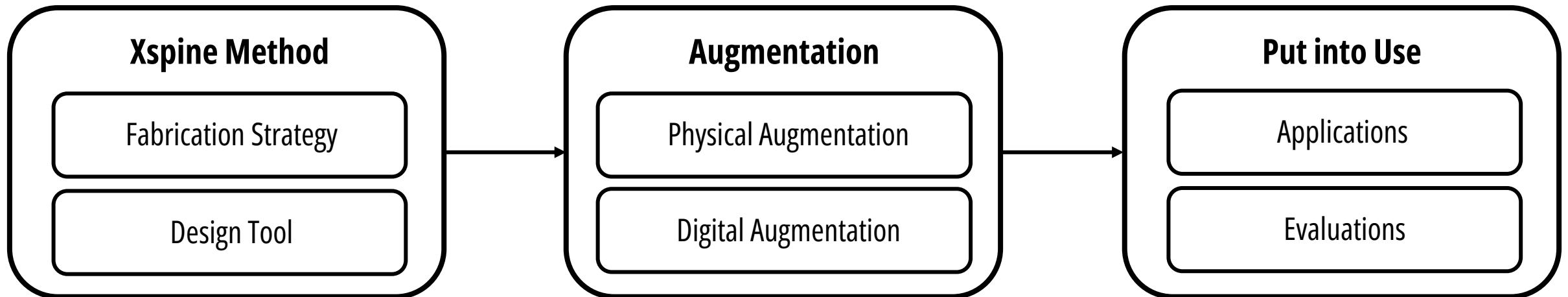
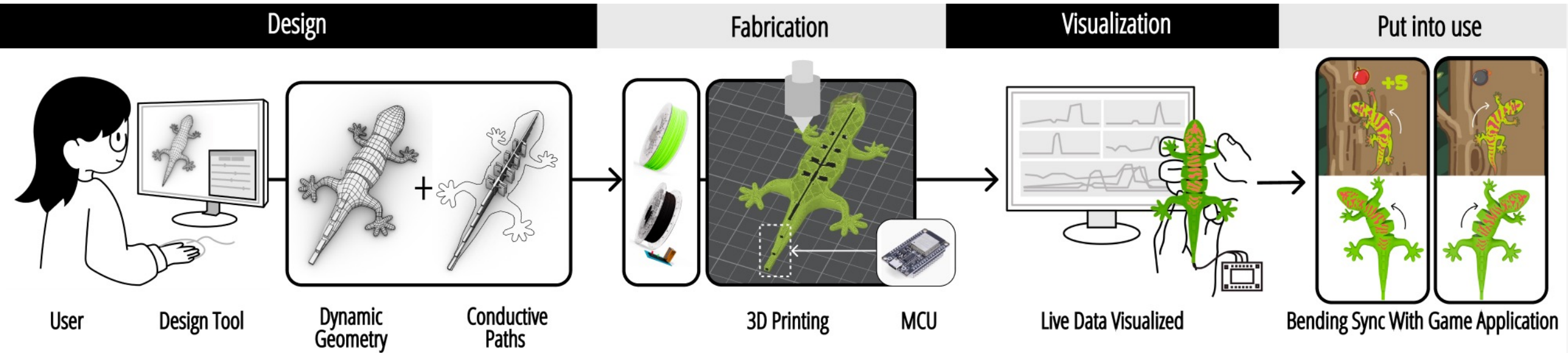
Input Motions

Applications

Input

A hand is holding a small, white, cube-shaped sensor. The sensor has a red dot on its side. It is connected to a white cable that has several similar sensors attached to it. The background is a plain, light-colored surface.

Xspine Method





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