Hand Me the Music: Making Music with Interactive Hand Gestures and Arm Movements

Best Project Award
Engineering Interactive Technologies
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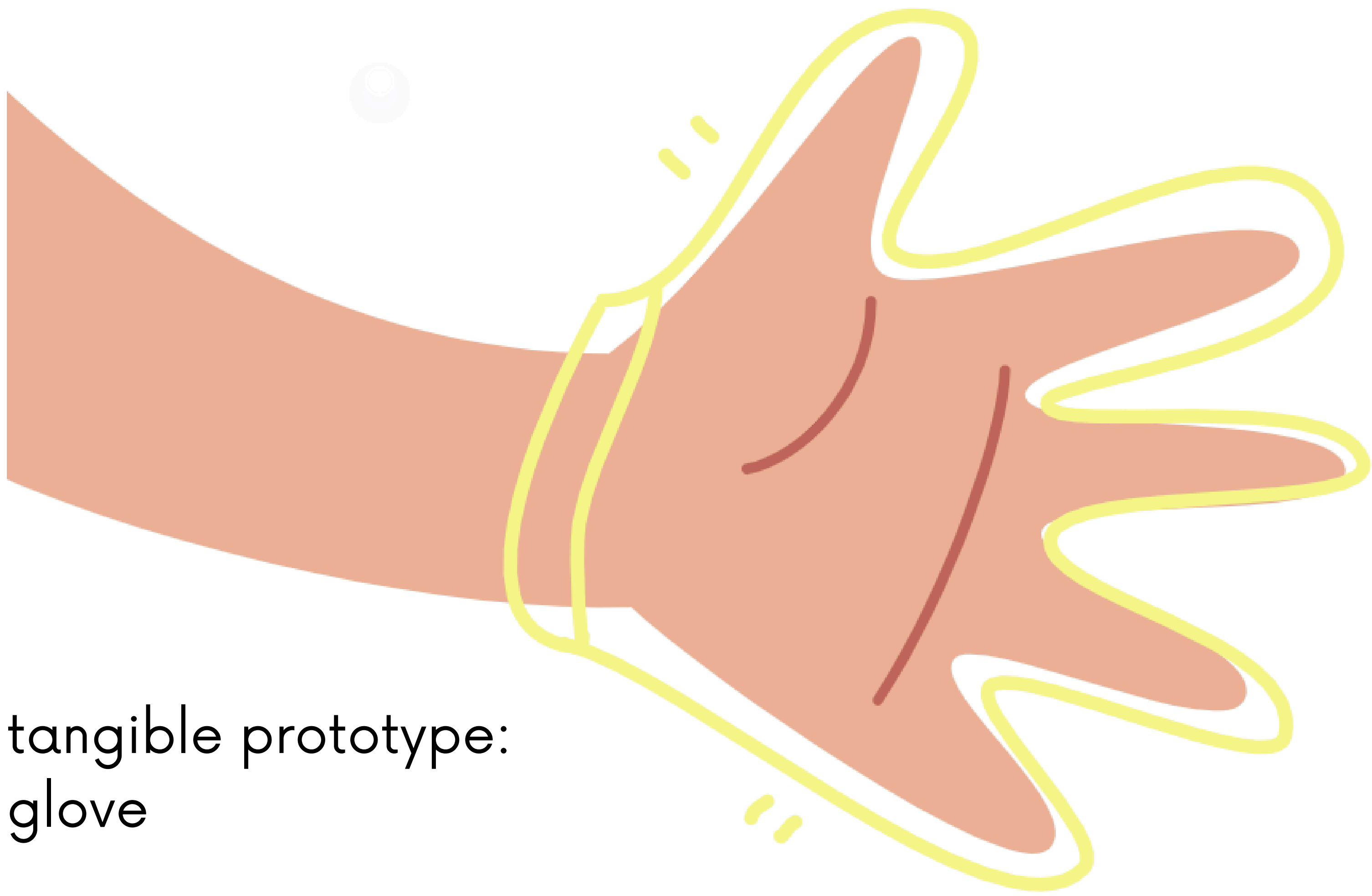
Project Workflow:

- Literature Review
- Gesture and Movement Design
- Establishing Hardware Requirements
- Software Development
- System Integration and Prototyping
- Usability Testing
- Analysis



tangible prototype: glove

My Role:

- Hardware and Software Engineer
- UI Designer
- Usability Testing
- Data Analysis
- Report Writing

Skills and Tools:

- Inertial Measurement Unit (IMU)
- Arduino Programming
- Force Sensors
- Circuit Design

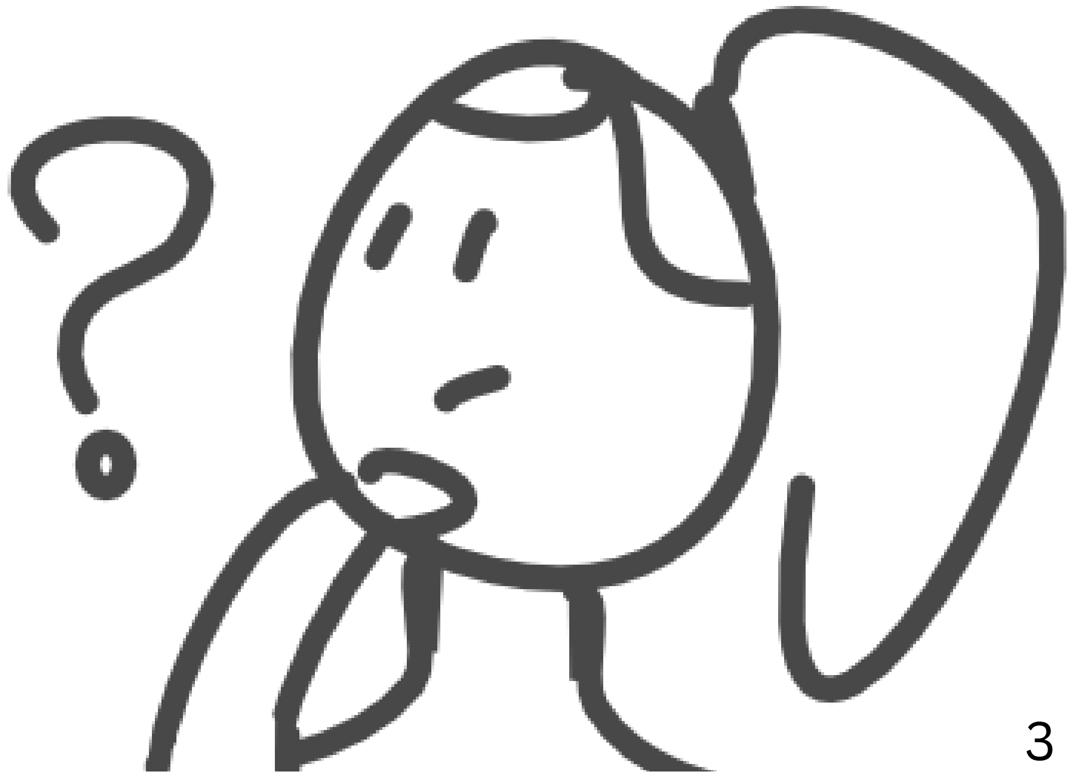
Members:

Candace Chen, Jiayi Ge, Ji Hyun Kim, Bailey Phillips, Zeyang Zheng

Motivation

Playing musical instruments and creating music offers a powerful and enjoyable form of self-expression. However, learning to play traditional musical instruments requires significant time and practice, which can limit participation to those with ample time and cost for owning multiple instruments.

How can we make learning to play a musical instrument more accessible to beginners, reducing both time investment and financial barriers?



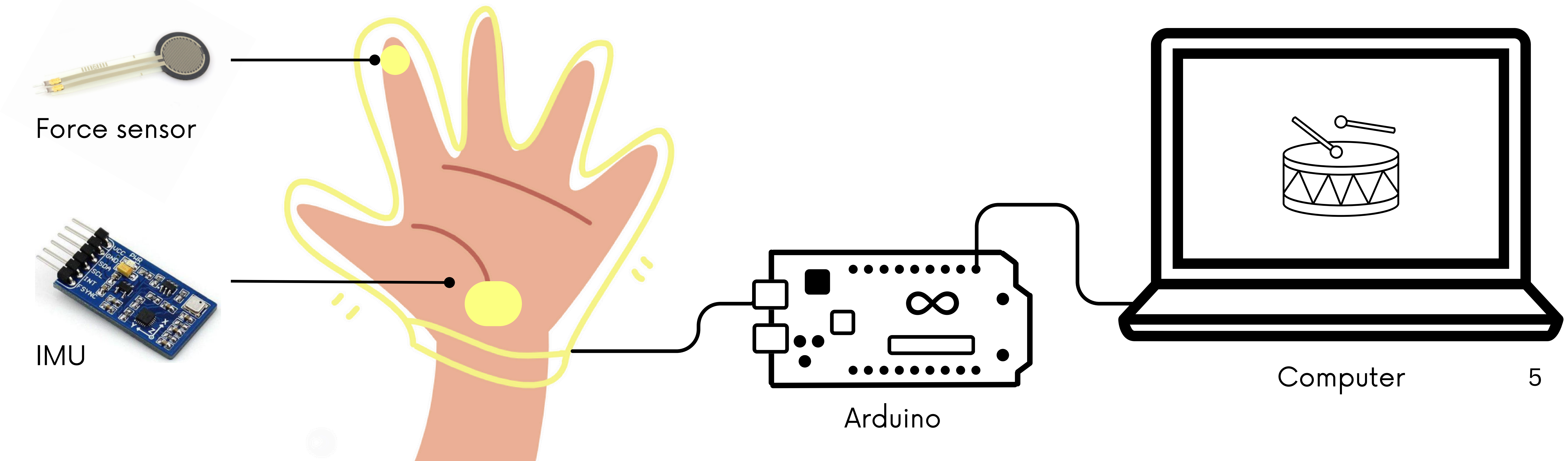
Desk Research

Our research found that advanced stage performances have long utilized sophisticated sensors to capture hand gestures and produce musical outputs. For example, Georgi et al. introduced a gesture recognition framework utilizing electromyography and IMU sensors [1]. More work from Makaussov et al. demonstrated that fine-grained gesture recognition, including finger movements, could be achieved on more basic, low-tech devices [2].

What if we repurpose this technology and make it more accessible to general users?

Establishing Hardware Requirements

To effectively measure distinct hand gestures for producing unique instrument sounds, we needed a combination of sensors capable of accurately capturing these movements. Leveraging our experience with accelerometers via IMU and force sensors from class and lab projects, we identified these as the ideal tools for distinguishing hand gestures. Using the Wizard of Oz technique and signal analysis, we determined optimal sensor placements on the hand and designed a glove-based wearable to keep the sensors in position.



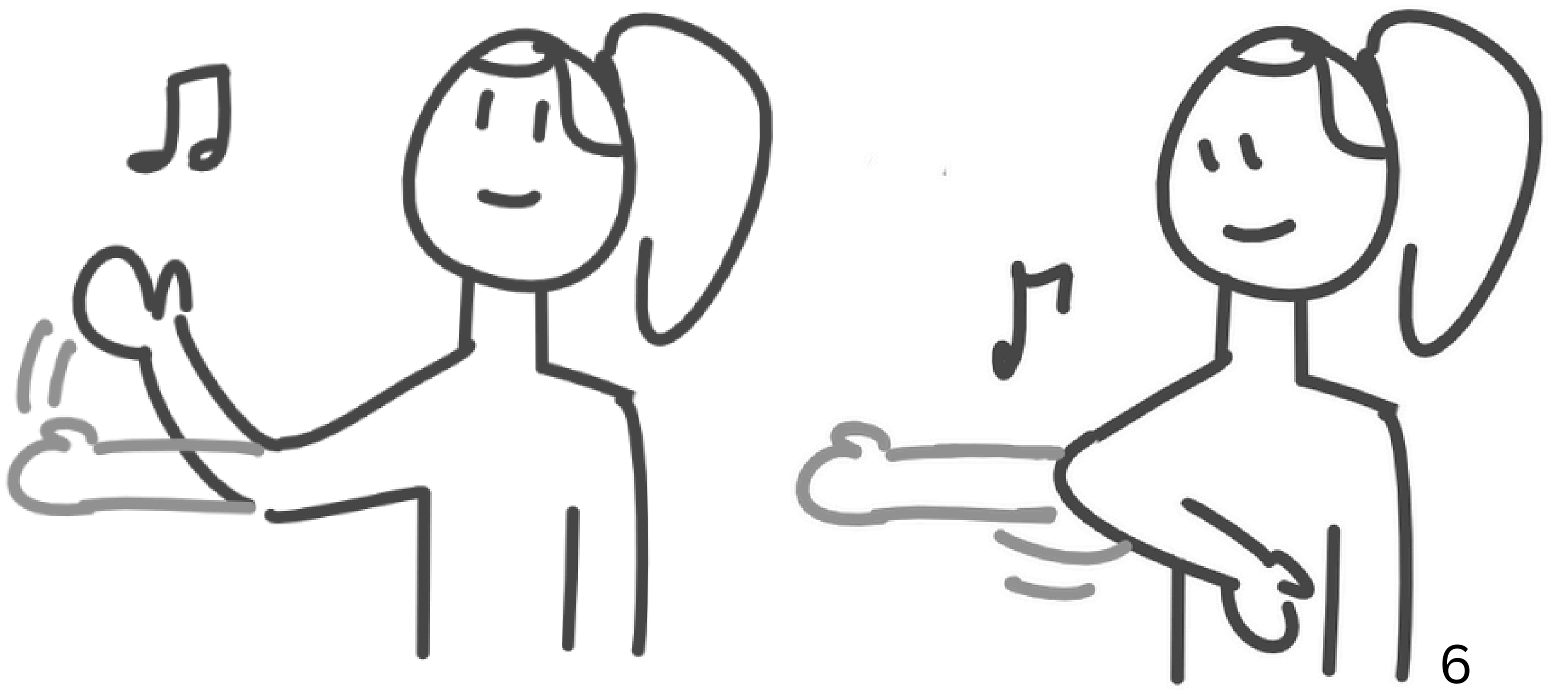
Designing Interactions

When designing an input modality and interaction, we have to consider gestures that map naturally to sounds you metaphorically ascribe to them. From further literature search and testing amongst the team, we decided on the following gesture to music mappings:

Instrument	Gesture Description
Drum	Up/down quick fist movement
Piano	Palm face down with little up/down pulses
Maraca	Palm face up with little up/down pulses
Guitar	Palm facing leftwards with left/right wrist movements

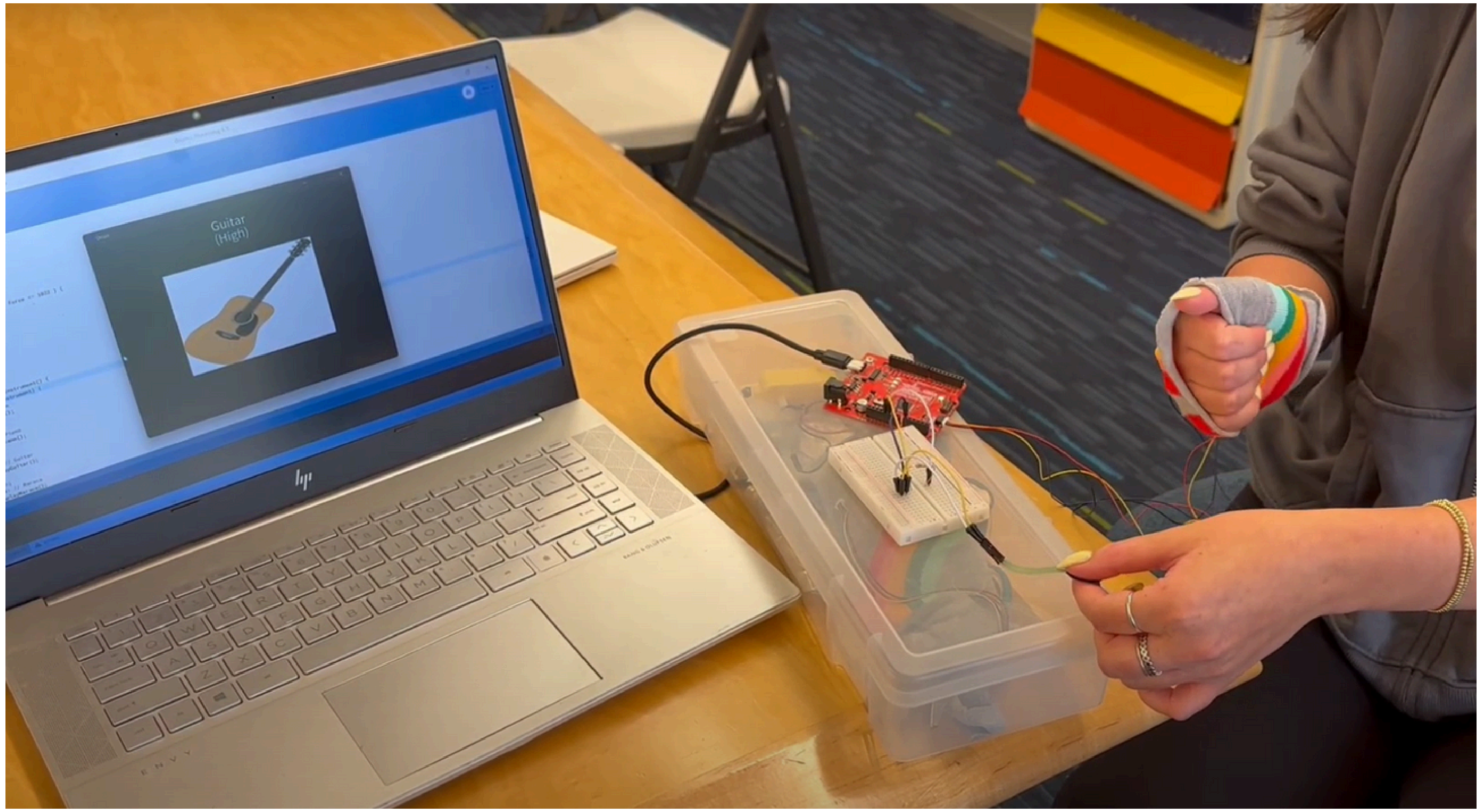
Table 1: Gesture Description

The force sensor was placed on the index finger to control sound pitch with different forces of press.



Software Implementation

For each gesture, I attached the IMU sensor to the back of the hand, performed the gesture, and observed the x, y, and z acceleration patterns using the Arduino IDE monitor. These patterns were then used to design the gesture **recognition algorithm**.



Setup

Software Implementation

The **algorithm** automatically recognizes all gestures without manual adjustments. It is divided into parts, each representing a different gesture, based on thresholds for x, y, and z readings:

- When the **first threshold** is met, the flag for that gesture is set to true.
- If within a set time, the **second threshold** is met and the first flag is true, the gesture is confirmed.
- This message is sent to the **Processing code** to notify that a gesture was made.
- The Processing code listens for notifications from **Arduino**, then checks the message and plays the corresponding sound using its **sound library**.
- For **visualization**, the corresponding instrument image is displayed on the screen with the current pitch to provide user feedback, which can be adjusted or removed as needed.

Usability Testing

The experiment aimed to evaluate the usability and performance of our prototype. Participants were asked to play each of the four instruments at three different pitches: low, medium, and high. We used a within-subject study design, where each participant completed all sessions—an effective approach given the small sample size. To ensure balanced exposure to all instruments, we used a counterbalancing method based on the Latin Square. The session order is outlined below.

Table 2. Session Order

Participant	Session 1	Session 2	Session 3	Session 4
P1	Piano	Drum	Maraca	Guitar
P2	Drum	Maraca	Guitar	Piano
P3	Maraca	Guitar	Piano	Drum
P4	Guitar	Piano	Drum	Maraca
P5	Piano	Maraca	Guitar	Drum
P6	Drum	Guitar	Maraca	Piano

Results and Evaluation

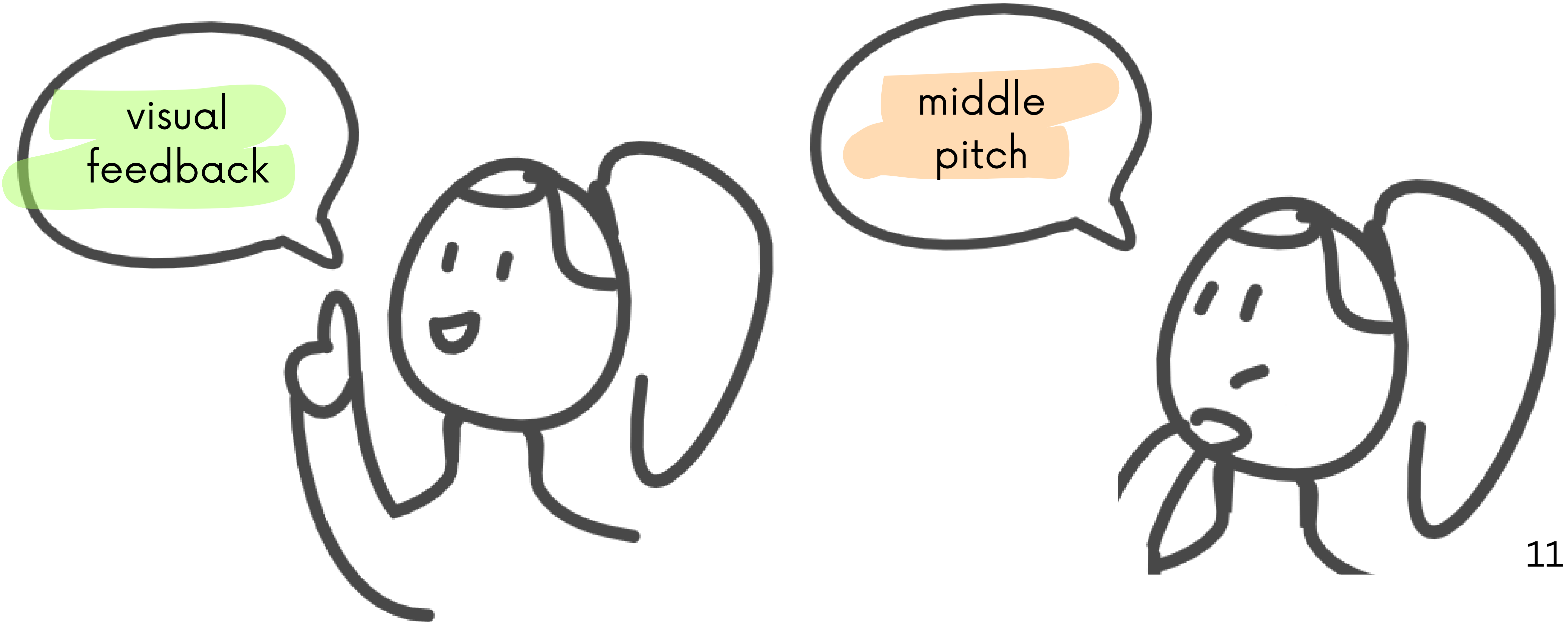
The experiment focused on evaluating two main aspects: accuracy and participant feedback. Accuracy was measured by the success rate of correctly triggering each instrument and pitch. Participant feedback was collected to understand user experiences and identify areas for improvement.

Table 3. Evaluation

Instrument	Pitch	Success Rate	
Piano	Low	91.7%	91.7%
	Mid	91.7%	
	High	91.7%	
Drum	Low	83.3%	80.5%
	Mid	75.0%	
	High	83.3%	
Maraca	Low	91.7%	70.1%
	Mid	50.0%	
	High	75.0%	
Guitar	Low	75.0%	77.7%
	Mid	75.0%	
	High	83.3%	

Qualitative Feedback

Participants provided feedback on the prototype's sensitivity, noting that the instruments sometimes triggered unintended sounds. They found the visual feedback helpful in confirming their actions. However, issues with the force sensor controlling the middle pitch highlighted the need for sensitivity adjustments. Participants also suggested that adding more notes for each instrument would improve the prototype's musicality.



Discussion

We built a **tangible interface** that provided users with an immersive, cost-effective way to **create music in real-time**. The glove allowed participants to freely engage with different instruments and experiment with various pitches, **fostering creativity** and a sense of ownership over their music. This **sense of ownership** stemmed from the **physical act of controlling musical** notes and their progression through gestures. Using a force sensor for pitch control, we realized that introducing more pitch options would be possible with alternative methods. Overall, our device enabled users to express themselves through music and hand gestures, offering **a unique, nontraditional way of interacting with music**. Despite limitations in time and resources, we successfully created an engaging and effective musical experience.

Reflection

Check out the Demo!

Accomplishments:

- Utilized the IMU accelerometer to recognize four distinct hand gestures with an accuracy rate of 80.5%.
- Integrated the hand gesture recognition system with musical instrument output using Processing code and Arduino.
- Employed a force sensor to control the instrument pitch via Processing and Arduino, enabling real-time pitch changes.

Our project received the **Best Project Award** in the **Engineering Interactive Technologies** course, recognized by our peers and Professor Dr. Seongkook Heo for its innovative implementation and engaging demonstration.

Reflection

I learned a lot from this project!

I polished my skills in study design, conducting literature reviews, qualitative user research, and analysis. I gained valuable leadership and project management experience and I feel proud of what we delivered. It was a smooth ride.

I thoroughly enjoyed the technical aspects of this project. Working with IMU, sensors, and Arduino boards rekindled my passion for tinkering, and it inspired me to always have a relaxing side project to pursue as a hobby.

Appendix and References

[1] Marcus Georgi, Christoph Amma, and Tanja Schultz. Recognizing Hand and Finger Gestures with IMU based Motion and EMG based Muscle Activity Sensing:. In Proceedings of the International Conference on Bio-inspired Systems and Signal Processing, pages 99–108, Lisbon, Portugal, 2015. SCITEPRESS - Science and Technology Publications.

[2] Oleg Makaussov, Mikhail Krassavin, Maxim Zhabinets, and Siamac Fazli. A Low-Cost, IMU-Based Real-Time On Device Gesture Recognition Glove. In 2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC), pages 3346–3351, Toronto, ON, Canada, October 2020. IEEE.

Disclaimer: All the cute illustrations in this portfolio were made by me.

Figure: complete results

	Session 1		Session 2		Session 3		Session 4	
P1	**Piano**		**Drum**		**Maraca**		**Guitar**	
	Low	2	Low	2	Low	2	Low	2
	Mid	1	Mid	2	Mid	1	Mid	2
	High	2	High	2	High	1	High	2
	total	**83%**	**total**	**100%**	**total**	**67%**	**total**	**100%**
P2	**Drum**		**Maraca**		**Guitar**		**Piano**	
	Low	2	Low	2	Low	2	Low	2
	Mid	2	Mid	1	Mid	1	Mid	2
	High	2	High	2	High	2	High	1
	total	**100%**	**total**	**83%**	**total**	**83%**	**total**	**83%**
P3	**Maraca**		**Guitar**		**Piano**		**Drum**	
	Low	2	Low	1	Low	1	Low	1
	Mid	2	Mid	2	Mid	2	Mid	1
	High	2	High	2	High	2	High	1
	total	**100%**	**total**	**83%**	**total**	**83%**	**total**	**50%**
P4	**Guitar**		**Piano**		**Drum**		**Maraca**	
	Low	2	Low	2	Low	2	Low	2
	Mid	1	Mid	2	Mid	1	Mid	0
	High	2	High	2	High	2	High	2
	total	**83%**	**total**	**100%**	**total**	**83%**	**total**	**67%**
P5	**Piano**		**Maraca**		**Guitar**		**Drum**	
	Low	2	Low	1	Low	1	Low	1
	Mid	2	Mid	2	Mid	1	Mid	2
	High	2	High	1	High	1	High	2
	total	**100%**	**total**	**67%**	**total**	**50%**	**total**	**83%**
P6	**Drum**		**Guitar**		**Maraca**		**Piano**	
	Low	2	Low	1	Low	2	Low	2
	Mid	1	Mid	2	Mid	0	Mid	2
	High	1	High	1	High	1	High	2
	total	**67%**	**total**	**67%**	**total**	**50%**	**total**	**100%**