Ultrasound-Based Gesture Recognition

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Limitations of Muscle Sensing Human-Machine Interfaces

Current muscle sensing methods are indirect, noisy, and unreliable for muscle-based human-machine control. This limitation becomes critical in prosthetic applications, where precise and responsive input is required.

Why Ultrasound for Muscle Sensing

Ultrasound can directly measure muscle movement, enabling more accurate and intuitive muscle movement sensing for machines.

Scale: 0 - Strong Disadvantage, 1 = Disadvantage, 2 = Advantage, 3 = Strong Advantage

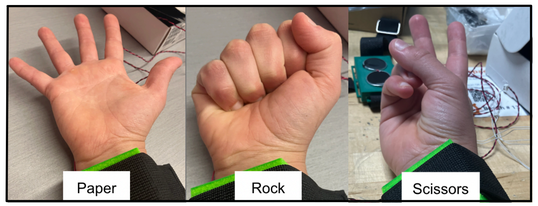
	MRI	CT	sEMG	FMG	Camera	Ultrasound
Cost	0	0	2	3	2	2
Real-Time	0	0	3	3	3	3
Signal Quality	3	2	2	2	1	3
Muscle Resolution	3	2	1	0	0	2
Comfort	0	0	2	2	3	2
Practicality	0	0	2	2	2	2
Average	1	0.67	2	2	1.83	**2.3**

Goal: Build a Wearable Ultrasound Sensing System

We developed a wearable system that translates real-world muscle activity into real-time gesture predictions for interactive applications.

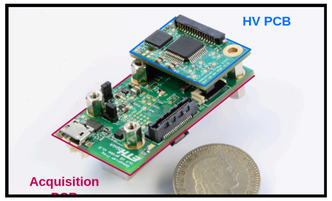
The system consists of four key components:

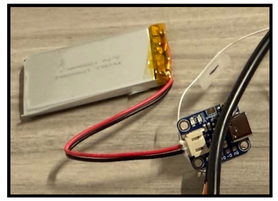
1. **Ultrasound Hardware**
2. **Wearable Mount and Brace**
3. **Machine Learning Model**
4. **Validation Application Interface**

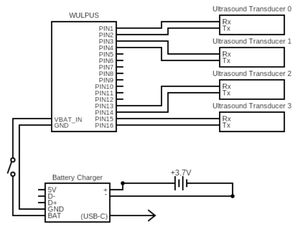


Ultrasound Hardware

The ultrasound hardware enables the system to capture real-time muscle signals. It consists of the Wearable Ultra Low Power Ultrasound (WULPUS) probe in A-mode and a battery-integrated charging circuit.

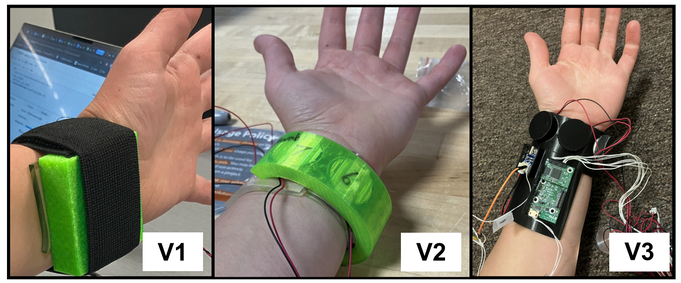






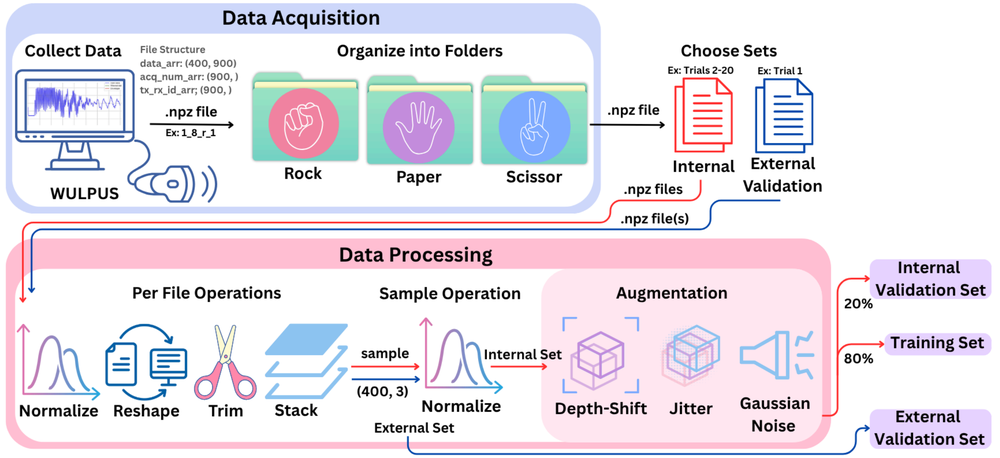
Wearable Mount and Brace

We created a brace to stabilize the system's sensors and house the hardware, ensuring consistent measurements. The brace went through three iterations.



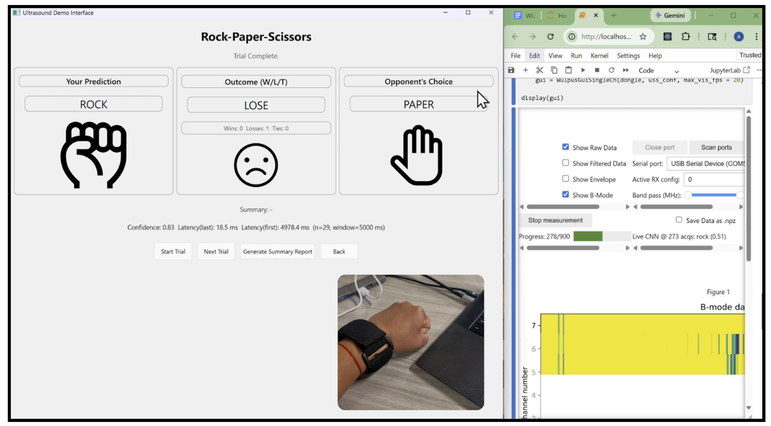
Machine Learning Model

The system's neural network classifies the newly collected data in real-time. The neural network is a 1D convolutional neural network that was trained extensively.



Validation Application Interface

The system is evaluated in a real-time setting, where a user's gestures are interpreted to play rock-paper-scissors. This demonstrates a proof-of-concept human–machine interface, showing how muscle activity can be translated into intuitive and responsive control of external systems.



Gesture Classification Performance

The system achieved high accuracy with unknown and real-world data. The system's performance was highest when the model was trained on data collected from the exact same position as the new real-time data. However, the model trained on a combination dataset was still able to correctly predict gestures from slightly different positions, although less consistently.