

The Emperor's New Instrument

18500 ECE Capstone: Final Presentation

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Use-Case Requirements

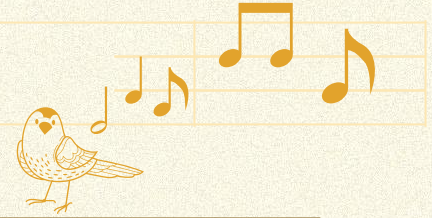


- A virtual music instrument controlled solely by hand movement and gestures.
 - CV for pitch control.
 - Wireless gloves for volume control and musical effects.
 - Synthesizer for customizable tone color, selected using gestures.
 - Real-time playing on laptop speaker.
 - Makes playing music more affordable and more convenient.

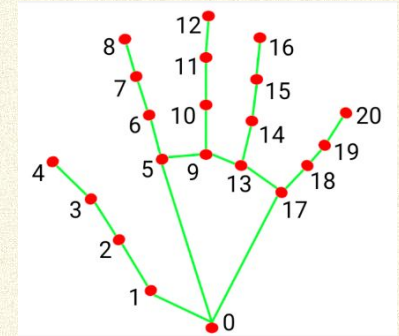
- Metrics
 - Detection Feedback speed: $\leq 10\text{ms}$
 - System weight and portability: ≤ 4.8 pounds
 - Battery Life: ≥ 5 hours
 - Plug-and-playability: $\geq 90\%$ success setup rate
 - Volume production accuracy: $\pm 0.5\text{dB}$ Error



Solution Approach

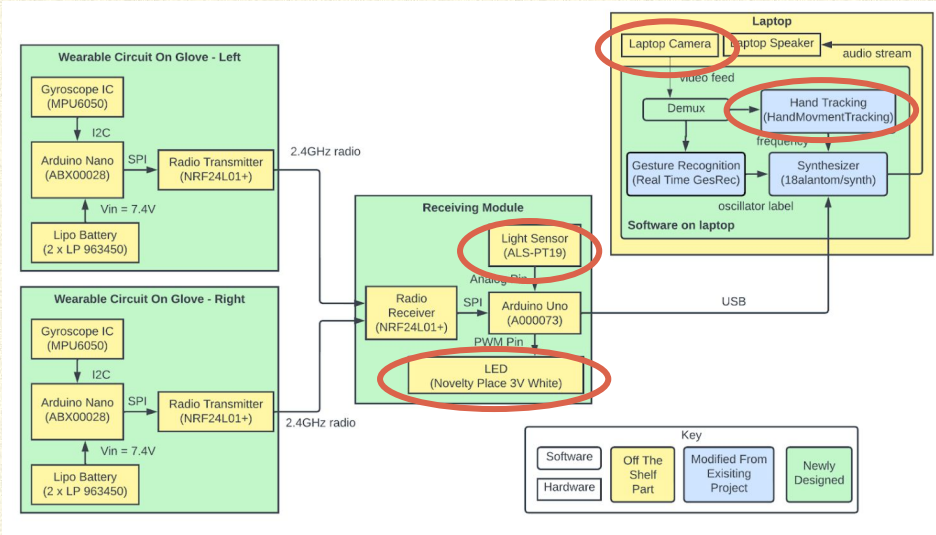


- Wearable circuit gloves (rotation detection)
- Gesture detection module
- Hand tracking module -> Color tracking module
 - The original hand tracking module uses mediapipe to track hand location. Since it tracks 21 different points, the delay is relatively high.
 - track 1 colored finger instead of 3 because it is more intuitive for the user, and image quadrant classification is faster
- Built-in camera -> External camera
 - There is a color difference between different computers' built in cameras. The same color detection range for different cameras could cause a potential problem
 - External lighting module is no longer needed

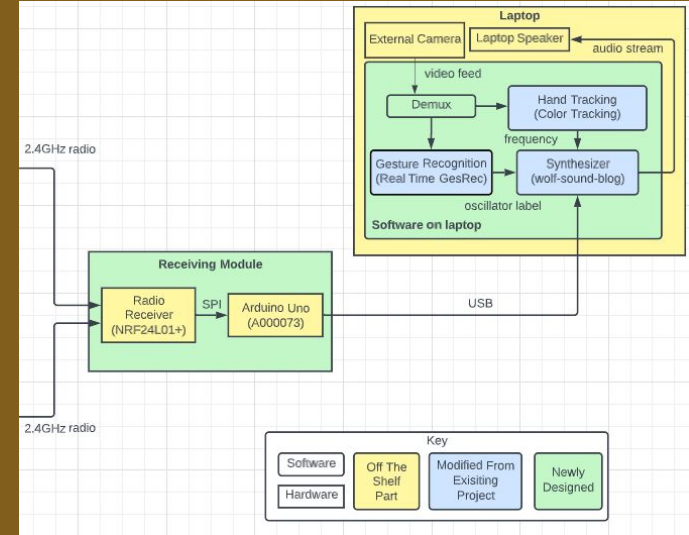




Solution Approach: Block Diagrams



Design Document Version



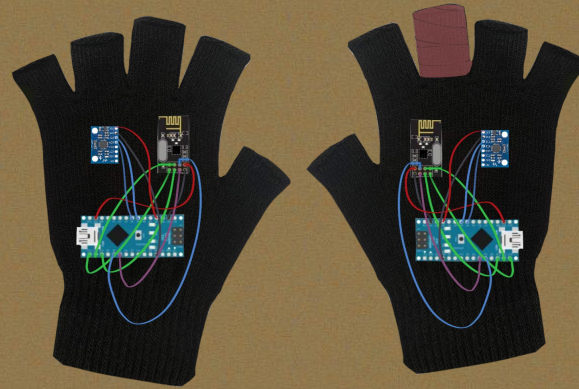
Final Implementation Changes



Complete Solution: Overview

On the right are images of our music production system

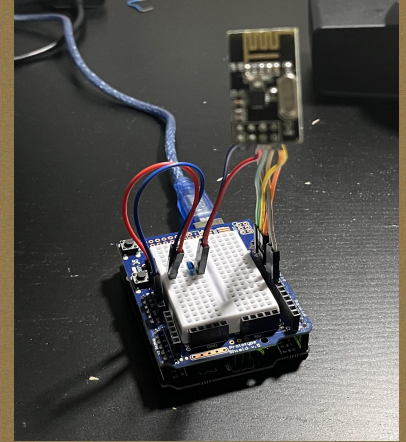
Back



Palm



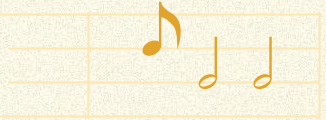
Laptop Screen



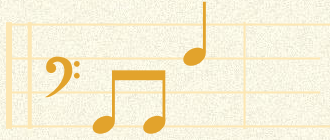
Receiving Module



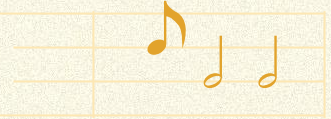
Testing, Verification & Validation



Criteria / Metric	Latency	Portability	High Sound Production Accuracy	Battery Life	Plug-and-Playability
Description	Time delay from movement of hand to sound being produced	Expected weight of our system (without laptop)	Halving volume(pitch angle) should decrease sound by 10 dB	Working time after one full charge	The success rate of setting up on Windows and macOS
Requirement	≤ 10 ms	≤ 4.8 pounds	± 0.5 dB Error	≥ 5 hours	$\geq 90\%$



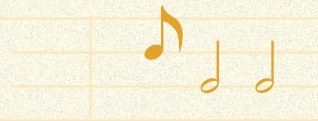
Tests Conducted



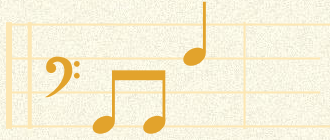
- Battery:
 - Measure the input voltage $\geq 7V$ (Arduino Nano minimum input);
 - Measure the input current and calculating battery Life
- Latency:
 - Radio transmitter + synthesizer's sound production
- Volume:
 - Measure decibel reading of various pitch angles
- Weight:
 - Sum of weights of all hardware components (excluding laptop)



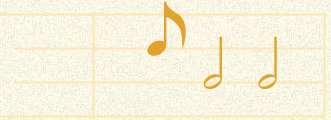
Testing Results



- Latency:
 - 8.33 ms (excluding rendering frame)
- Weight:
 - Camera (& cable + cap): 141 g
 - Gyroscope: 2.1 g * 2 pieces
 - Transmitter: 2.2 g * 3 pieces
 - Arduino Nano: 5 g * 2 pieces
 - Arduino Uno: 25 g
 - Gloves (unit: pair): 25 g
 - Sum: $141 + 2.1 * 2 + 2.2 * 3 + 5 * 2 + 25 + 25 \approx 220 \text{ g} = 0.485 \text{ pounds} \ll 4.8 \text{ pounds}$



Testing Results



- Volume:
 - Hand angle 90° (vertical): 77.1 dB
 - Hand angle 45° (should be half of max volume): 67.2 dB
 - Hand angle 0° (horizontal): environmental noise
- Battery:
 - Input voltage (2 batteries): 7.4V
 - Input current (2 batteries): $\approx 50\text{mA}$
 - Battery life: $1800\text{mAh} / 50\text{mA} * (1 - 40\%) = 21.6\text{h}$

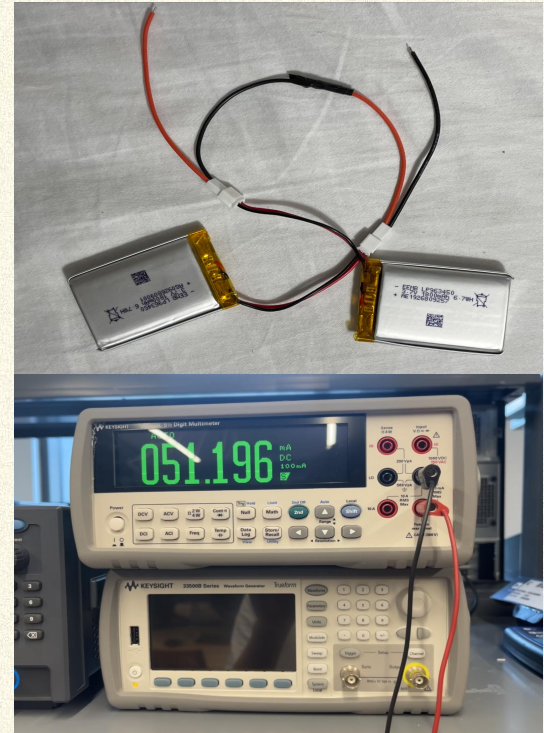
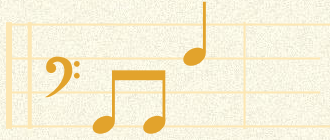




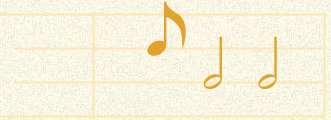
Table of Performance



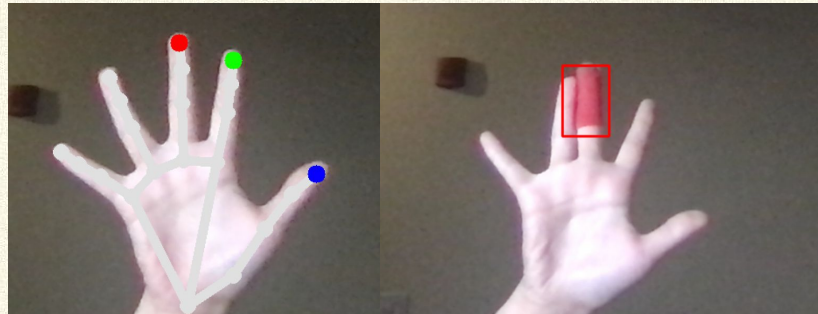
Criteria / Metric	Latency	Portability	High Sound Production Accuracy	Battery Life	Plug-and-Playability
Requirement	≤ 10 ms	≤ 4.8 pounds	± 0.5 dB Error	≥ 5 hours	$\geq 90\%$
Test Results	8.33ms	0.485 pounds	0.1dB	≈ 21.6 hours	TBD
Notes	Excluding render latency	N/A	Relative volume intensity; Max value depends on users	Battery Capacity/ Current * (1 - discharge safety)	N/A



Design Trade-Offs



- Camera module
 - Laptop camera: Variable resolution, no low light color correction
 - External webcam: Fixed resolution, adjustable fill light
- Battery
 - 9V alkaline battery: 7hr battery life, non rechargeable
 - Two 3.7V LiPo battery: >20hr battery life, rechargeable
- Tracking
 - Hand tracking: >8ms to just track a frame (no rendering), noticeable lag
 - Color tracking: <2.5ms to both track and render a frame



Project Management

