

MUDRAMOR: FEATHER INTERFACE FOR PERVASIVE COMPUTING NETWORKS

Associated with *"The Zoo - Functional Prototyping with Electronics SoSe2025"*

Shriya Singh

M.Sc. Human-Computer Interaction
shriya.singh@uni-weimar.de

Note: We used ESP-Now to enable a pervasive computing network. This protocol supports multiple network topologies: one-to-one, one-to-many, and many-to-many.

Ever thought about having a silent alternative to door bell like a visual notifier? My project explores such a device...with room for modification to commercialize it, not only as an art installation but rather as a functional part of a smart home (e.g., the spring pockets could be pen holders, weighing sensor could weigh keys)

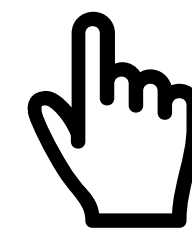
ABSTRACT

This report presents Feather Interface for Pervasive Computing Networks, *MudraMor*, a poetic exploration of tactile interaction inspired by the motion and symbolism of peacock feathers.

Rooted in my personal experience of growing up in India, this project traces the journey of MudraMor from early idea generation, i.e., choosing animals as inspiration to iterative prototyping of a feather-based communication device. I will discuss the design challenges, ideation dead ends, and evolving decisions that led to the final system: a device that sends messages through subtle, minimal gestures like lifting a feather or placing a paper cup.

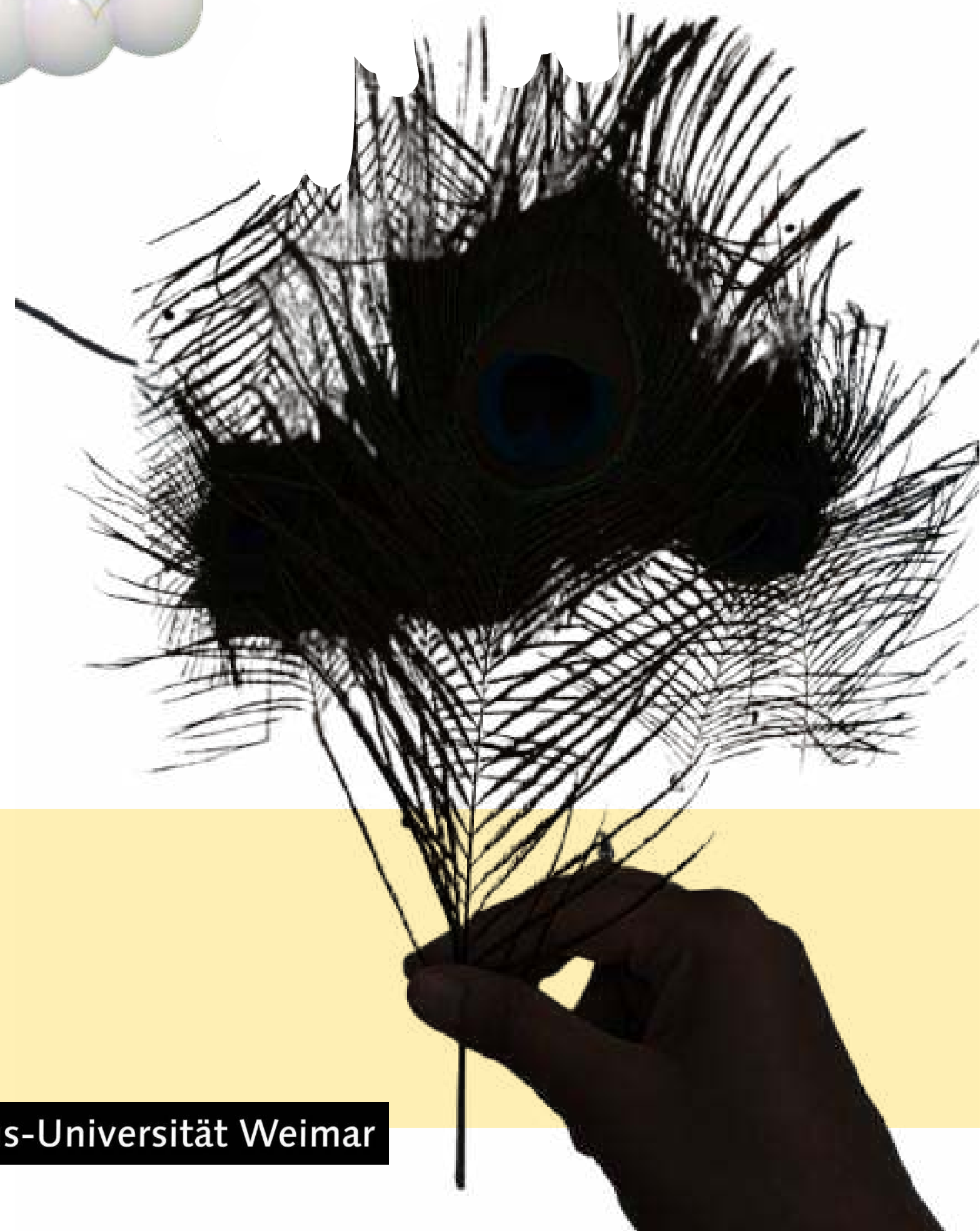
The report details how different components (weighing sensor, spring contact, servo feather fan) were integrated, and how symbolic motion became interactive functionality. The outcome is a networked, embodied interface that embraces low-effort input and aesthetic expressivity.

The closing sections reflect on what didn't work, key learnings, and future directions for improvement and where I will be bringing together theory, technical detail, and personal narrative into one cohesive work. So Stay tuned!



MOTIVATION & RELEVANCE

The inspiration for MudraMor stems from my desire to reimagine interaction through lightweight, poetic (touchless) gestures. Drawing from artist Rebecca Horn's feather sculptures, my project connects tactile computing to childhood memories of peacocks in India, where they are both culturally revered and visually arresting. Their feathers are iconic, shimmery, full of motion and they evoke a powerful medium for expressing digital interaction in a calm, embodied way. The project also aligns with broader HCI themes like tangible interaction, zero interface, and calm technology essentially pushing interaction design beyond screens and voice commands.



GOAL OF THE WORK

- To explore new interface modalities using minimal, tactile gestures
- To build a working prototype that sends and receives messages using feathers, springs, and weight
- To investigate emotive expression through mechanical motion (feather fan)
- To integrate interaction and symbolism into a unified tangible device



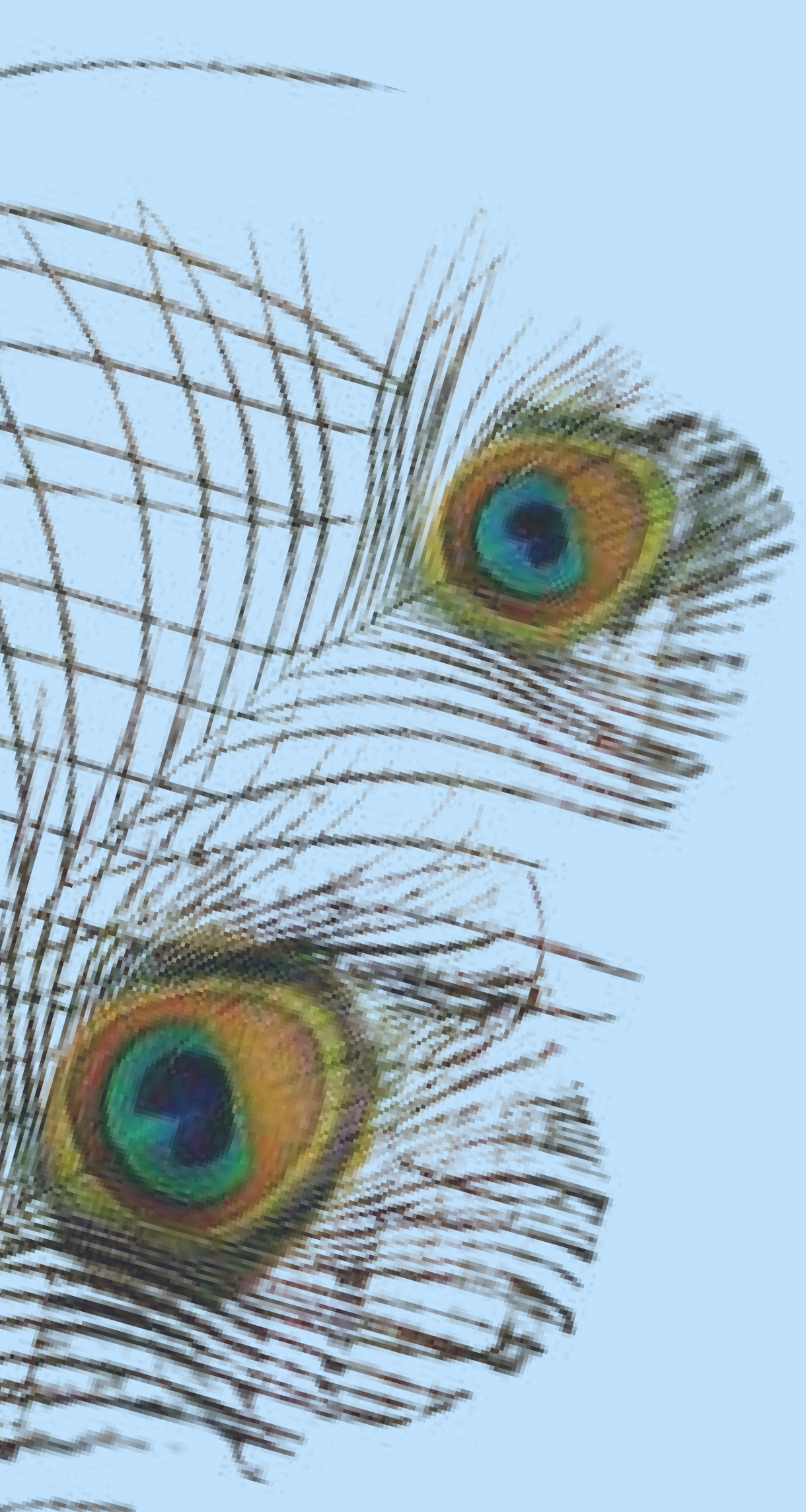
Rebecca Horn
(24 March 1944 – 6 September 2024) a German visual artist best known for her installation art, film directing and body modifications

CONTENTS OF THE REPORT

The report details:

- Initial idea exploration and animal inspiration framework
- The development and integration of:
 - a. A weighing sensor (load cell + HX711)
 - b. A feather fan output mechanism (servo + linkage)
 - c. A spring-wire input system to trigger message sending
- Iterative prototyping (laser cutting, 3D printing, coding)
- Literature and artistic references (e.g., Rebecca Horn, Neelkanth by Mahadevi Varma)
- Reflection on failed ideas like a sandbox or bioscope interaction model
- Coding and communication design via ESP-Now





OUTCOMES

What Worked

- Final servo-based feather fan output
- Spring contact input and weighing system to address message to other devices
- Integration of poetic (read swish) motion and tangible functionality

What Didn't Work

- Feather weight too light for load cell, switched to paper cups
- Servo linkages had to be 3D printed and recalibrated multiple times
- Hardware sourcing and accurate assembly (e.g., pipe diameters, tube fits)
- No initial communication protocol, designed late in the process

If done again, more early planning for integration, testing materials, and better mechanical prototyping tools would help. Still, the final result is a fully working concept system.



Mahadevi Varma (26 March 1907 – 11 September 1987) was an Indian Hindi-language poet, essayist and short-story writer. A prominent figure of Hindi literature, Varma is considered one of the four major pillars of the Chhayavadi era in Hindi literature.

A story I remember reading as a kid was this one, it has stayed with me even now after more than a decade has passed!

“Neelkanth” by M.Varma is a tale of a peacock she raised from his early days as a chick to his adult life.

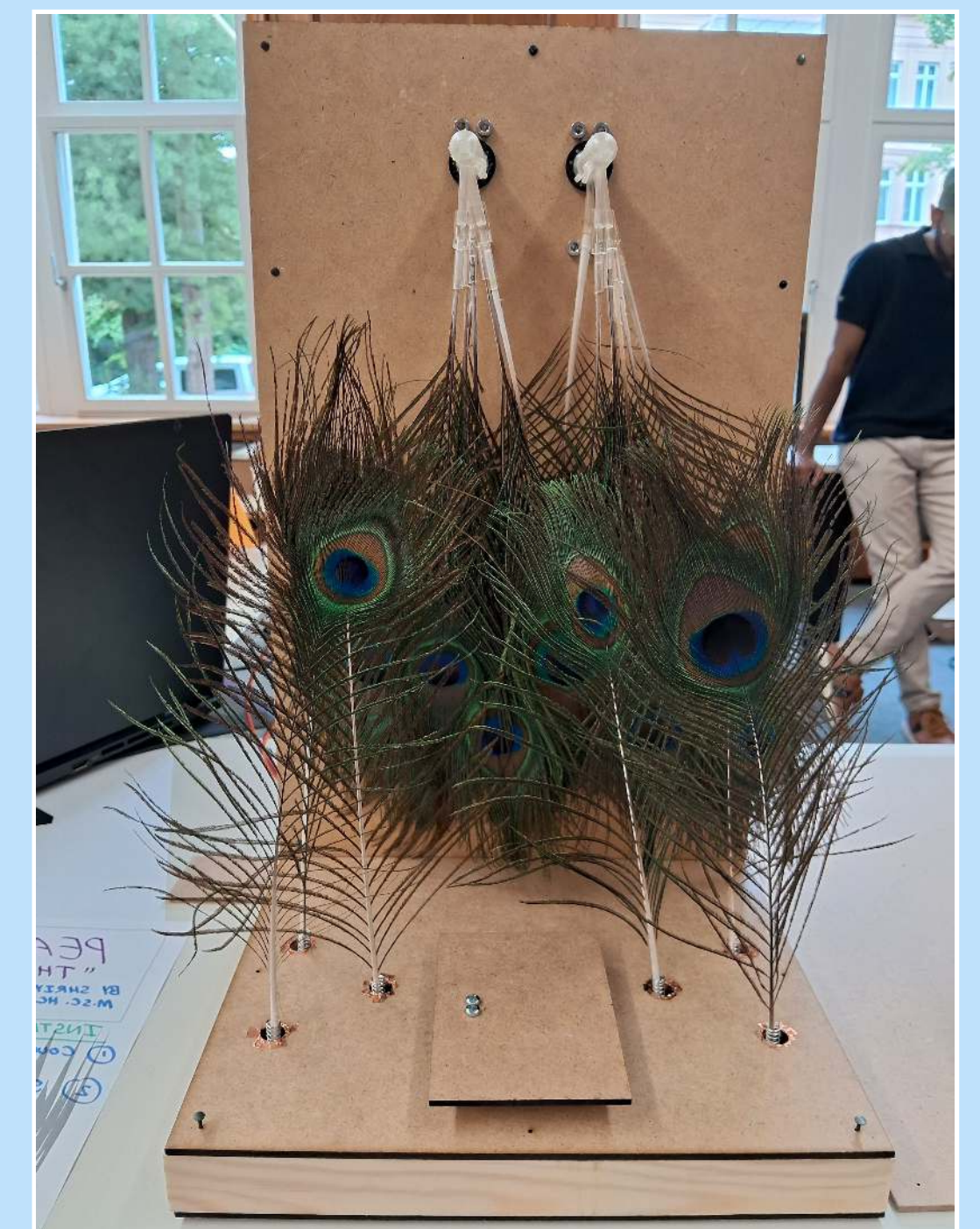


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INTRODUCTION

Tangible interaction in human-computer interaction (HCI) emphasizes the use of physical objects and environments as interfaces, allowing users to engage naturally through direct manipulation and sensory experience. This approach aims to bridge the gap between the digital and physical worlds by leveraging material qualities and embodied interaction to create more intuitive and meaningful user experiences.

Minimal interfaces focus on reducing visual and cognitive clutter by limiting interface elements to only the essential information and controls. This minimalist design principle enhances usability by emphasizing clarity, simplicity, and ease of interaction, helping users to focus attention on primary tasks without distraction.

Motion and touch play crucial roles in communication within HCI. Motion, such as gestures and dynamic animations, provides important visual feedback and guides user attention, enhancing the intuitiveness and responsiveness of interfaces. Touch, as a fundamental channel of non-verbal human communication, conveys emotional and social information, making interactions more engaging and effective.

Incorporating motion and touch in HCI supports natural, embodied forms of communication, enabling interfaces to connect with users on a sensory and affective level.

Together, these elements contribute to designing human-centered interfaces that are expressive, efficient, and socially attuned.

The interaction paradigm explored in this project draws from piezo-resistive touch sensing and the metaphor of hair-like interfaces, enabling delicate gestures such as stroking, twirling, and hovering to be interpreted as intentional input. These interactions represent a shift toward ultra-lightweight, near-zero-force tangible communication. Though this was not practically used in the device itself.



GENERAL CHALLENGE

Tangible interaction systems often struggle to balance sensitivity and reliability in touch-based inputs. While capacitive and resistive sensing afford nuanced gestures, they are highly susceptible to environmental noise, unintentional contact, and inconsistent signal fidelity. Generating output that matches the tactility of such input, without breaking the illusion of seamlessness, remains a core design challenge.

In practice, the ultra-lightweight nature of feathers posed a technical constraint, failing to register on the load cell without added material. The design also faced iterative setbacks, including misaligned servo linkages, inaccurate tube fittings, and fragile 3D prints. Achieving synchronous integration of input, addressing, and output mechanisms within a compact physical form required constant adaptation and hands-on calibration.

TECHNOLOGY USED

Arduino

Arduino is an open-source microcontroller platform widely used in prototyping interactive devices. It provides GPIO (general-purpose input/output) pins to interface with sensors, actuators, and communication modules. This project uses Arduino Uno or Nano to handle servo motion, input detection, and message routing.

ESP-NOW

ESP-NOW is a lightweight wireless communication protocol developed by Espressif for ESP8266/ESP32 microcontrollers. It allows low-latency, connectionless message exchange between devices, ideal for one-to-one or one-to-many transmission without setting up Wi-Fi. It's used here to send messages between devices in the network.

Weighing Sensor (Load Cell + HX711)

A miniature load cell (TAL221) connected via an HX711 amplifier detects minute changes in weight. Placing objects like paper cups triggers specific weight ranges, each mapped to a receiver device ID, enabling the system to determine who the message should be sent to.

Servo Motors

Servo motors are used to fan out the feathers in response to incoming messages. The rotation angle is mapped to message intensity or category, creating a visually expressive output. The servo is controlled via PWM signals from the Arduino.

Spring-Contact Rings

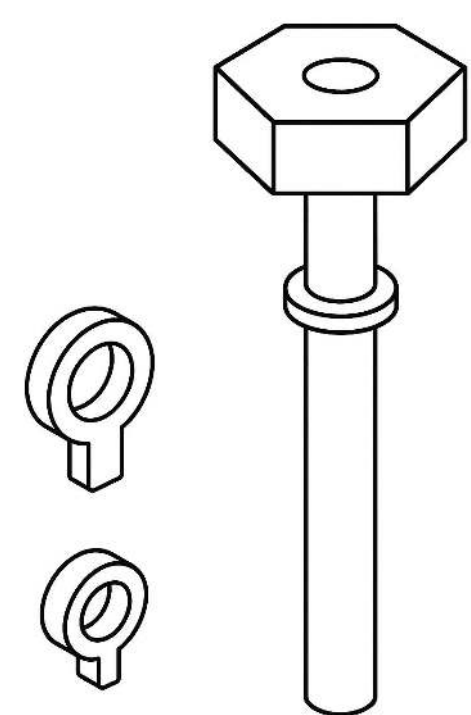
These are conductive spring-loaded inputs which close a circuit when a feather is inserted, functioning as a mechanical switch. Each spring pocket corresponds to a specific message type or intensity, enabling symbolic encoding via physical placement.

3D Printing

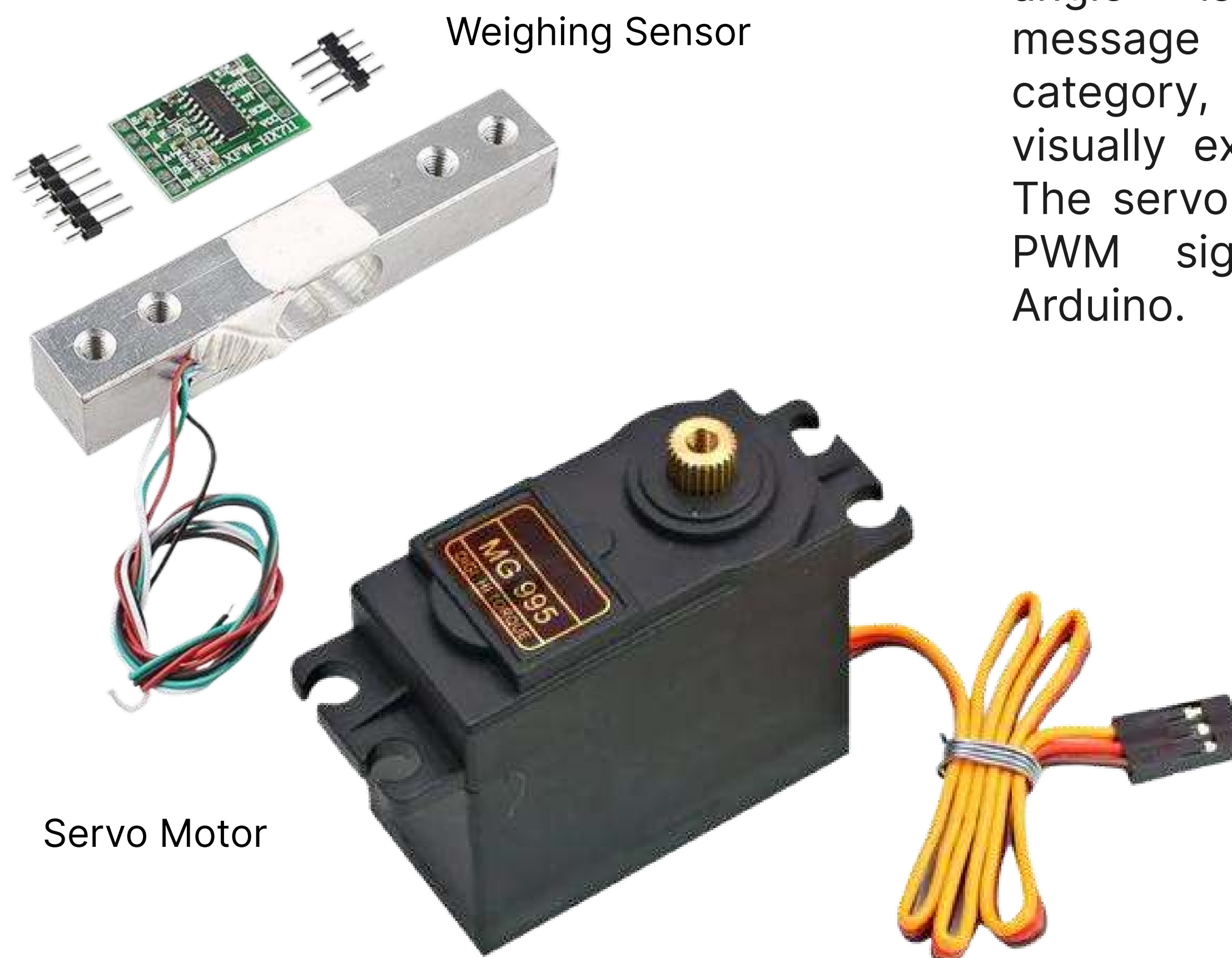
Custom mechanical parts, such as caps, linkages, and feather holders, were designed in Fusion 360 and fabricated using FDM 3D printing. This allowed for tailored fits and iterative design of motion components.

Laser Cutting

Structural components like the wooden base and mechanical housing were laser cut from plywood or acrylic. Laser cutting enabled precise, rapid fabrication of flat geometries and allowed easy adjustments during prototyping.



We 3D printed caps for the servo motors and linkages in the form of rings with edges that helped create the curtain effect in the feathers.



RELATED WORK

The project also takes inspiration from Rebecca Horn's performative sculptural works, particularly her kinetic installations have long explored the poetic potential of subtle mechanical motion. In particular, works like *Raven's Choice* (2009–2014) and *Zen of Raven – Federskulptur* demonstrate how feathers and fragile materials can evoke both calm and tension through slow, rhythmic activation. These wall-mounted and vitrine-contained pieces inspired the form and motion logic behind my own feather-based interface.

INTERACTION PARADIGMS

This project builds on the principles of Calm Technology and Tangible User Interfaces (TUIs). It explores interaction models that reduce cognitive and physical effort, situating technology at the periphery of attention. Instead of tapping or swiping screens, users engage through lightweight gestures such as inserting a feather, touching a spring, or placing a paper cup. These gestures translate into symbolic data: message composition, addressing, and emotional intensity.

Closely related is the Zero-UI paradigm, which moves away from screen-based or graphical interfaces, instead enabling interaction through natural modalities such as gesture, proximity, voice, or material-based sensing. These frameworks are particularly relevant in the context of tangible and ambient computing, where devices like the feather interface aim to blend seamlessly into the environment while enabling expressive communication through subtle physical interactions.

The device also fits within research on embodied interaction, where computing systems are grounded in physical experience. Here, symbolic actions (like stroking a feather) and culturally meaningful metaphors (like a peacock's dance) are transformed into computational input and output. The result is a hybrid system that blends poetic expression, cultural semiotics, and networked interactivity.

Scrapbook of
Rebecca Horn's
works



AIM OF THE WORK

The primary aim of this project was to develop a tangible interface device capable of bidirectional message exchange within a distributed network of physical nodes. The system was designed with three discrete functional modules: (1) message composition and dispatch via lightweight, physical interactions, (2) target-specific message addressing, and (3) expressive message reception through dynamic motion. Conceptually, this translates into a modular framework where users can compose a message using embodied gestures (such as inserting feathers into spring-loaded inputs), specify its intensity or emotional valence, and assign a receiver using weight-based selection. The goal was to create a minimal-interaction, low-force communication protocol, both expressive and symbolic, capable of operating across a mesh of connected devices, thus integrating input, output, and addressability into a single, cohesive tangible artifact.

RELEVANT & KEY FEATURES

- **Expressive Motion Output Inspired by Peacock Plumage**
The device fans out a series of feather elements using a servo-actuated mechanism, visually referencing the courtship display of a peacock. By modulating the angular spread of the feathers, the system conveys varying intensities or semantic nuances, with each angle representing a distinct message category or emotional tone.
- **Addressing via Weight-Based Receiver Selection**
A miniature load cell is embedded in the device to detect subtle changes in weight (e.g., via the placement of paper cups or similar objects). Each weight range is pre-mapped to a specific receiver ID within the network, allowing for selective communication with one of nine possible target nodes (excluding the sender itself).

- **Spring-Contact Inputs for Message Encoding**
Feather insertions into spring-loaded contact pockets complete a circuit and signal message intent. These pockets function as gestural encoders, enabling the user to specify content or categories of meaning. In a speculative extension, this model could be applied to address contacts within a smartphone or smart home environment, introducing symbolic interaction into everyday messaging. Together, these three components enable a tangible communication device that integrates embodied input, analog addressing, and affective output, merging poetic symbolism with functional computation.

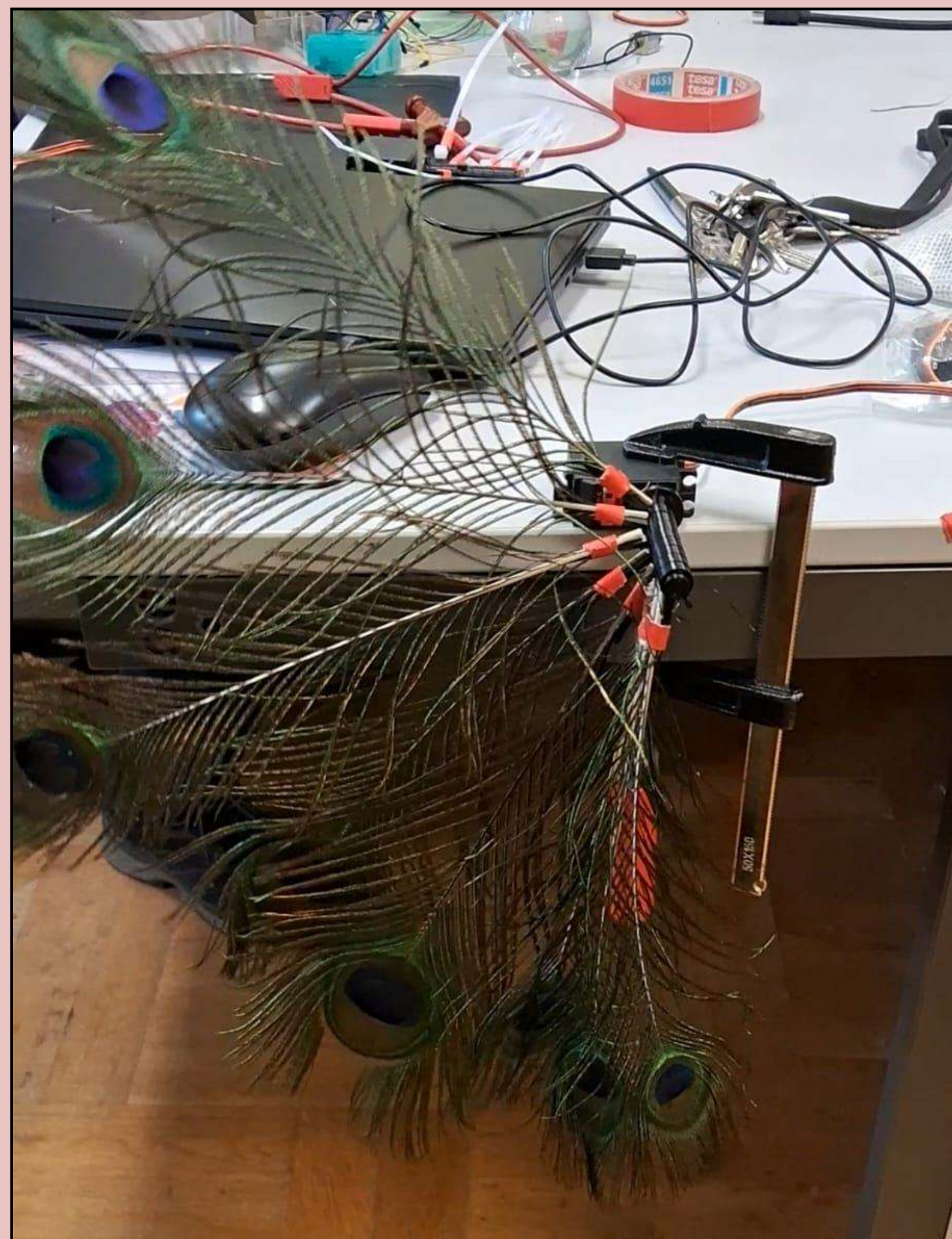
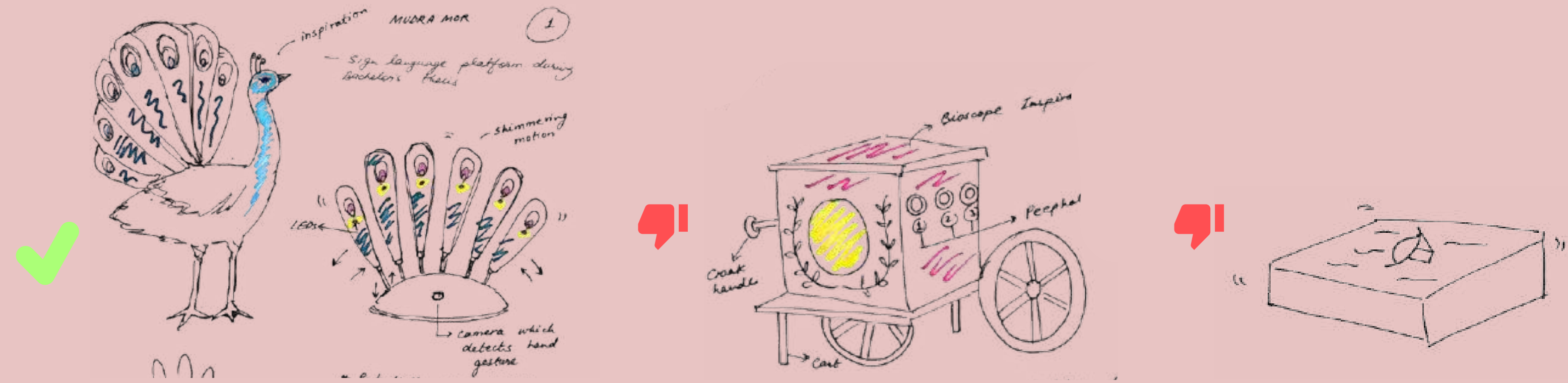
WHY THE PEACOCK?

The device draws on the peacock's profound cultural resonance in India, where it is celebrated as a national symbol and revered in temples, scriptures, and folklore. Its feathers, iridescent, eye-like, and expansive, embody a centuries-old aesthetic language of beauty, dignity, and transcendence, appearing in classical art, handicrafts, and literature such as Mahadevi Varma's *Neelkanth*. By referencing the fanning motion of the peacock's tail, the interface transforms a culturally iconic gesture into an embodied interaction metaphor, bridging heritage, symbolism, and tangible computing. Oftentimes, I saw peacocks dancing in the rain with their fanned out, to me, it looked like they were rejoicing or welcoming me.

DESIGN PROCESS

The final design of MudraMor emerged as a compact, all-in-one feather-based communication interface that enables message input, reception, and modulation of intensity within a single, portable device. This unification was motivated by the need for simplicity, mobility, and seamless embodied interaction. The goal was to move beyond distributed systems and instead create an intuitive, tangible object where every part of the message cycle that is, sending, receiving, and configuring is physically embedded.

Deeply inspired by the peacock, a bird revered in Indian culture and close to my childhood memories, the design draws on the peacock's majestic feather fan as a metaphor for expression and gesture. This symbolic reference motivated both the physical form and the motion logic of the device.



How we started



How we finished

EXPLORATION, DECISIONS & ITERATION

The development process involved considerable trial and error. Initial concepts included a bioscope-inspired message viewer and an interactive sand art installation, both of which were ultimately discarded due to their high fabrication complexity and time constraints.

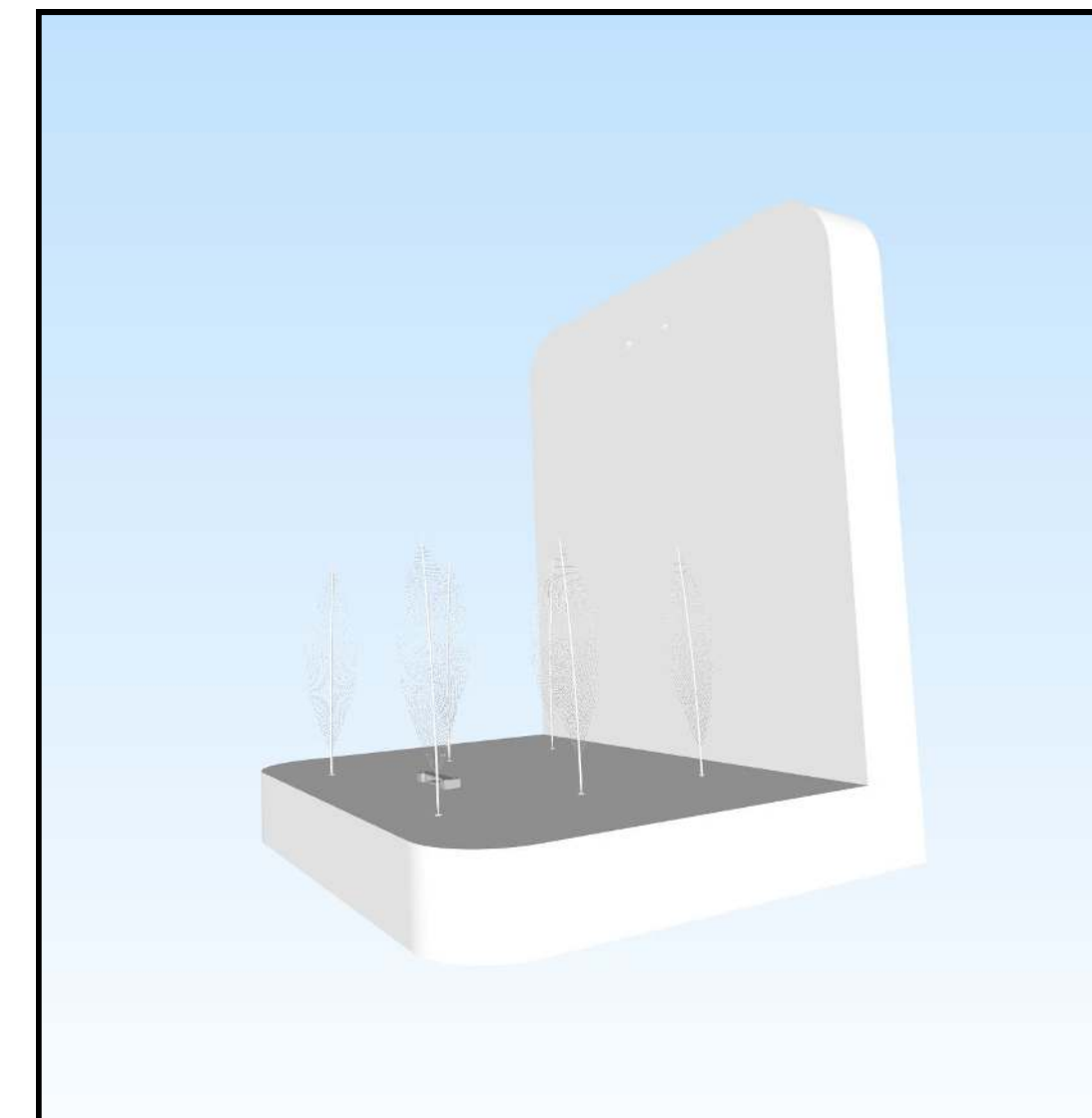
Early prototypes featured separated modules, one unit for sending, one for receiving, and one for adjusting message intensity. However, I chose to consolidate them into a single artifact to simplify interaction and ensure system coherence. This decision was both functional and poetic: it allowed for a coherent narrative in interaction, echoing the symbolic wholeness of the peacock's display.

Problems encountered included:

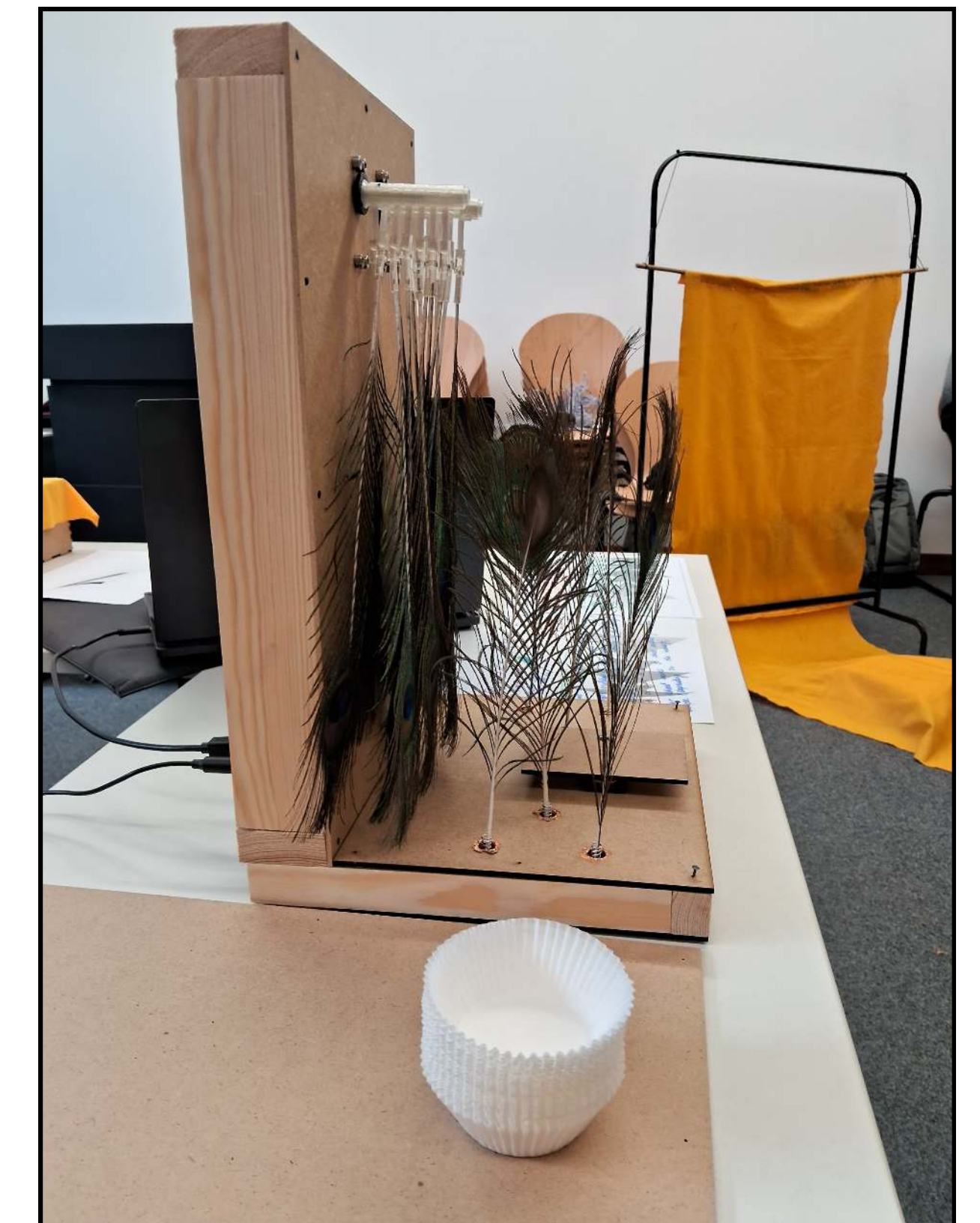
- Inaccurate laser cutting measurements,
- Servo motor angle mismatches,
- Lack of lightweight sensor detection for feathers (leading to last-minute substitution with paper cups),
- And mechanical instability in linkage designs: requiring multiple reprints.

Despite these setbacks, the design converged into a unified, responsive, and expressive artifact capable of communicating emotion and intention through minimal touch-based interaction.

Side-by-side comparison of the proof-of-concept and the actual prototype



3D design of the MudraMor

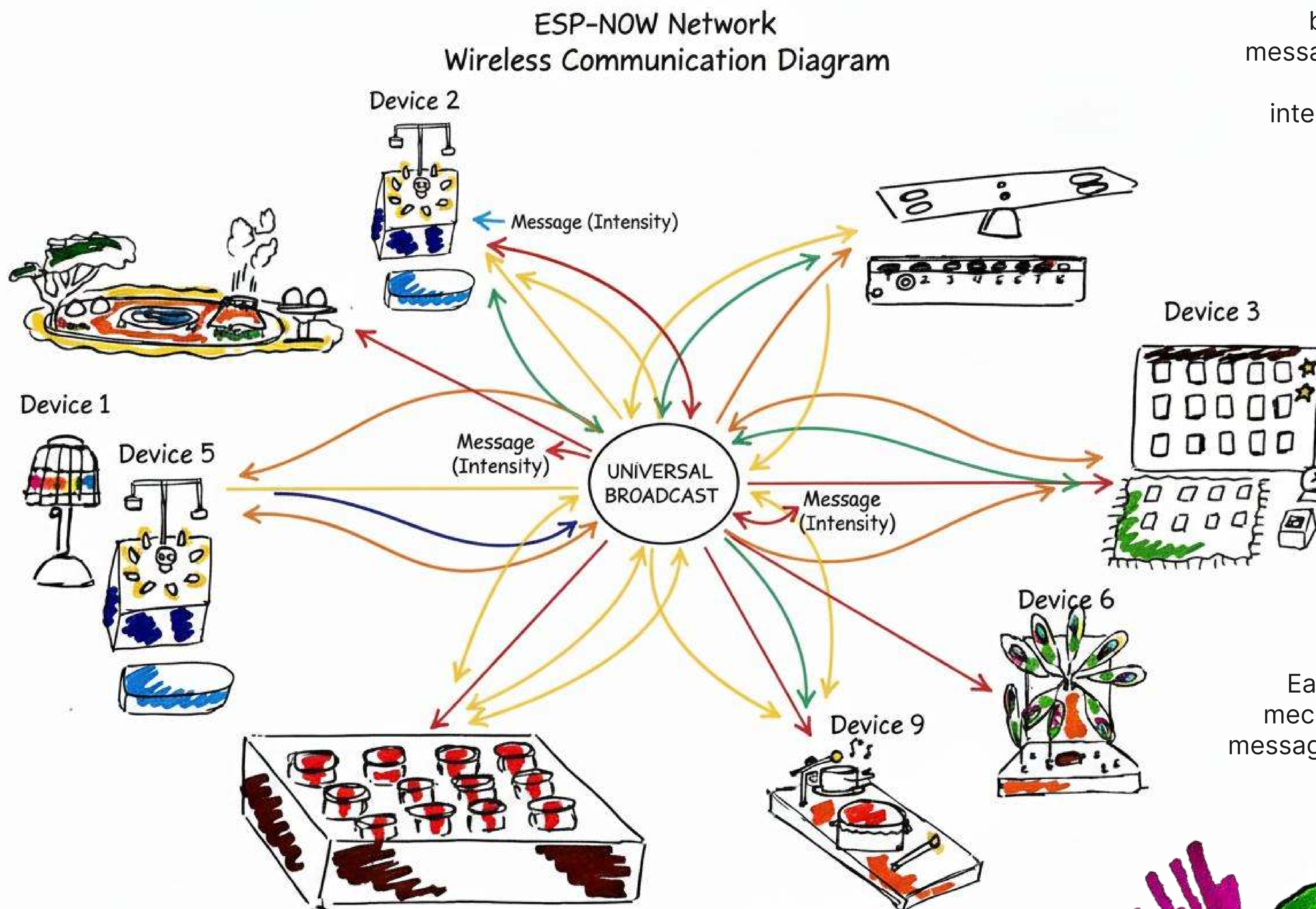


Side-view of the actual device

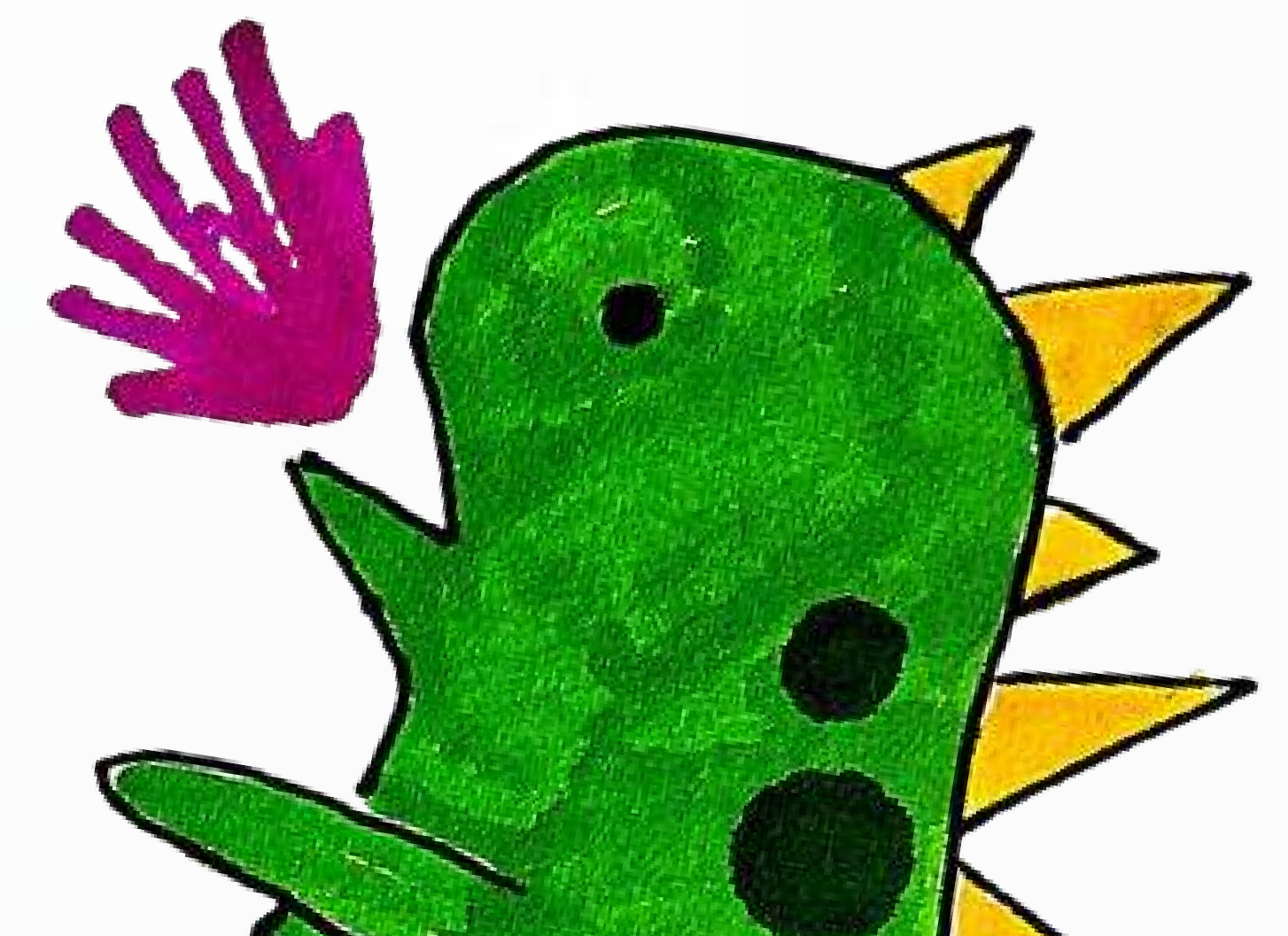


This project was part of "The Zoo" course wherein 8 other students built devices that we formed a ESP-NOW network with. each device could interact with the other by calling its address (Device #) through their own interaction method, i.e., tapping a drum, weighing stone, pulling strings, putting pressure, balancing yourself on a board and so on.

This diagram showcases the multiple one-to-one (device to device), one-to-many (universal messages) that were potentially possible in this network resulting in a beautiful cacophony of messages across the board. Multiple one-to-one interaction simultaneously were possible.



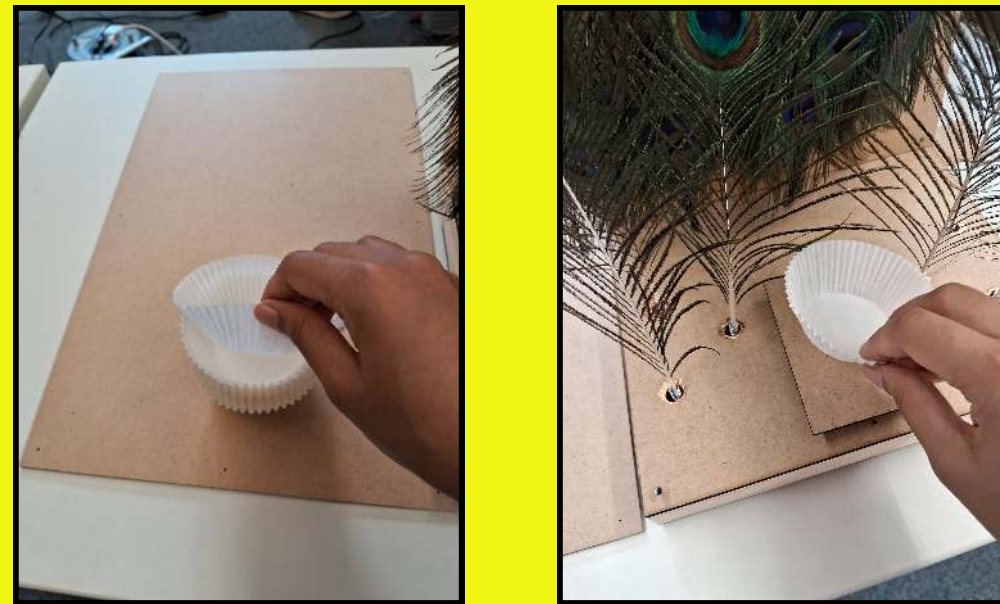
Each device had its own mechanism for setting the message intensity or content of the message.



HOW MUDRAMOR WORKS

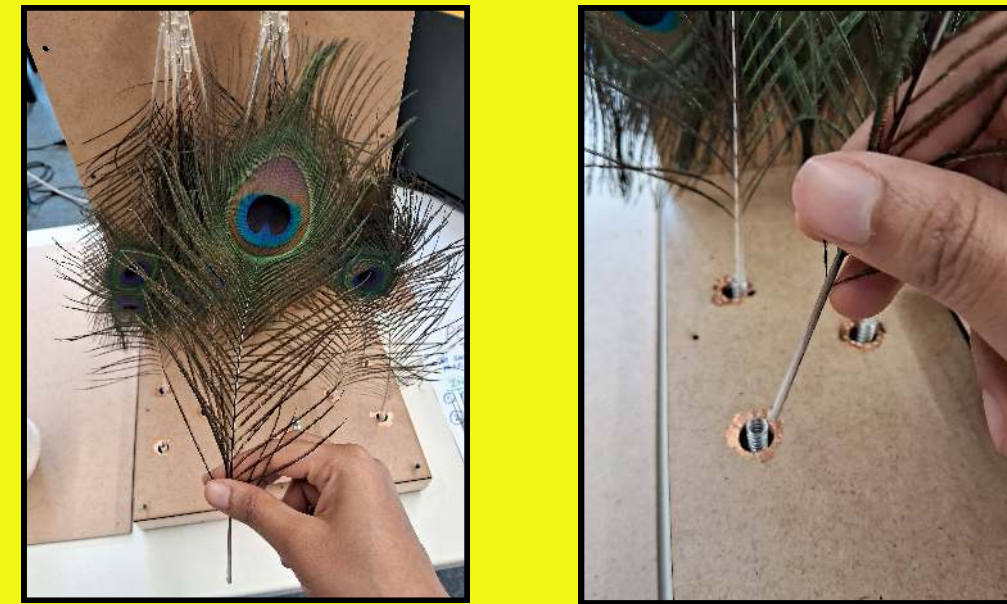
SENDING A MESSAGE

1. Select Recipient



Count paper cups = Recipient Device #

2. Set Intensity



of Spring Pockets Completed
= Message Intensity

3. Send Message



Stroke feather or blow on it lightly to
complete circuit (Send!)

RECEIVING A MESSAGE

1. Sender Directs a Message to my Device



Checks servo receiver module

2. Wireless Signal Received



of Spring Pockets Completed
= Message Intensity

3. Swish Motion



Feathers fan out (based on intensity),
2 servo motors rotate in opposite
directions, here, it is full intensity.

DISCUSSION & CONCLUSION

While MudraMor succeeded in demonstrating a compact, expressive shell for low-effort communication, several limitations and avenues for future improvement remain:

- **Sensor Sensitivity & Material Limitations:** The load cell struggled to reliably detect ultra-light feathers, so we substituted heavier objects (paper cups). Future versions could integrate capacitive sensing, piezoelectric elements, or strain gauges better tuned to feather weight.
-
- **Scaling & Network Robustness:** The current design maps weight ranges to a limited number of devices; expanding to many nodes or dynamic addressing would require more robust addressing schemes or scalable protocols (e.g., mesh networking).
-
- **Expressivity & Feedback Modalities:** Beyond motion and light, richer feedback (e.g. soft haptics, sound, or dynamic texture) could deepen expressivity.
-
- **Durability & Calibration Drift:** Mechanical wear, sensor drift, and physical alignment issues weakened long-term stability. Future systems would benefit from automated calibration routines or modular replacement parts.
-
- **User Testing & Interaction Study:** We have limited user evaluations. Future work should conduct in situ studies to assess how intuitive the gestures are, how users interpret the feather motions, and how error-prone the system is in real-world contexts.

This device sits at the intersection of tangible user interfaces (TUIs) and calm, ambient interaction. By materializing communication through feathers, springs, and weight, it embodies digital states in physical gestures and motile form. In doing so, it reinforces the core premise of TUIs: that physical form can directly represent computational content (as articulated by Ishii & Ullmer's tangible bits framework).

What it adds or challenges:

- **Novel input metaphors:** Most TUIs depend on grasping, rotating, or pushing objects; this work emphasizes near-zero-force gestures (stroking, lifting, inserting), pushing the boundary of what counts as “tangible control.”
- **Expressive, symbolic motion as output:** Rather than traditional displays or feedback, this adds kinetic output as a communicative medium, motion that encodes meaning.
- **Aesthetic-cultural embedding:** The project demonstrates how cultural symbolism (peacock feathers) can be deeply integrated into interaction, not just as decoration but as a semantic substrate.

What it confirms:

- It supports the argument that tangible interfaces can maintain peripheral, low-attention engagement (a principle explored in research on peripheral tangible interaction) [22]
- It echoes critiques in literature that highlight failure modes of tangible systems, for instance, issues of form factor, context of use, and scaling complexity (Matviienko et al.)

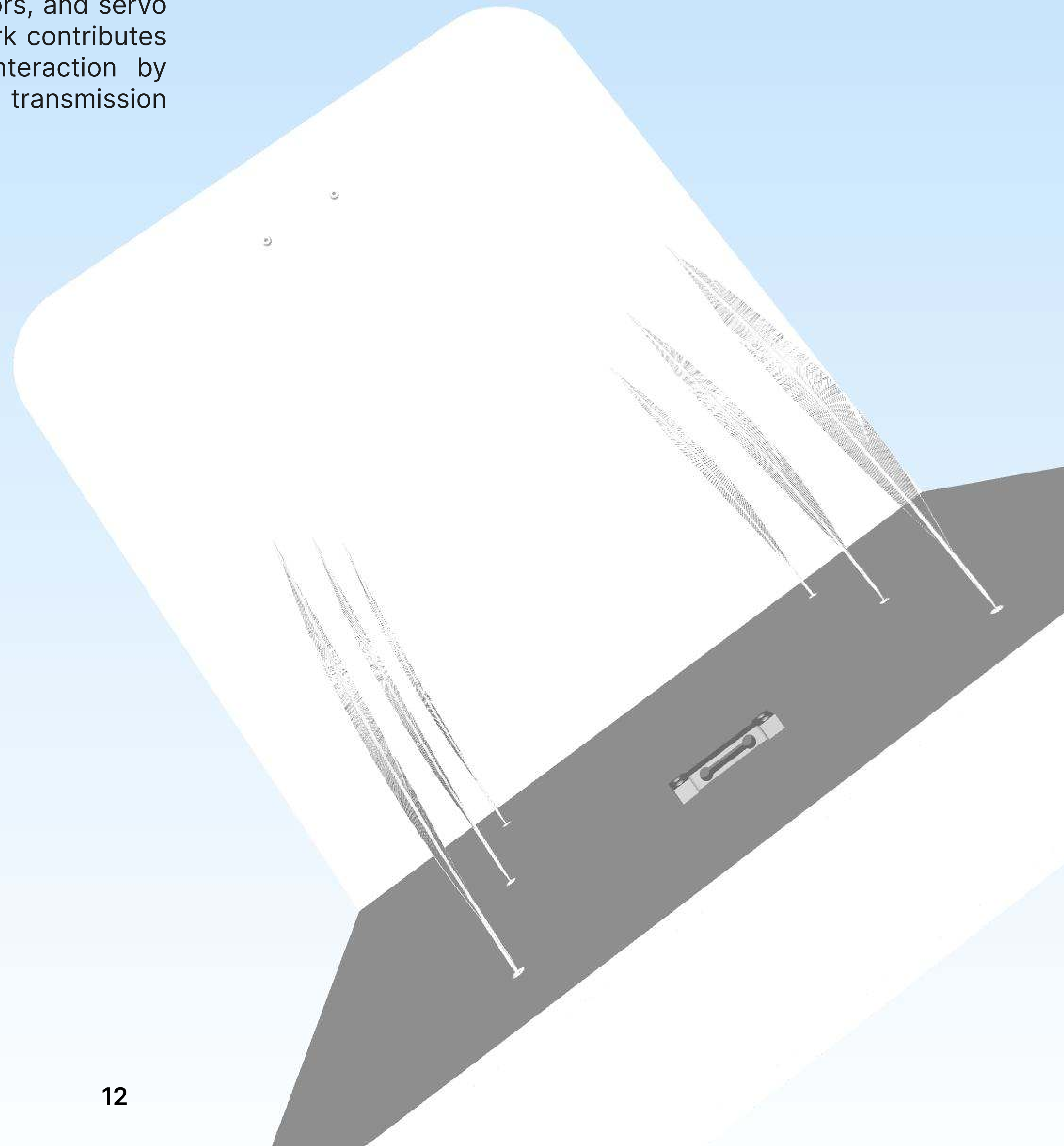
Points of disagreement:

- Classical TUI literature often assumes robust manipulation (grasping, twisting) whereas this work privileges delicate, hair-like gestures, which may conflict with existing assumptions about affordances.
- Many tangible systems emphasize modularity or expansion, but here the design choice was integration into a monolithic device, limiting modular scalability, this challenges standard practices in TUI design.
- Where many TUIs embed only convenience or data mapping, this project attempts poetics and affect, bridging art and HCI in a deeper way, questioning the boundary between tool and sculpture.

MudraMor is a tangible, poetic computing device that explores minimal, gesture-based communication through feather motion, inspired by cultural symbolism and embodied interaction. It enables message exchange using physical inputs: touching, lifting, inserting, without traditional screens. The project demonstrates how lightweight materials and sensory mechanisms (spring pockets, weighing sensors, and servo fans) can support expressive, zero-UI interfaces. This work contributes to the discourse on calm technology and tangible interaction by proposing an alternative, affective model of message transmission rooted in material sensitivity and cultural narrative.

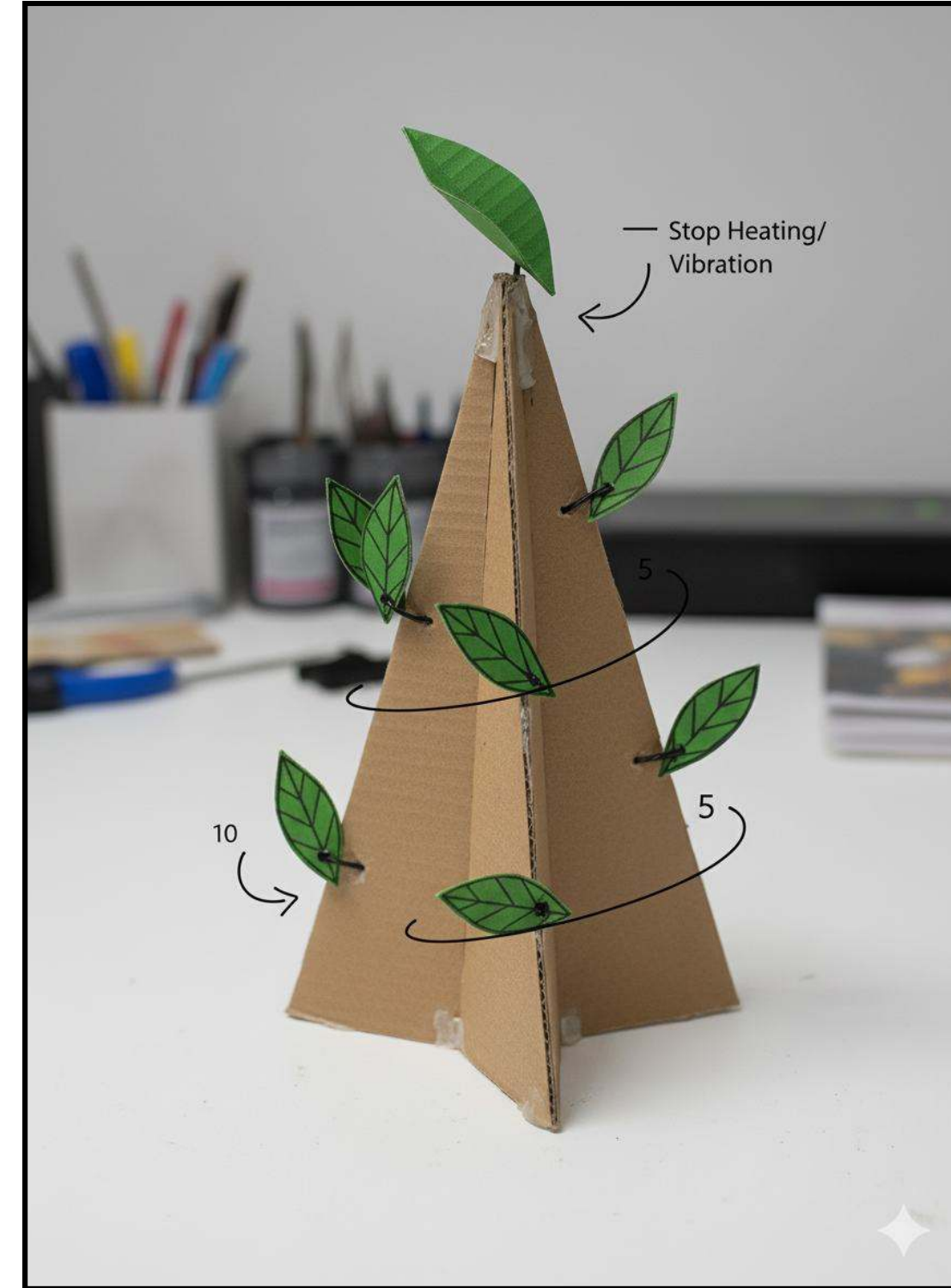
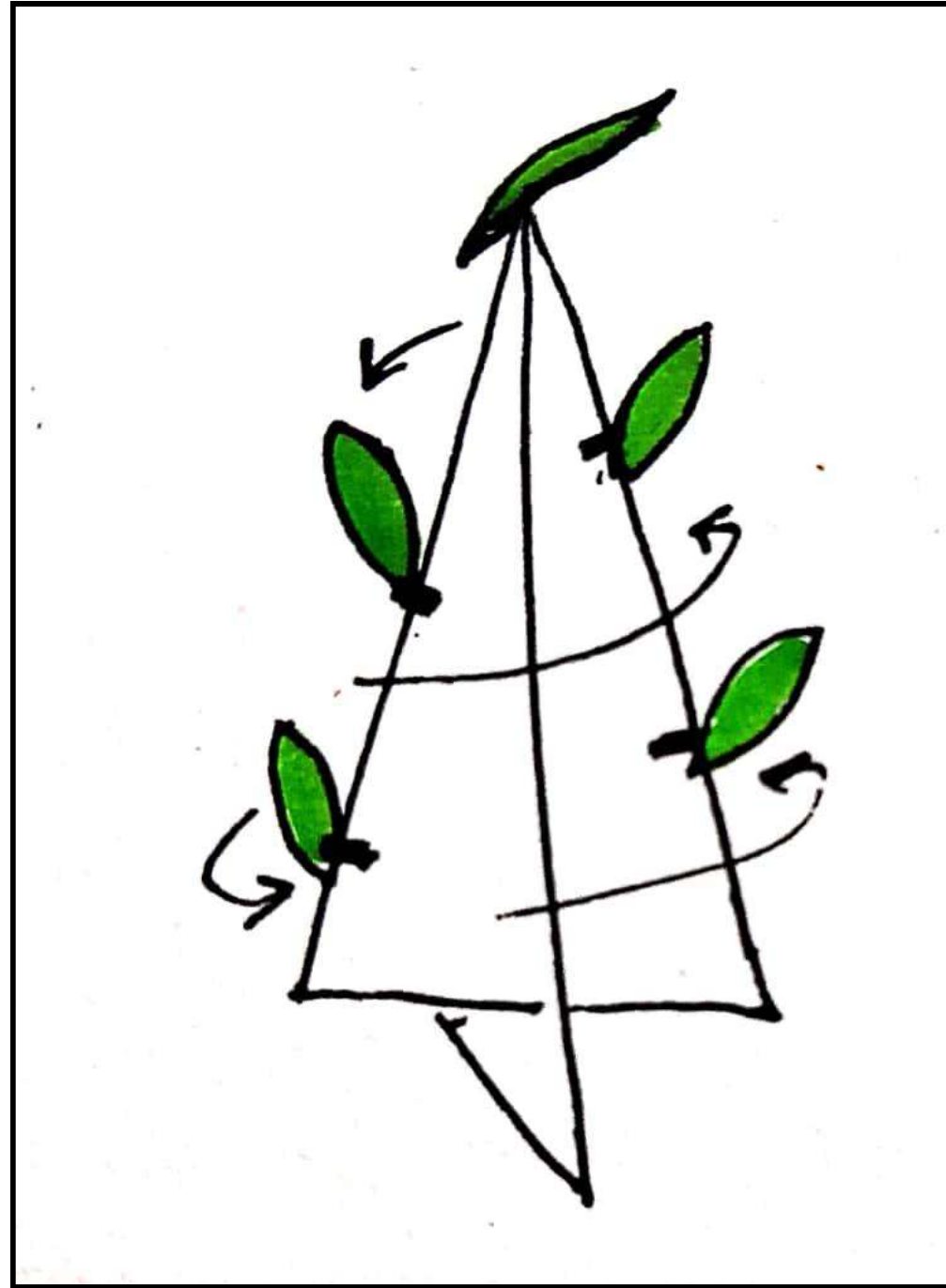
Appendix:

- Code (Arduino Sketch File): <https://app.arduino.cc/sketches/72d2602c-c35a-4ba4-b557-1f240e2736e9?nav=GenAI&view-mode=preview>
- Raw Media files (Google Drive Folder): https://drive.google.com/drive/folders/1AzK_Lr8GODUlgusKfm8JX3DBYA7kPHbg?usp=sharing

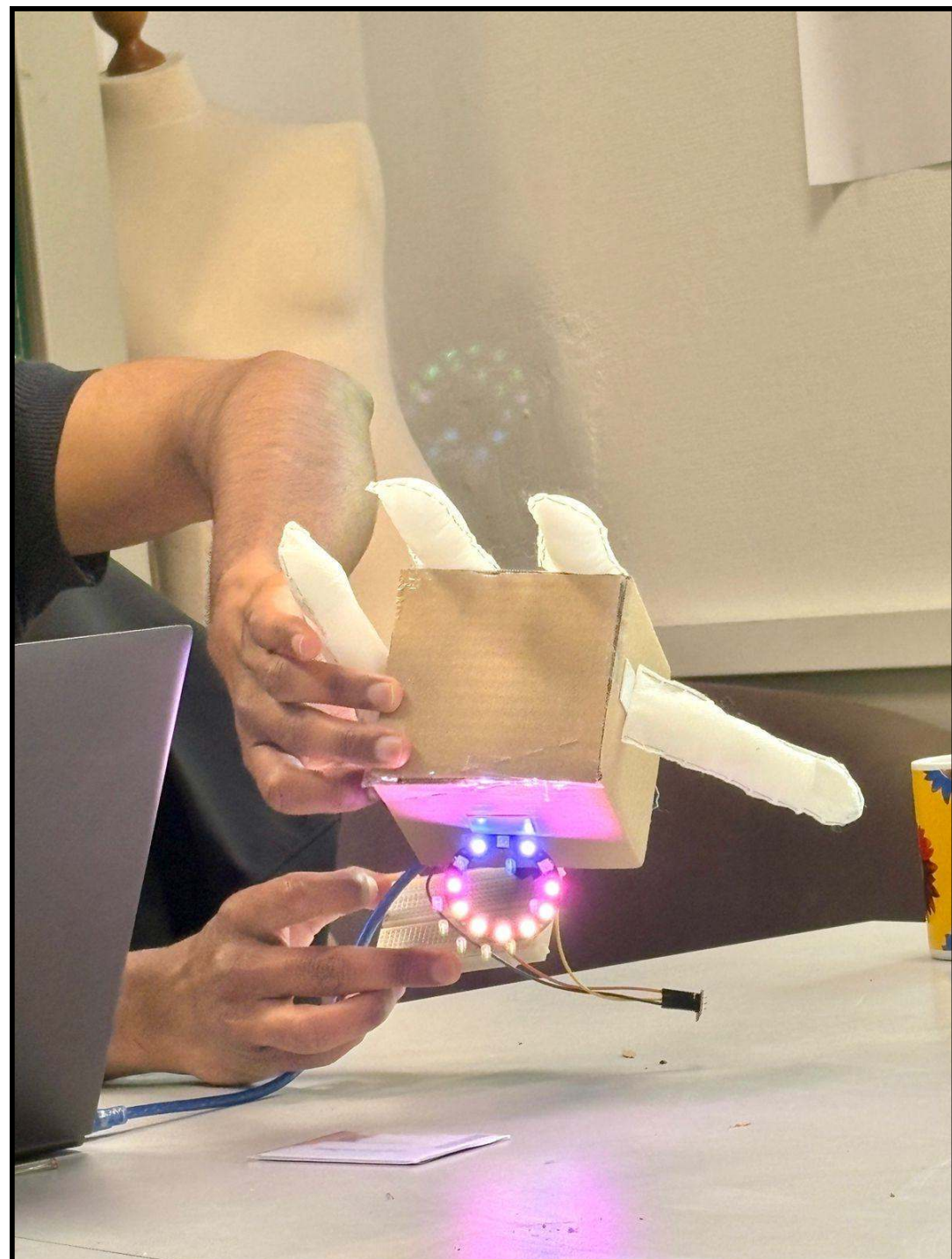


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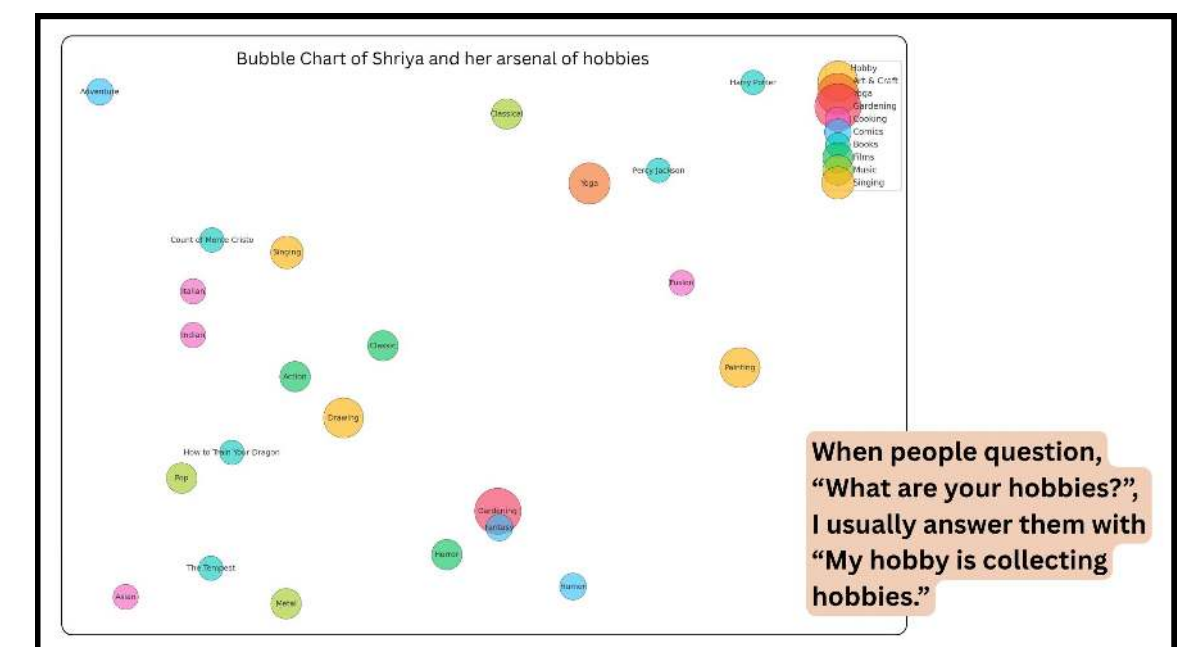
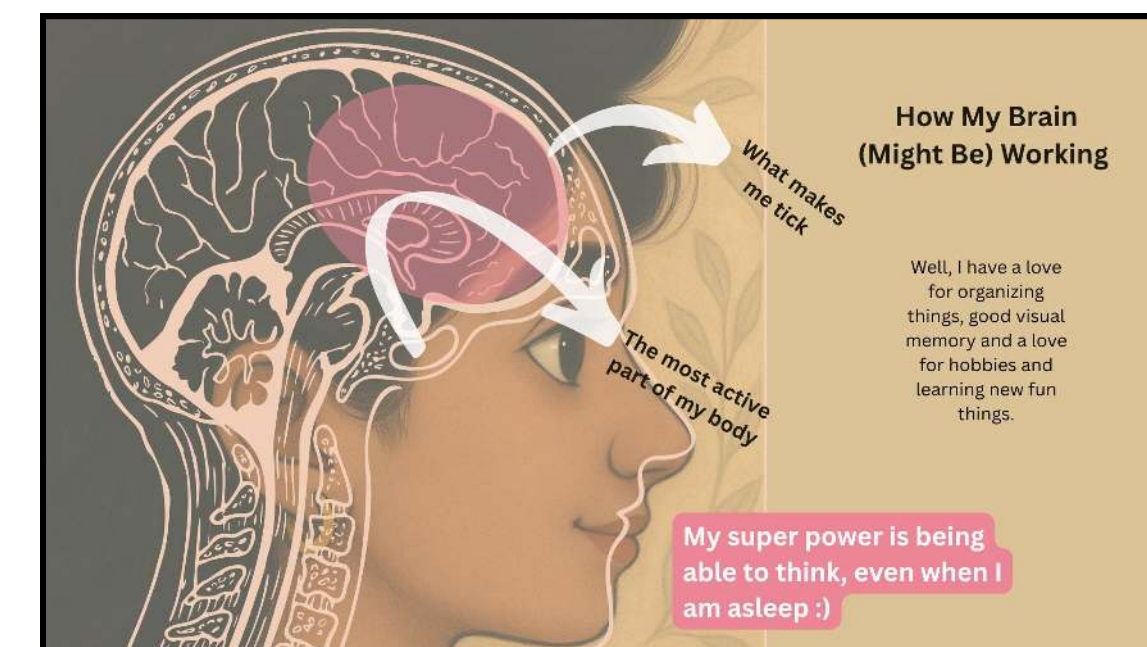
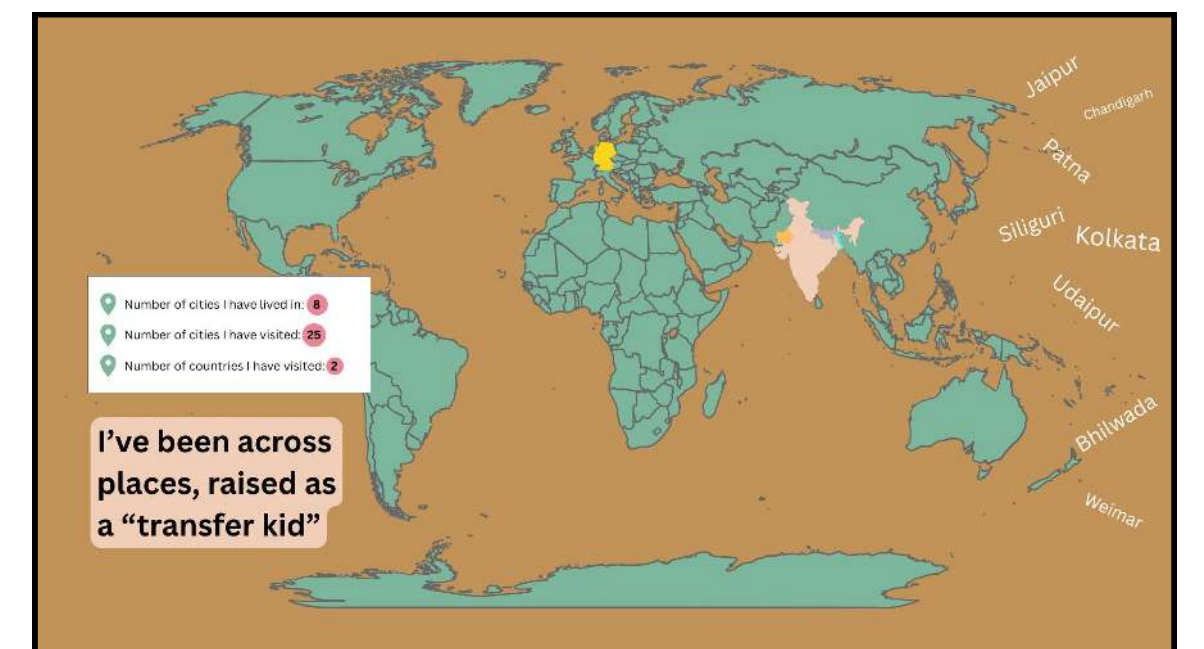
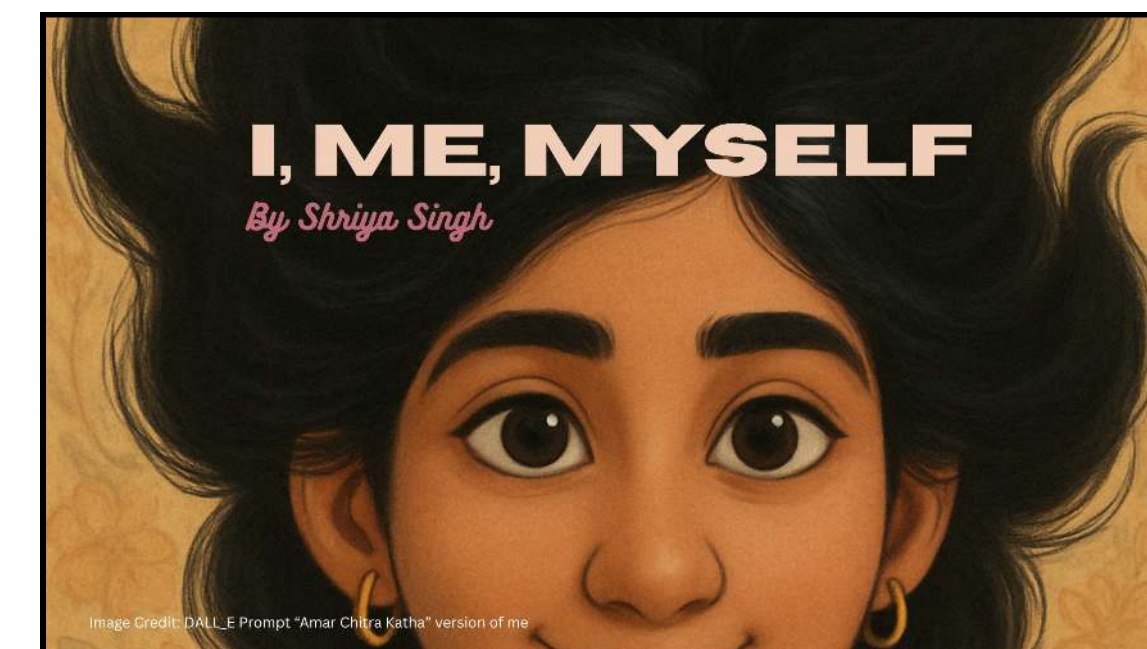


I created a cardboard prototype for the following homework:
A reminder for the complete darkness.
It needs to be set without any visual and auditive feedback through touch.
The alarm happens as a touch sensation, such as change of shape, position, haptic, temperature...or whatnot. Again without any visual or auditive feedback.



I created a small prototype using a ring light and button as a homework with another course mate.

I created an introduction slides with fun facts about myself with some figures too!



Note: AI-Use Declaration to recreate and document the initial cardboard version of the clock prototype.
 Prompt Used:
 "Generate a realistic image of a handmade cardboard prototype device used in a tangible interaction project, with flaps, spring mechanism, and slots for feathers or similar tactile inputs. Keep background plain and show from an angled view."

A flat box filled with fine sand on a vibrating platform. It sends messages by selecting vibration codes. It receives any message and interprets it by vibrating in different rhythms that sculpt the sand in subtle ways.

OUTPUT (Receives and interprets):

The box vibrates sand in unique patterns:

1. Celebration → Circular sweeping vibration
2. Emergency → Sharp, high-intensity pulse
3. Calm → Gentle, slow undulation
4. Direction → Linear side-to-side shake
5. Confession → Short nervous stutter pulses
6. Storytime → Rhythmic wave pattern

INPUT (Sends message):

One slider or rotary switch to pick a message type:

- a. Celebration
- b. Emergency
- c. Calm
- d. Direction
- e. Confession
- f. Storytime

These are broadcasted as symbolic codes (1-6) to other devices.

MESSAGES:

The sand becomes a living canvas, interpreting others' device messages through tactile, visual pattern formation.

MUDRA MOR ①

inspiration — Sign language platform during Bachelor's thesis

shimmering motion

LEDs

camera which detects hand gesture

* Potentially can include speech recognition or output in bird peacock sounds etc.

→ open the fan

→ tell a story

- Diff. hand prompts tied to diff. routines/rituals
- Diff. lights and colors can be combined together for complex, customized messages
- Can be used as a reminder, timer, storyteller but not in a regular way.
- Secret way of communication, diff. for each user
- Used as an education tool or for deaf and mute children (all kinds of users)

A peacock-inspired fan that physically opens in different styles to reflect the kind of message it receives. It sends messages through touch pattern interactions.

INPUT (Sends message):

- 3-4 capacitive touchpads or FSRs detect hand patterns or taps.
- Different touch patterns = different emotional or situational messages sent (e.g., celebration, alarm, rest, confusion, hello).

OUTPUT (Receives and interprets):

Each received message controls servo motor positions to open/close the fan differently, e.g.:

- Excitement → Fan opens dramatically + RGB glow
- Panic → Rapid fluttering motion
- Calm → Slow, soft half-open fan
- Playfulness → Flick-flick open-close loop
- Warning → One-sided jerk with red light
- Greeting → Quick full spread then retraction

MESSAGES:

Emotion types:

1. Excitement
2. Panic
3. Calm
4. Playfulness
5. Warning
6. Greeting

I ideated and presented 3 potential concepts for my device, we ended going with MudraMor after a series of discussions in-class and one-on-one.

Chalchitra
- Kahanihale
- Storyscope

②

Bioscope Inspiration

Ozone repair
habitat repair
solar villages
Forests regrowing
inspirational stories

Peepholes

Crank handle

Cart

You only get GOOD NEWS!

Printer

Peepholes

handle

Data backed stories

* Print out screenshots!

Battery recorder encoders
Light sensor
Proximity sensor

Optimism in tech
Exp. for reflecting on good change

→ Peekbox that uses light, motion and sensor driven interaction to reveal climate optimism stories

→ Box remains dark unless you turn a crank slowly, scene lights up

→ ENGAGE GENTLY!

→ Peek into both holes will get image blurred

A small bioscope-inspired box where users peek in. The box shows a changing internal scene (e.g. LED scene or paper wheel) based on received messages. It sends messages via emotion dial selection.

OUTPUT (Receives and interprets):

Each emotion triggers a different internal scene via rotation/motor/LEDs:

1. Joy → Yellow filters, flickering stars
2. Alert → Red flashing LEDs
3. Nostalgia → Sepia-toned rotating memory reel
4. Confusion → Spinning patterns / foggy film
5. Urgency → Rapid light flashes + buzzer
6. Serenity → Cool blue + slow fade transitions

INPUT (Sends message):

One selector dial lets the user send an emotion/mood/state by choosing a label like:

1. Joy
2. Alert
3. Nostalgia
4. Confusion
5. Urgency
6. Serenity

MESSAGES:

You interpret visual messages from others and translate them into visual-mood scenes inside your bioscope.

SAND ART + VISUAL MESSAGES ③

sand

vibration

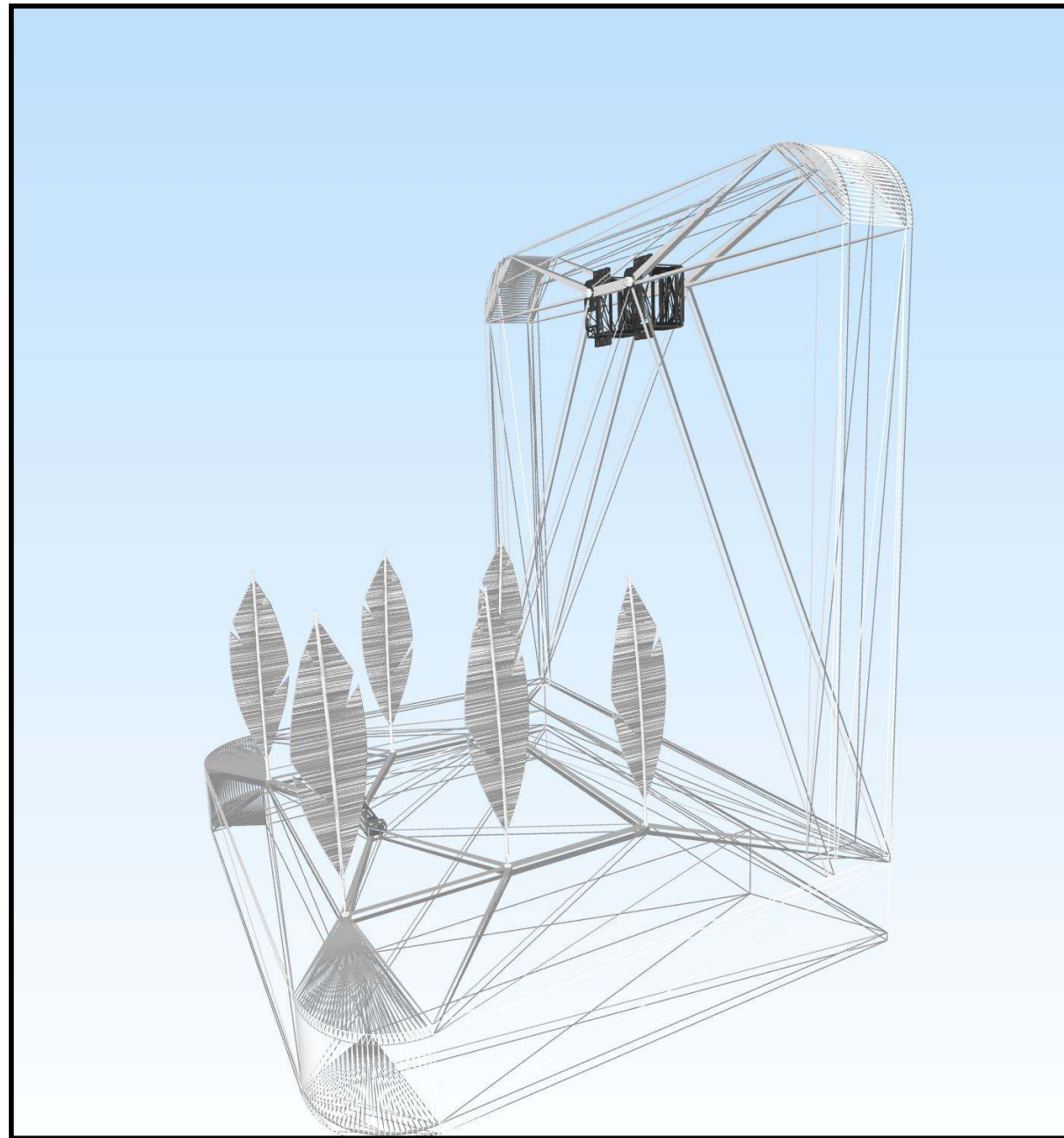
Inspiration
→ chalk art
→ sand art

* Materiality
* Physicalization of data (meaningful to users)
* Tech for social good
* Optimism in place of misanthropy
* Interactivity with elements

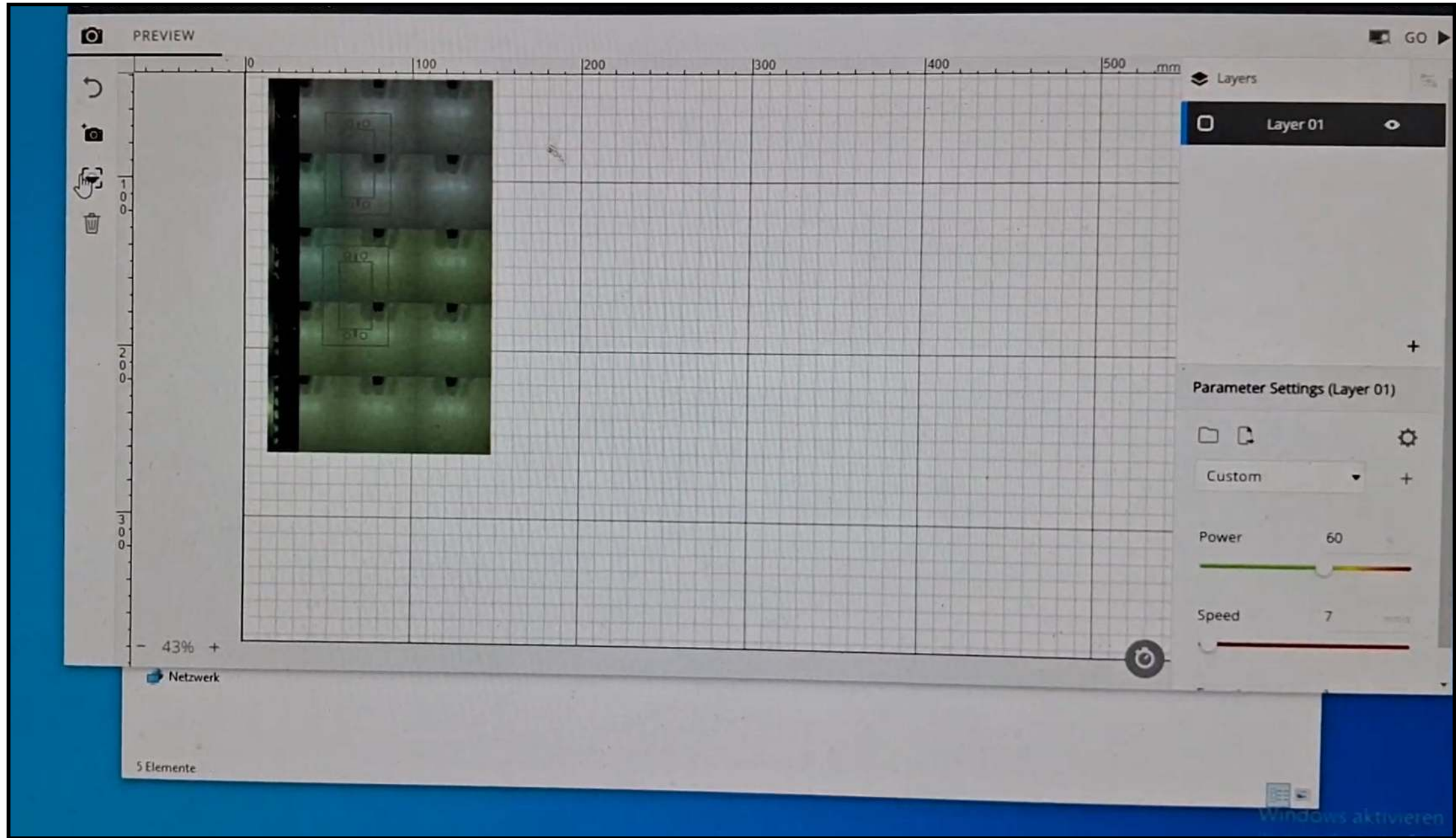
SHOWS A MESSAGE

User can interact directly

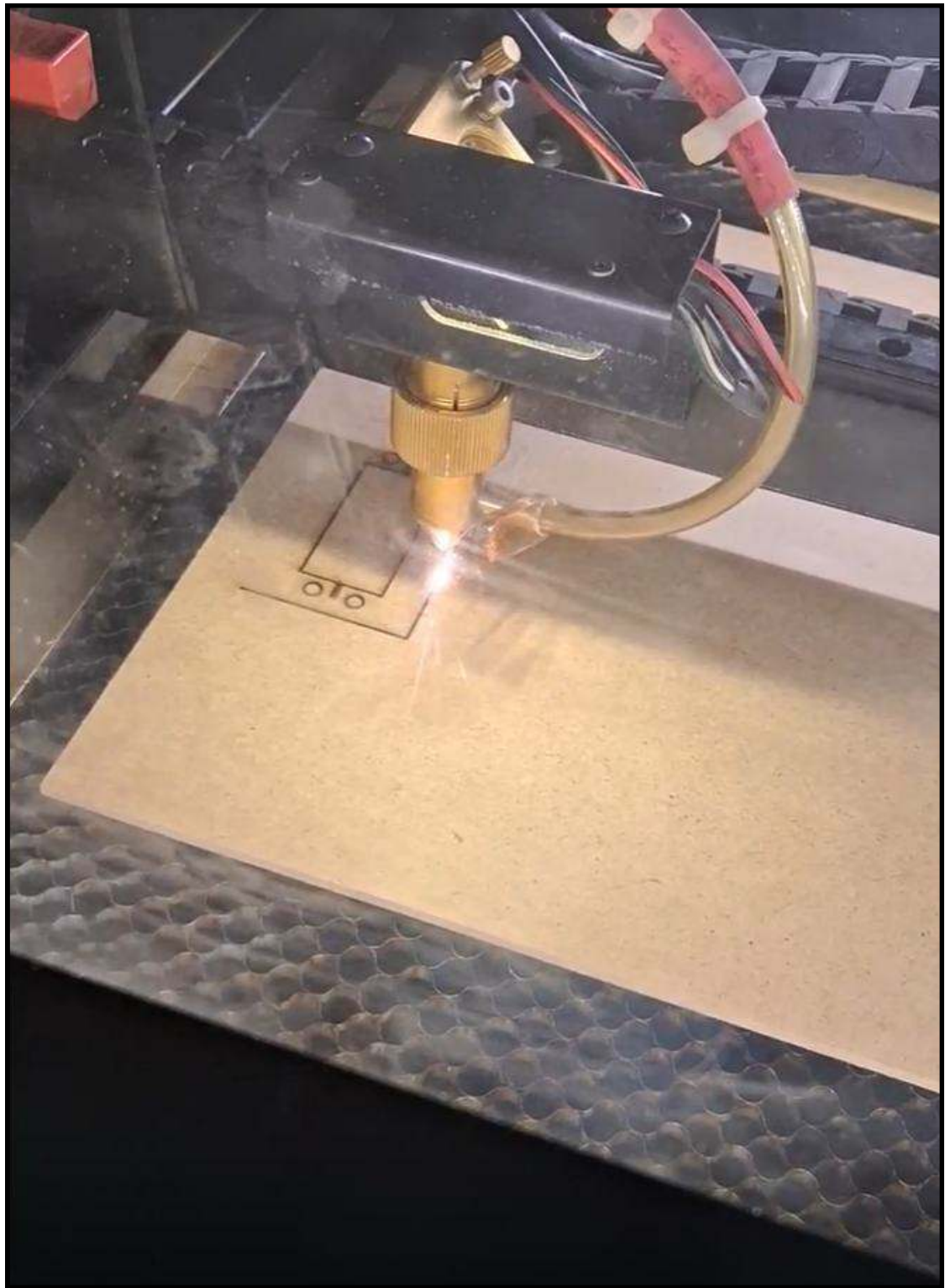
→ clears the message (Wipes board clean)



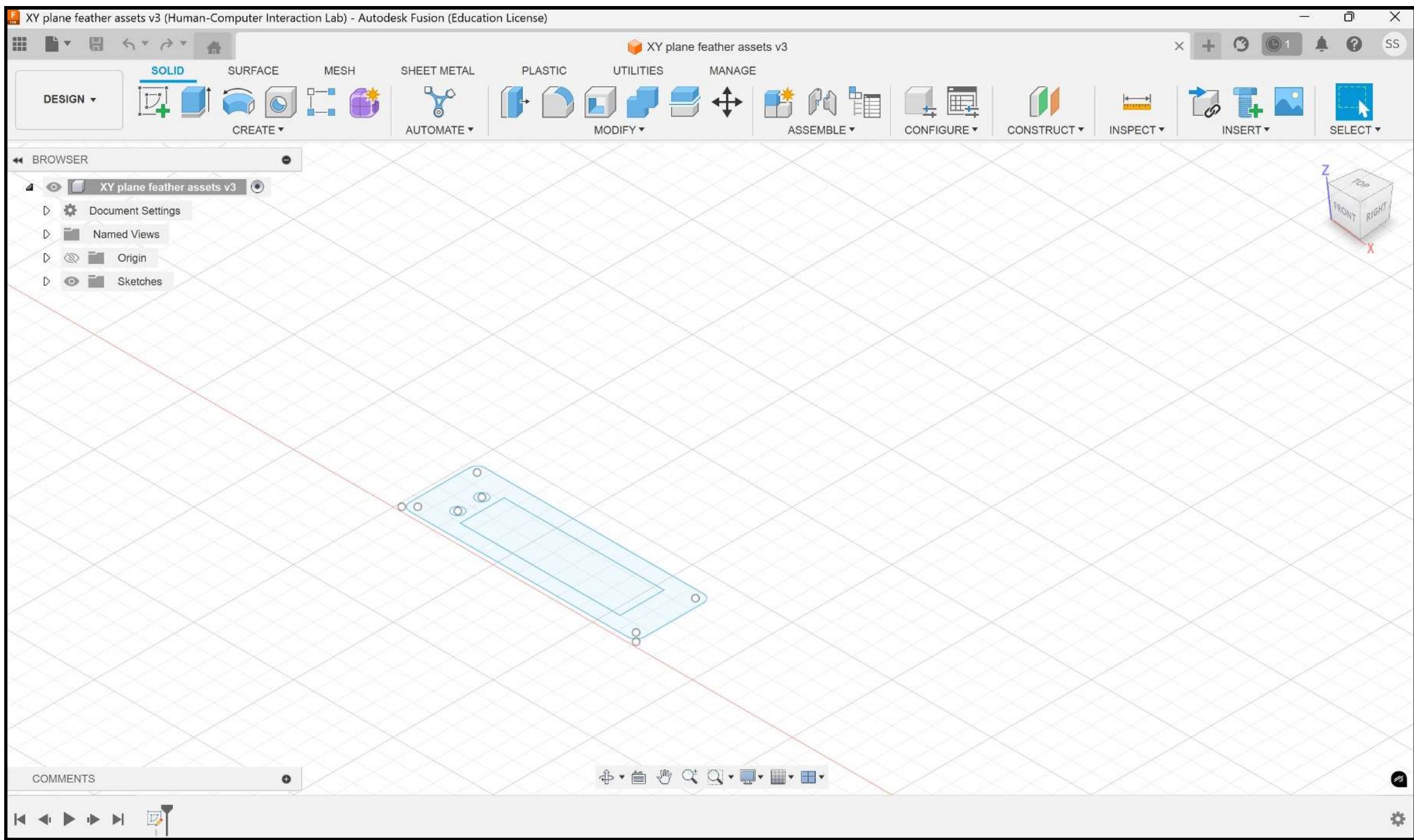
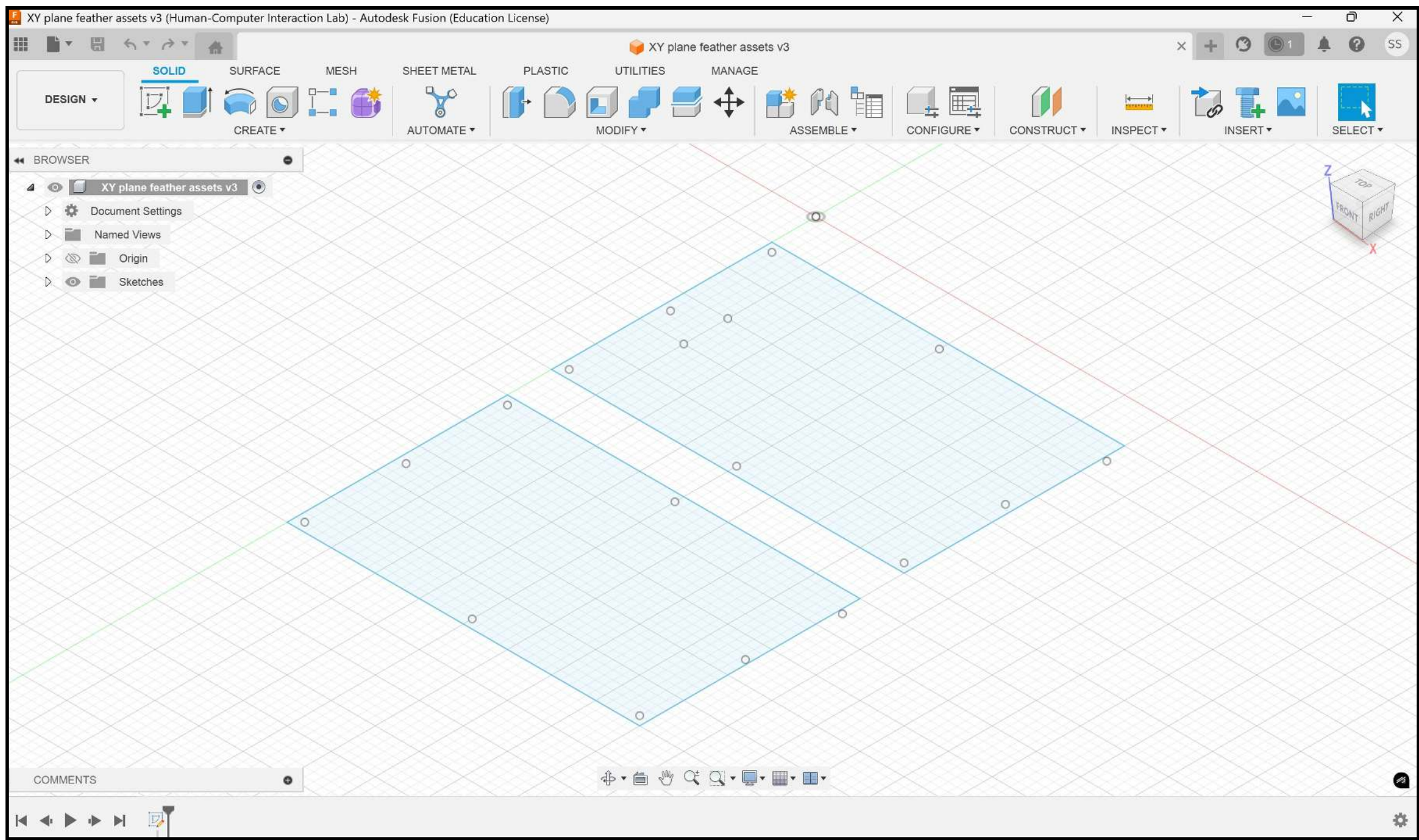
I created a 3D model of my proof of concept of MudraMor after doing a crash course in Fusion360



I used our laser cutting device with assistance from Hannes for the device.

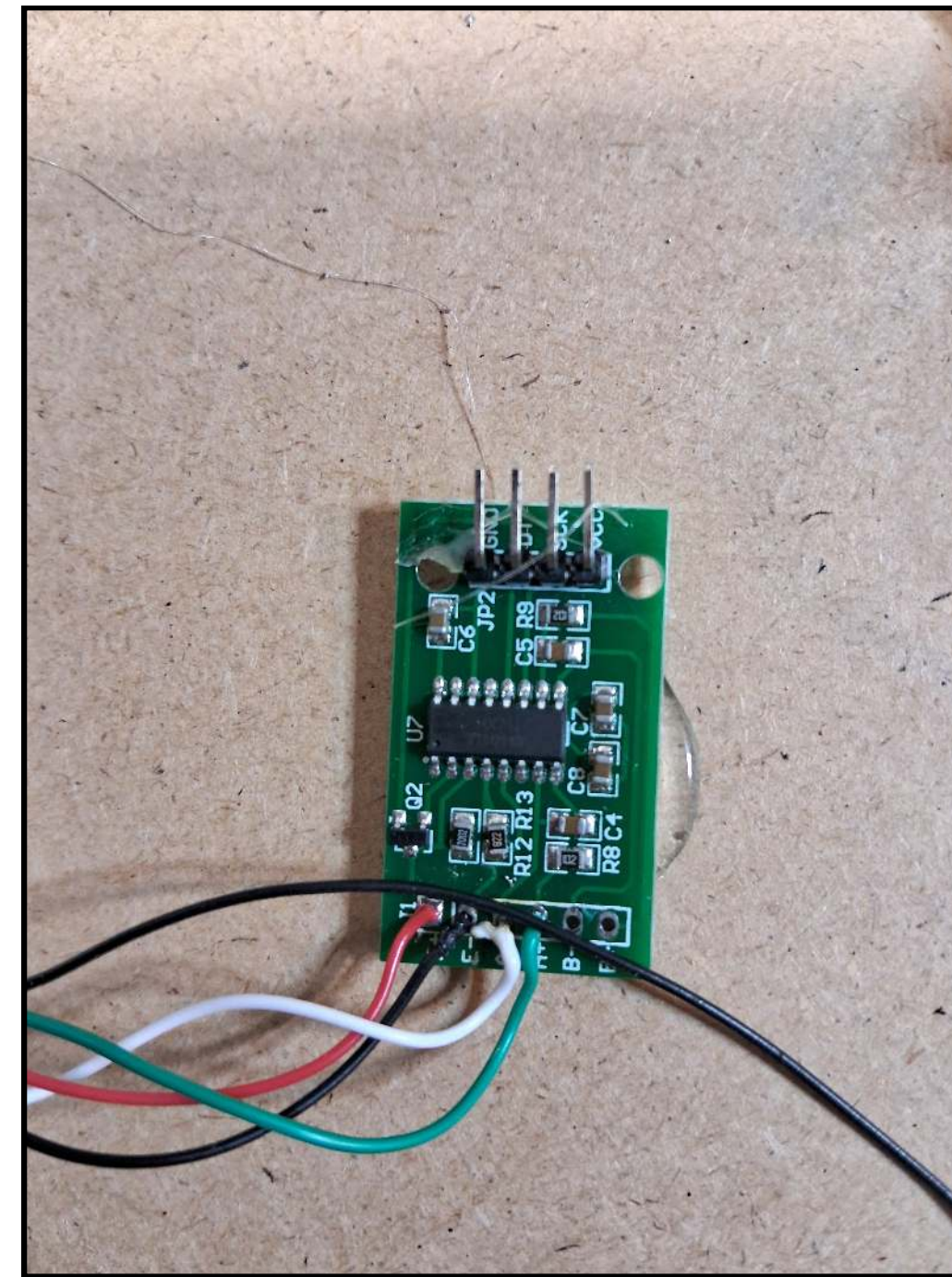
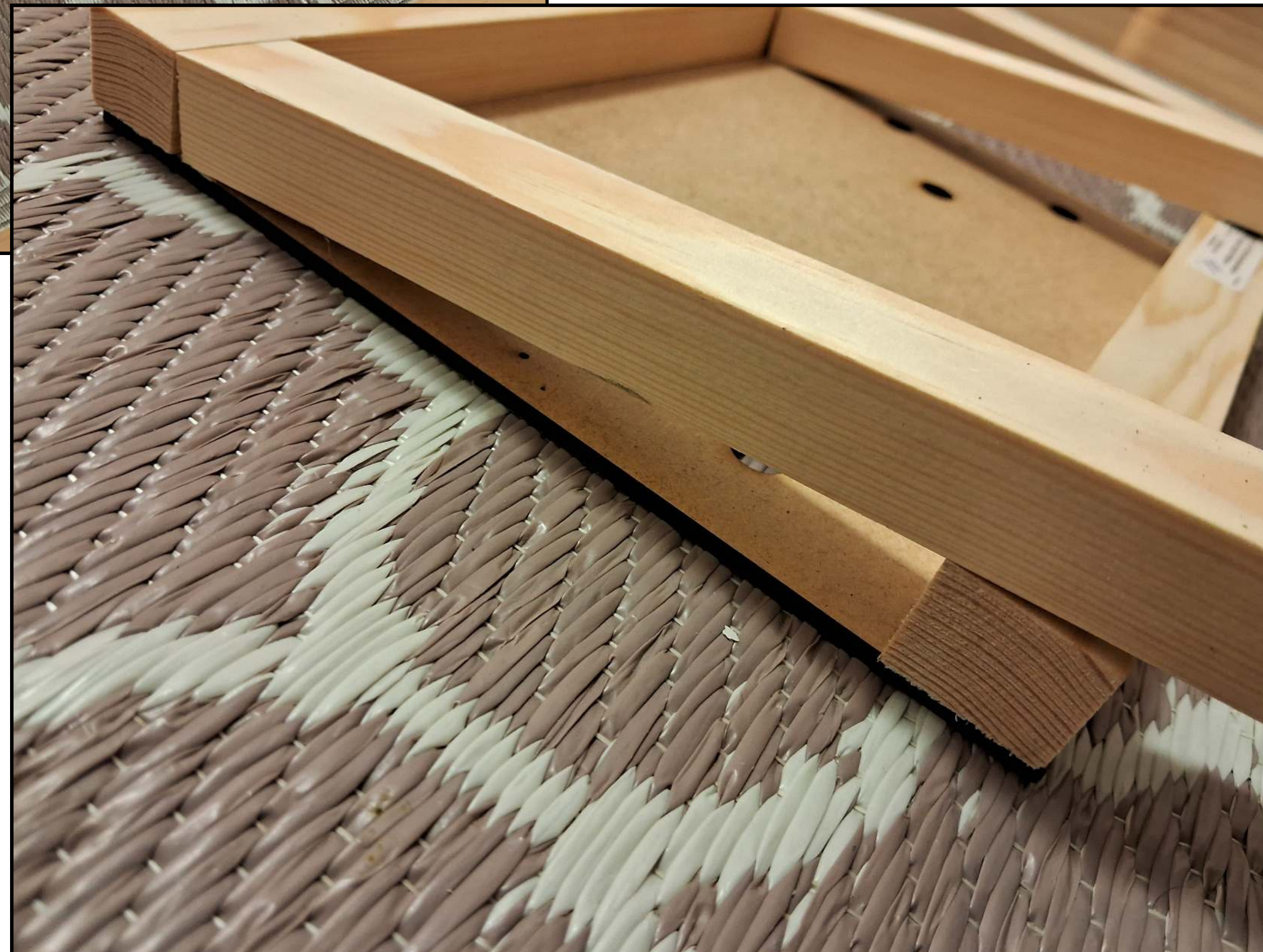


I made 2D measurements for laser cutting on Fusion360 for my device.

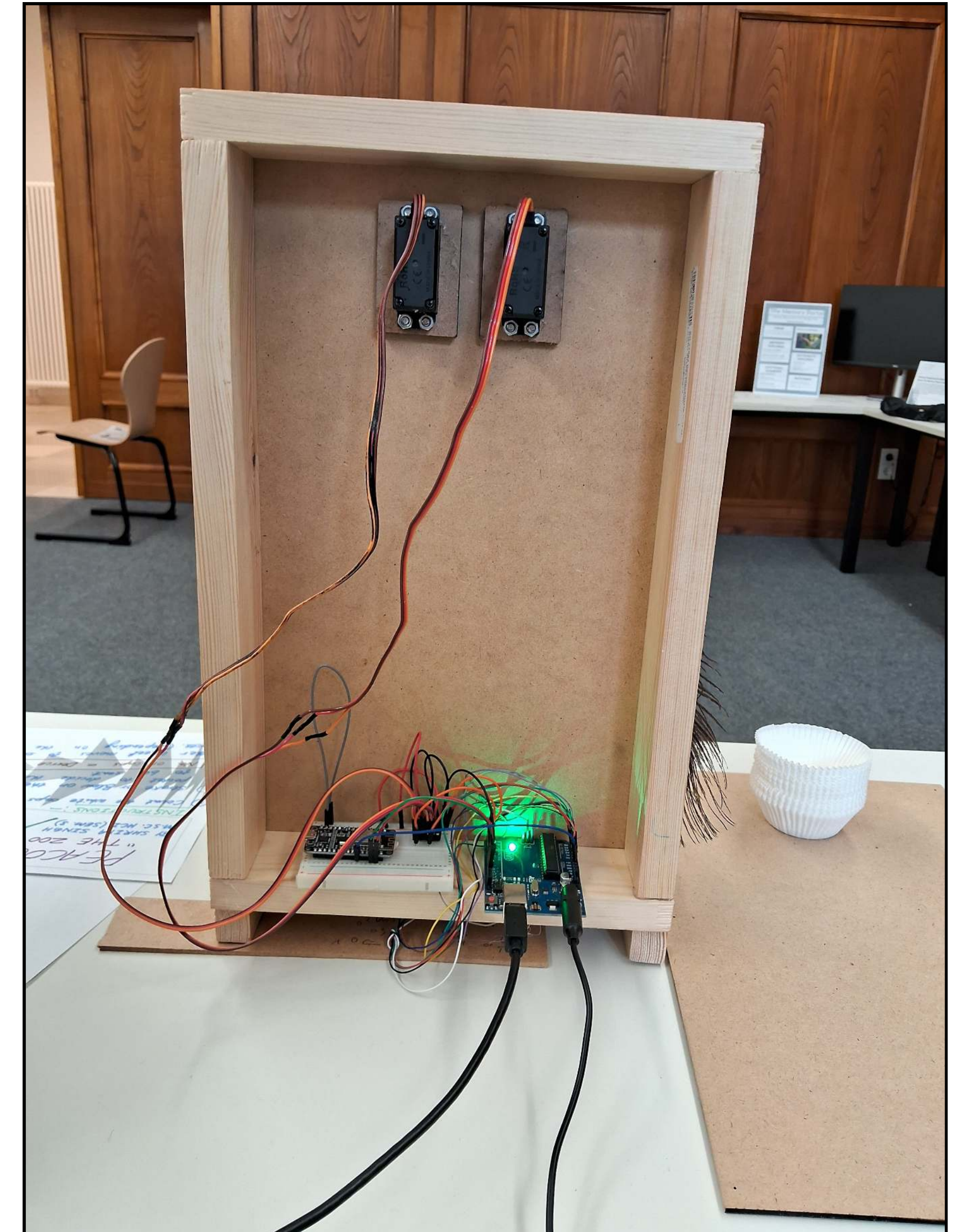




I procured wooden planks for the body of my device, measurements were inaccurate so i used a sawing tool at our lab to make it even.



I started testing ESP-NOW module to understand it better.



At this point, homework and classwork had blended into one together. Hannes and I finished this prototype before Summaery25 started.

AI-Use Declaration

AI tools were used in this project to:

- Generate Arduino code for servo-actuated tail motion, ESP-NOW messaging, and sensor logic
- Create an illustration of the Scorpion Interface's sending/receiving mechanism
- Find and format references related to tangible interaction and communication devices

Why AI was used:

To speed up code prototyping, clearly visualize a novel device concept, and quickly locate supporting literature under tight time constraints.

Example Prompt Used for Image Generation:

"Generate a detailed isometric illustration of a scorpion-inspired tangible interaction device with a segmented servo-actuated tail that flicks to send messages and curls to receive. Include a spring pocket and weighing sensor at the base for message selection. Clean technical style."

Pincer Interface for Distributed Tangible Messaging Devices

Abstract

This report presents a conceptual and mechanical exploration of the Scorpion Interface which is a novel, embodied communication system inspired by the behavioral and anatomical features of scorpions who are quite a common sight in Rajasthan (India) where I spent a major chunk of my life. The interface seeks to reimagine message transmission within pervasive computing networks using gesture-triggered tail movements and sting-like micro-interactions. Built with low-cost components and designed for minimal touch-based activation, the device mimics scorpion behavior to convey varying levels of message intensity. This brief “extra-tasksque” report details the motivation, inspirations, theoretical framing, technical setup, design decisions, failures, and future opportunities for extending this concept in tangible interaction research.

1. Introduction

Inspired by the creature’s evolutionary sophistication and cultural symbolism, the Pincer Interface proposes a poetic yet technically viable form of device-to-device communication. The report explores how the iconic tail motion like arching, flicking, or curling...can serve as a metaphor for intention, urgency, and addressability in a connected system of tangible interfaces. This device reflects an effort to explore post-touch paradigms of interaction using mechanical form and gesture rather than buttons or screens.



2. Theoretical Background & Related Work

2.1 Cultural & Symbolic Influence

Scorpions have occupied a unique place in Indian mythologies and folklores, they are often associated with both danger and resilience. Their presence in desert cultures and their distinct communicative posture serve as metaphors for alertness and intent. The gesture of curling their tail in preparation to strike inspired the movement logic in this interface.

2.2 Calm Technology and Zero UI

Following Weiser and Brown's vision of Calm Computing, the Pincer (Scorpion) Interface operates peripherally, its gestural feedback is ambient rather than attention-seeking. The device embodies a Zero-UI philosophy, relying on body language of machines rather than traditional screen interfaces to communicate intent and data.

2.3 Technical Foundations

- Arduino Nano/Uno for core control
- Servo motors to animate the tail gesture
- Piezo sensors or capacitive touch pads for input trigger
- ESP-NOW for peer-to-peer communication across devices
- Optional: Force-sensing resistor (FSR) at the sting tip to simulate 'sting' intensity
- 3D printed exoskeleton for aesthetics + structural housing



3. Design Process

3.1 Initial Concept

The early idea involved splitting the scorpion body into:

- Input segment (touch-based, underbelly or leg pads),
- Output segment (tail movement),
- Messaging controller (intensity + recipient encoding).

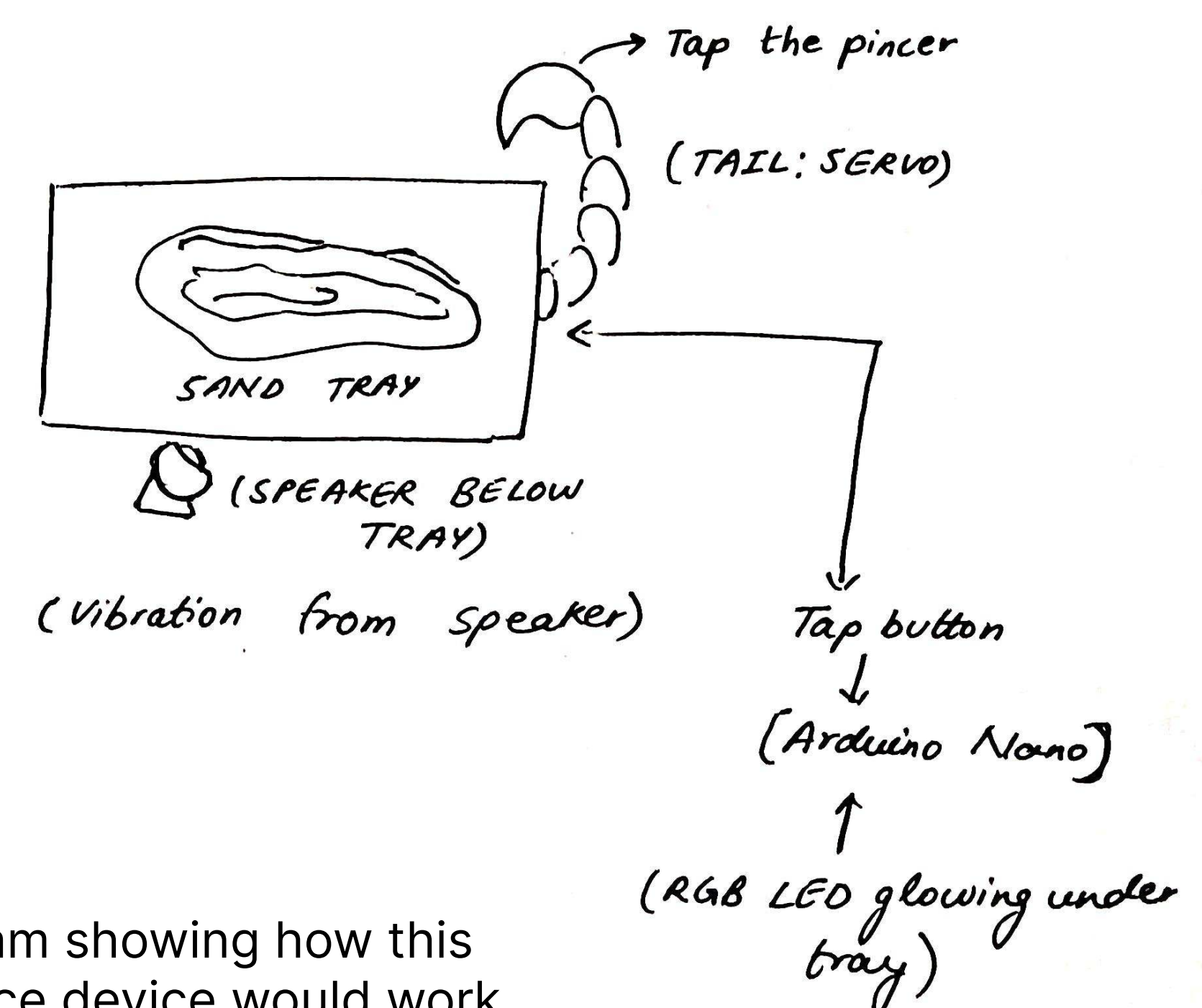
This was refined into a compact design where tail movement is the message.

3.2 Mechanical Approach

A servo-powered curved tail structure moves in discrete steps (30°, 60°, 90°) based on message content or urgency. The sting point optionally presses a soft button or touches a metal ring, completing a circuit to signal message sending.

3.3 Decisions and Drawbacks

- Quite a bit of a challenge: creating a flexible yet resilient tail that mimics arching
- Issue: over-rotation or under-powering the servo
- Dropped Ideas: using a sand-based terrain, LED exoskeleton patterns
- Combined: messaging, intensity encoding, and recipient detection into one tail-based mechanic



A small diagram showing how this pincer interface device would work

4. Discussion

4.1 What This Work Adds

- Offers a new metaphor for tangible, embodied communication
- Reinforces the idea of expressive movement as message
- Contributes to ongoing discussions in TEI around minimal-actuation interfaces
-

4.2 Relation to Literature

- Confirms concepts proposed in “Slow Technology” and “Calm Interfaces”
- Challenges the need for high-resolution input by proposing symbolic motion
- Disagrees with screen-heavy messaging interfaces in HCI
-

4.3 Limitations

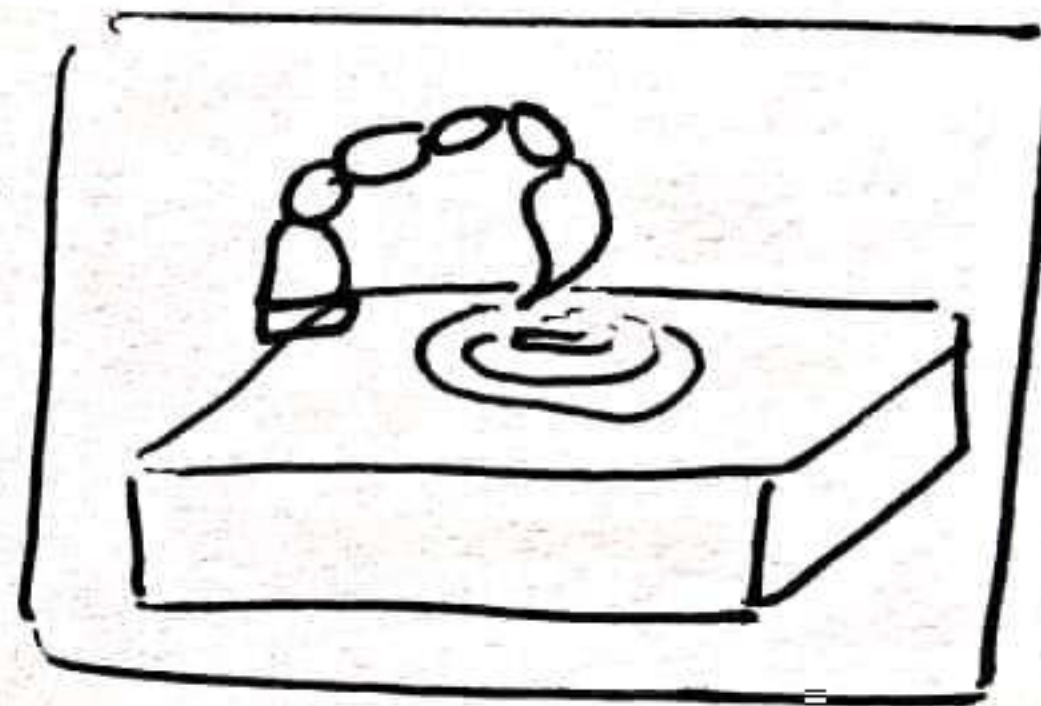
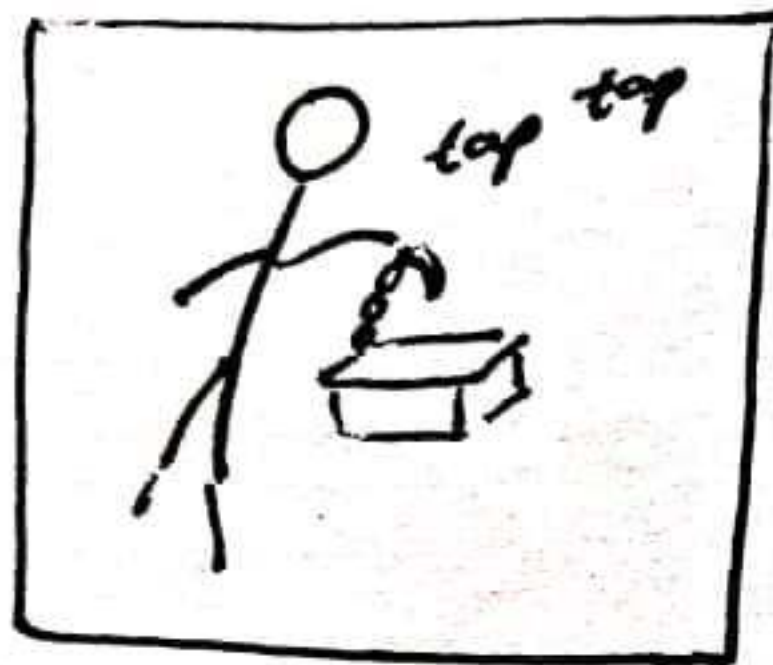
- Tail movement may not scale well for long-range messaging
- Interpretation of tail gestures may vary; requires calibration
- Not suitable for all accessibility contexts

5. Conclusion

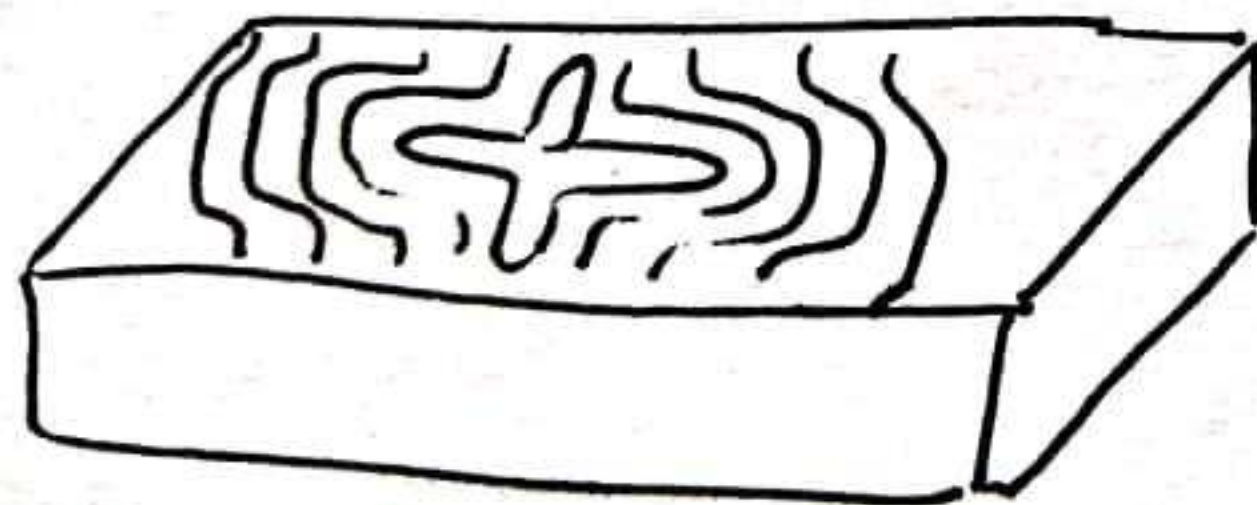
The Pincer Interface presents a novel tangible interaction mechanism for expressive, low-bandwidth communication between devices. Through motion metaphors, it transforms the act of sending and receiving messages into a performative gesture, evoking both cultural symbolism and technical curiosity. This work encourages further exploration of nonverbal interfaces and poetic robotics in the domain of distributed physical computing.

6. Storyboard

1. User taps the pincer button on top to trigger movement and set intensity of the message



2. If the pincer interface device receives a message then a pre-recorded vibration is played on the bottom of the sand plate showcasing a unique pattern linked to the sender.



3. The sand plate will show a unique pattern each time to show the reception of a message or to show a universal message.

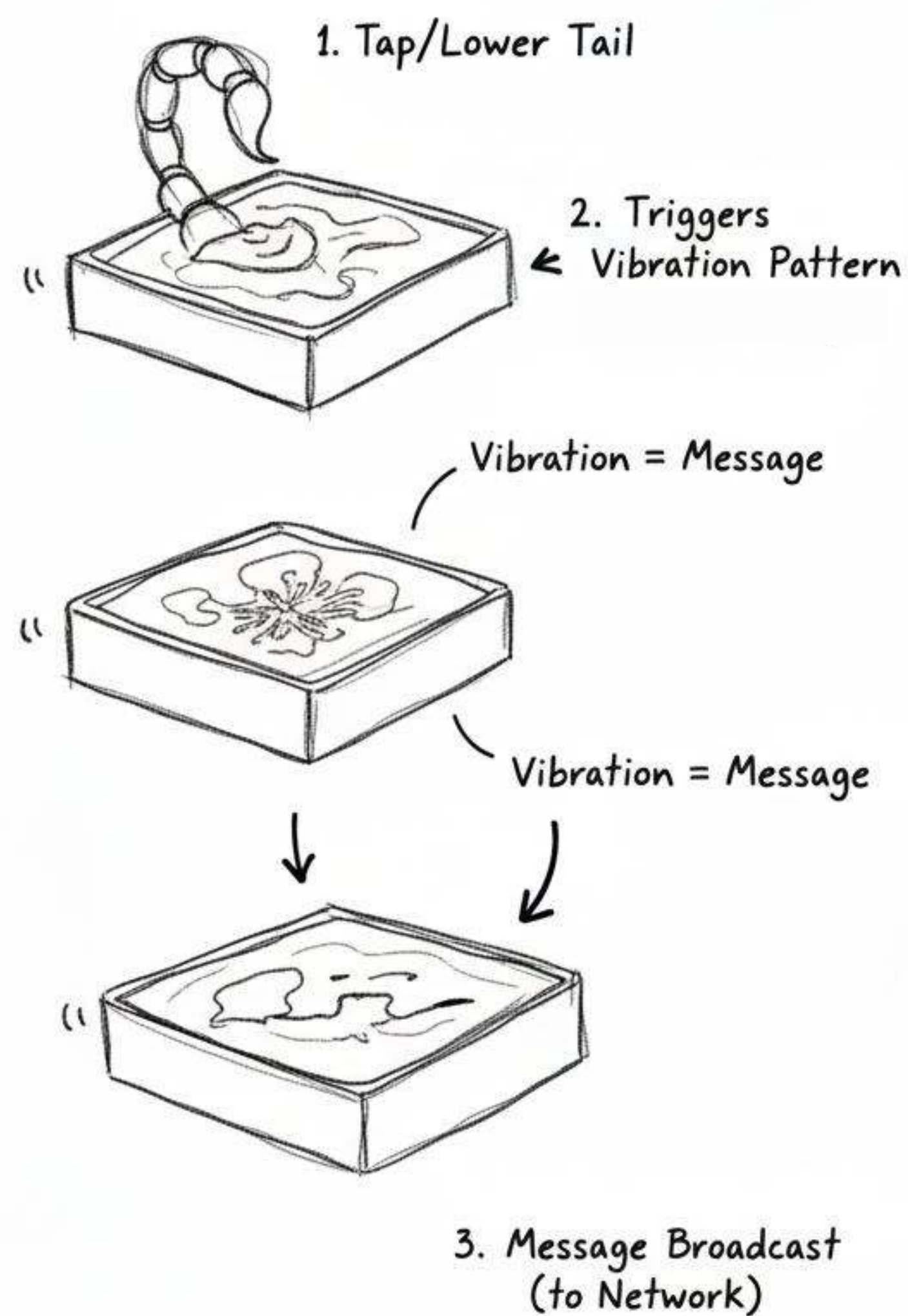
Send Mechanism

- The user taps or lowers the tail once.
- This triggers a pre-recorded vibration pattern (stored in code) to play on the sand surface.
- That vibration = the message, which gets "broadcast" to the network (via ESP-NOW, if wireless; or just simulated in a solo prototype).

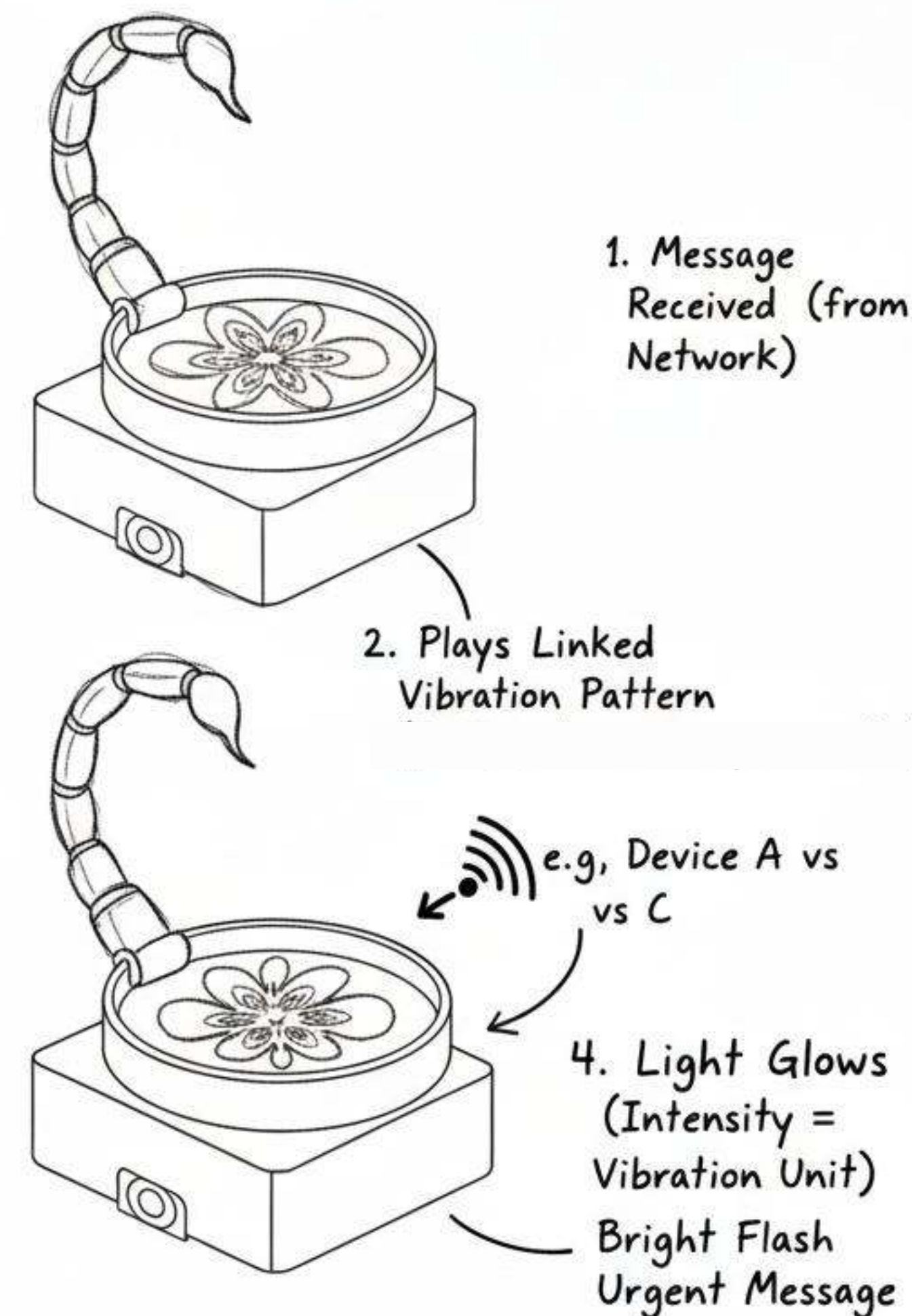
Receive Mechanism

- When another device in the network sends a message:
 - Your device plays a linked vibration pattern (just like above).
 - The light glows at a specific intensity:
 - e.g., soft glow = casual message, bright flash = urgent
 - The pattern in sand differs slightly to reflect who sent it (e.g., device A vs B vs C → different waveforms).

SEND MECHANISM



RECEIVE MECHANISM



7. Component and its Role

- Arduino Nano / UnoMicrocontroller to run logic
- Mini Speaker / Transducer to play vibration on surface
- White fine sand / powder for cymatic visuals
- LED (RGB or white) to show intensity
- Servo motor (SG90 or similar) to actuate the tail
- 3D printed / sculpted "tail" for symbolic interaction
- Pushbutton / touch sensor to detect the tail tap
- ESP8266 / ESP-NOW for networked communication

8. Code

```
#include <Servo.h>
```

```
Servo tailServo;  
int buttonPin = 2;  
int speakerPin = 6;  
int ledR = 3;  
int ledG = 4;  
int ledB = 5;
```

```
bool buttonPressed = false;
```

```
void setup() {  
  tailServo.attach(9);  
  pinMode(buttonPin, INPUT_PULLUP);  
  pinMode(speakerPin, OUTPUT);  
  pinMode(ledR, OUTPUT);  
  pinMode(ledG, OUTPUT);  
  pinMode(ledB, OUTPUT);  

```

```
  // Initial LED state  
  analogWrite(ledR, 0);  
  analogWrite(ledG, 0);  
  analogWrite(ledB, 0);  
}
```

```
void loop() {  
  // Check for tail tap (button press)  
  if (digitalRead(buttonPin) == LOW && !buttonPressed) {  
    buttonPressed = true;  
    sendMessage();  
  }  
}
```

```
  // Reset button state after release  
  if (digitalRead(buttonPin) == HIGH) {  
    buttonPressed = false;  
  }  
  
  // Simulated message receive check  
  if (/* condition to simulate received message */) {  
    receiveMessage(/*messageID*/);  
  }  
}
```

```
void sendMessage() {  
  tailServo.write(45); // small tail flick  
  delay(300);  
  tailServo.write(0);  
  
  // Play vibration pattern  
  tone(speakerPin, 120); // frequency in Hz  
  delay(500);  
  noTone(speakerPin);  
}
```

```
void receiveMessage(/*int messageID*/) {  
  // Light up with intensity  
  analogWrite(ledR, 255); // Red = urgent  
  analogWrite(ledG, 100); // Optional green tint  
  analogWrite(ledB, 0);  

```

```
  // Play pre-coded vibration  
  tone(speakerPin, 200); delay(300);  
  tone(speakerPin, 150); delay(300);  
  noTone(speakerPin);  
}
```