UMassAmherst

Electronic Piano Teacher

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Problem Statement

Learning piano is an arduous and multifaceted endeavor. It requires training of fine motor skills, muscle memory, and multitasking.

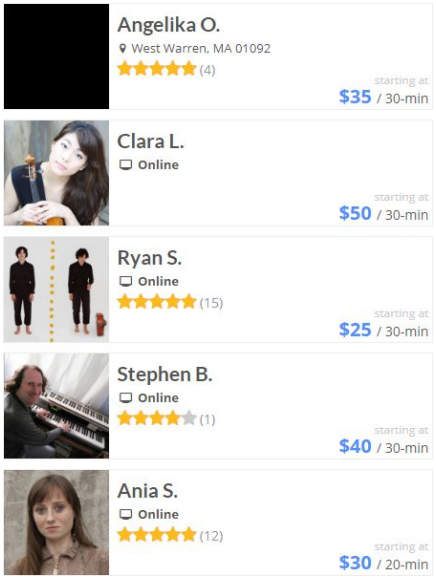
Someone trying to practice piano must focus on:

- which notes to play
- which finger to play with
- the sound of the notes themselves
- and the timing and rhythm by which the notes should be played

It is commonplace for this learning process to be supervised and reinforced by a piano teacher.

Design Alternatives - #1 Actual Human Teacher

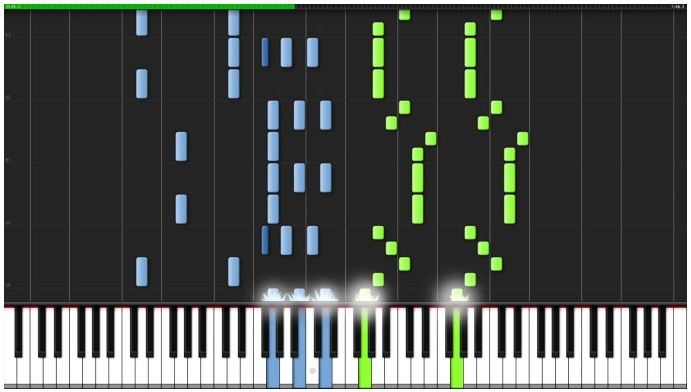
- Piano teachers are often expensive to hire ($50 - $100/hr in Amherst Area)
- Lessons require scheduling with another person
- People may be opposed to playing in front of someone at first
- Quality greatly varies



Design Alternatives - #2 Piano Teaching Software

- Synthesia - a computer application that displays midi information on a “piano roll” as it moves towards a virtual keyboard where it highlights the specific keys that should be pressed

- Does not display any information on physical keyboard
- Does not incorporate feedback
- Requires a computer
- Does not show sheet music



Design Alternatives - #3 Haptic Feedback

- 2008 Conference Paper from Georgia Institute of Technology
- More focused on passive learning
- Successfully demonstrated that haptic stimulus can help develop muscle memory

- Does not scale to complex songs
- Does not incorporate feedback
- Does not display sheet music
- Does not display any information on physical keyboard
- Ambiguous whether it accepts MIDI or is pre-programmed

K. Huang, E. Yi-Luen Do, and T. Starner, “Piano touch: A wearable haptic piano instruction system for passive learning of piano skills,” in Proceedings - International Symposium on Wearable Computers, ISWC, 2008, pp. 41–44.
A. Bleicher, “Learn New Skills With Superhuman Speed,” IEEE Spectrum: Technology, Engineering, and Science News, 28-May-2014. [Online]. Available: https://spectrum.ieee.org/consumer-electronics/portable-devices/learn-new-skills-with-superhuman-speed. [Accessed: 13-Oct-2018].

Design Alternatives - #4 Smart Piano

- Displays sheet music, lights up key to press, detects which notes you hit

- Low quality keyboard or very expensive
- Only works with songs from their app's library ($$$)
- No haptic feedback

The ONE Smart Piano Light Keyboard, 61-Key Portable Keyboard, Electric MIDI Keyboard

from $ 299.99 ~~$ 339.98~~

The ONE Smart Piano, Weighted 88 keys Digital Piano, Grand Graded Hammer Action Keys Upright Piano

from $ 1,499.99 ~~$ 1,575.98~~

The ONE Smart Keyboard Pro, 88-Key Portable Digital Piano Keyboard, Weighted Hammer Action Keys

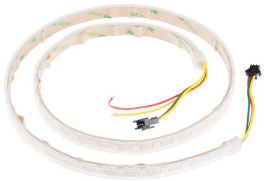
$ 799.99

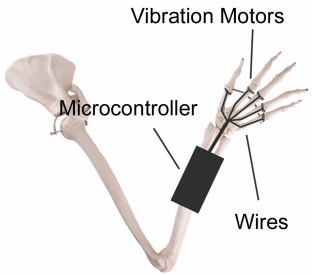
Solution

We propose a system that automatically supervises the piano learning process at the early stages using a combination of haptic and visual stimulation to accelerate muscle memory development.

The System:

- Signals the user on what note to play at what time with which finger
- Detect when the notes being played are correct or incorrect (and possibly detect correct timing as well)
- Display sheet music or piano roll on a tablet screen

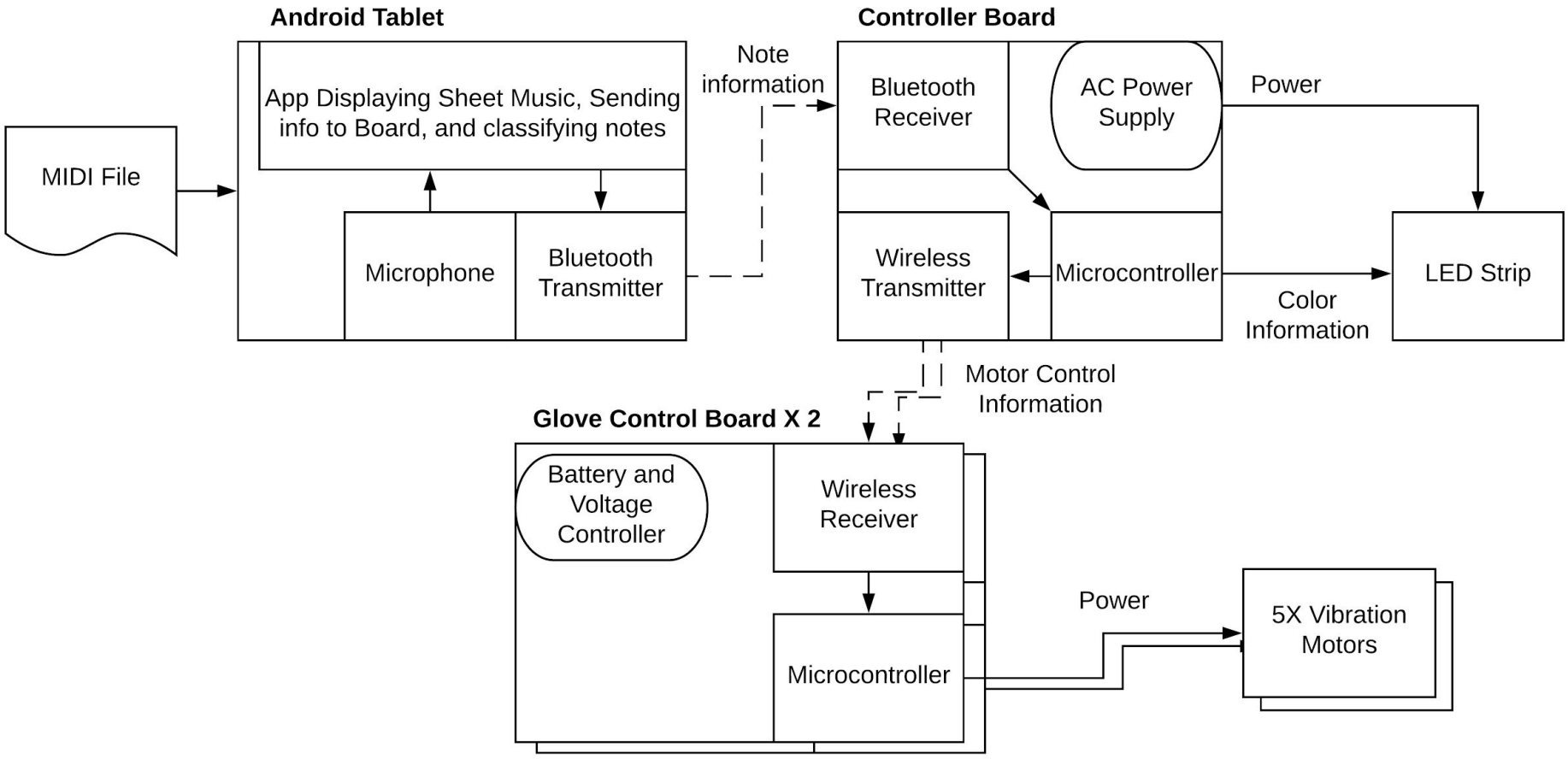




Requirement Specifications

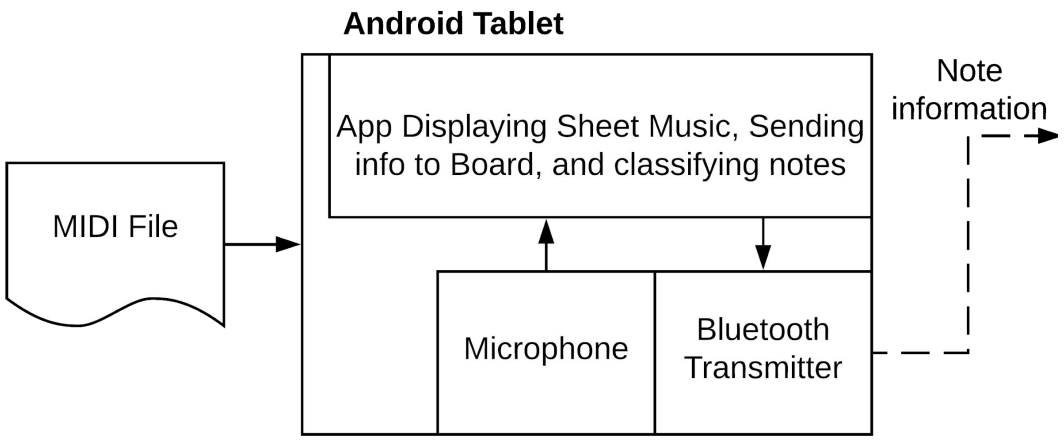
- **Instruction:** System should show the user sheet music, what note on the piano that corresponds to, which fingers to use to hit those notes, and detect errors
- **Synchronization:** All signals to the user for each note should arrive within 100ms of each other
- **Accuracy of note detection:** Correctly detects single melody notes more than 90% of the time in a quiet room (chords are stretch goal)
- **Latency of note detection:** Note detection should provide live feedback. No more than 1 second of latency
- **Usability:**
  - **Non-obstructive:** System should not obstruct normal finger mobility
  - **Battery life:** up to 2 hours
  - **Range:** within 10 feet
  - **Retrofit-ability:** Any standard width (48 inch) 88 key keyboard
  - **Cost:** “Mass production” system must cost less than $250 ~ 2-4 piano lessons

Block Diagram



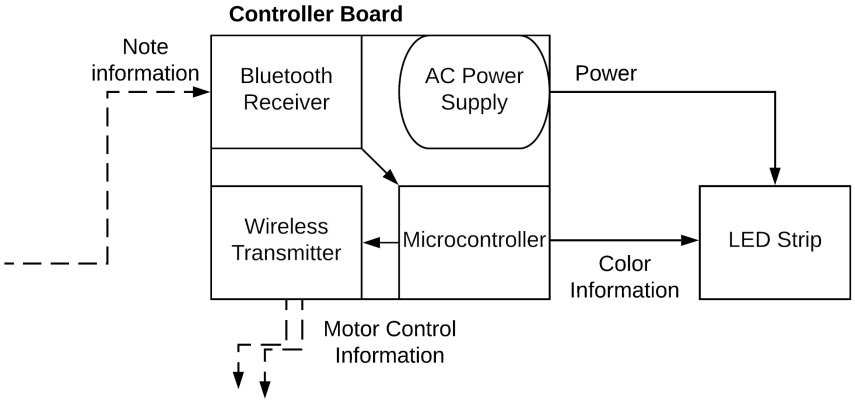
Subsystem: Tablet

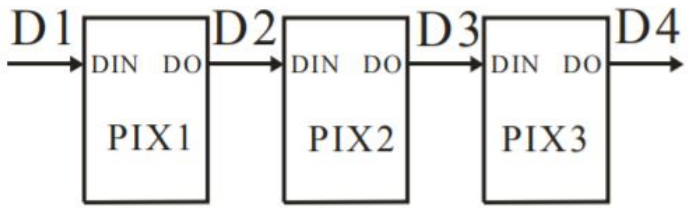
- Contains app interface for user to select input song
- MIDI is processed into note data which is then sent to the microcontroller which relays the signals to the respective subsystems as the notes display on the tablet screen
- Finger selection model determines which fingers should play what note based on previous and future notes
- Classifies auditory feedback from microphone to determine if notes are played correctly



Subsystem: LED Strip & Controller Board

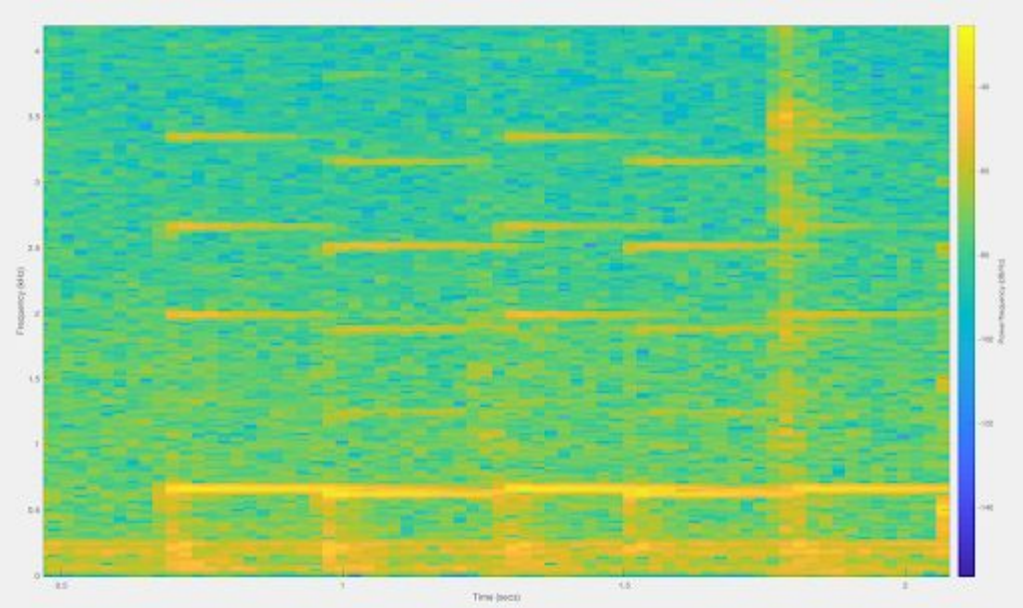
- Microcontroller connected to strip of 88 LEDs, 1 per key
- A lit LED corresponds to the next key to press
- W2812, in series.
- Receive information through bluetooth from tablet
- Broadcast note information to wireless gloves
- Non-Obstructive: W2812 are thin, and can be arranged in one bar that gets attached over the keys





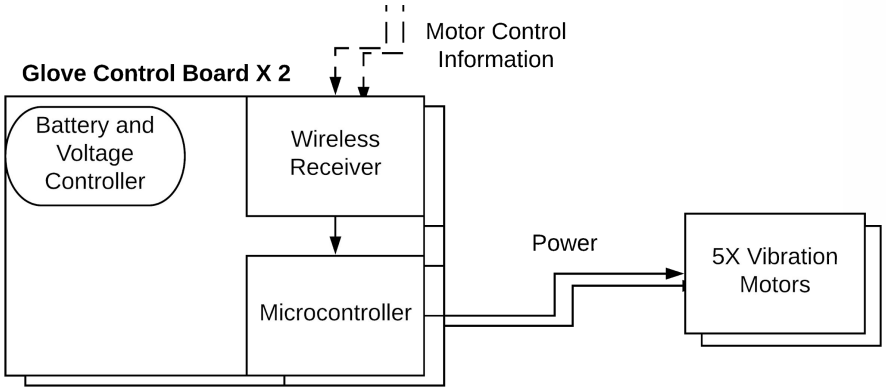
Subsystem: Microphone

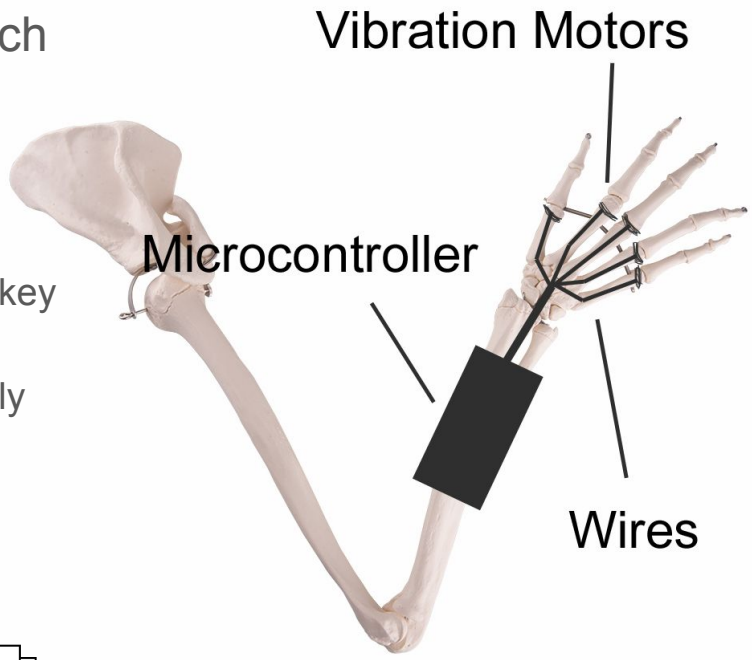
- The sound of the piano's note will get picked up by tablet microphone
- Determines if played note matches MIDI note
- Allows system to show user their mistakes



Subsystem: Glove

- Two fingerless handpieces that the user wears, one on each hand.
- Contains 5 small vibration motors, one on each finger.
- Teaches user which fingers to use
- Possible extensions:
  - Feedback inside the glove will also tell if you hit the key with the correct finger
  - Glove could be used independently to learn passively





MDR Prototype specifications

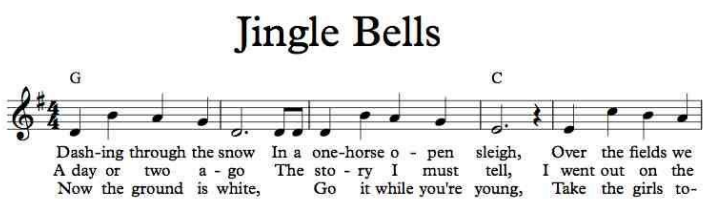
- Get all interfaces working (Tablet -> Control board -> Gloves/LEDs)
- Demonstration of microphone listening to piano, communicating to LED strip and lighting up the notes you played
- Collected training dataset of MIDI files with labels for musical key and possibly finger placement for finger to note model

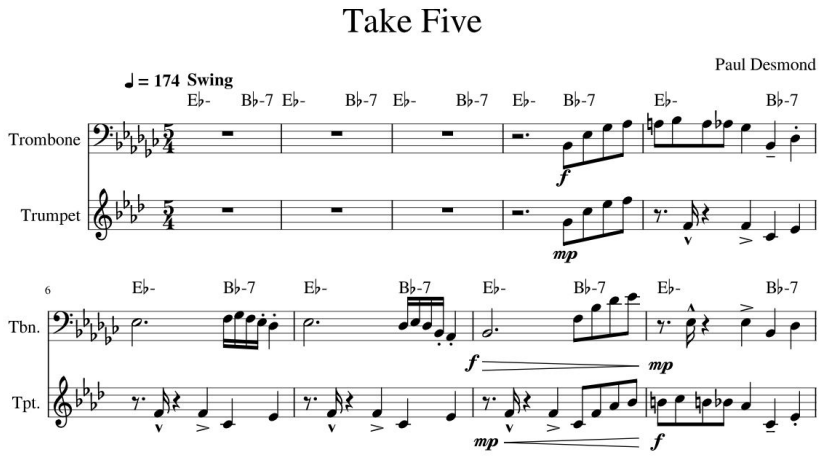
Budget

DESCRIPTION	PRICE IN USD
88x WS2812B LEDs	35
3x Microcontrollers	30
1x Tablet (Amazon Fire)	150
10x Vibration motors	50
1x Pair of gloves	15
1x Housing	0
1x Microphone (optional)	75
1x Wall plug power supply	15
1x Bluetooth Receiver/Transceivers	20
TOTAL	**390**
Slack	**110**

Risks

- Tablet is doing a lot, we may end up using a computer to perform the calculations and simply display the sheet music or midi information on a monitor
- In more complex musical compositions notes will be harder to pick out; Potential ceiling to how complex tunes we can support
- While there are studies confirming that haptic stimulus can help one learn, it might not be as effective as we think





Breakdown by student

We will all work collaboratively on each part but each member will take ownership/leadership of one subsystem:

- Joe: Tablet application
- Cassius: PCB and microcontrollers
- Matt: Interface between subsystems
- Aleksa: embedded code running on microcontroller

Since we will be prioritizing hardware this semester, Aleksa and Joe will be assisting in development of the microcontroller and interfaces.

What We Are Going to Demo

- Keyboard, likely an electric one for convenience, set up, with all parts of the project set up to it.
- Preload the tablet with a simple song.
- Demoers sit down at the piano, and are tasked with learning this song with the help of this device.

Questions?