‘Sing us a song, you’re the piano pi’

Talking Piano

Team B2

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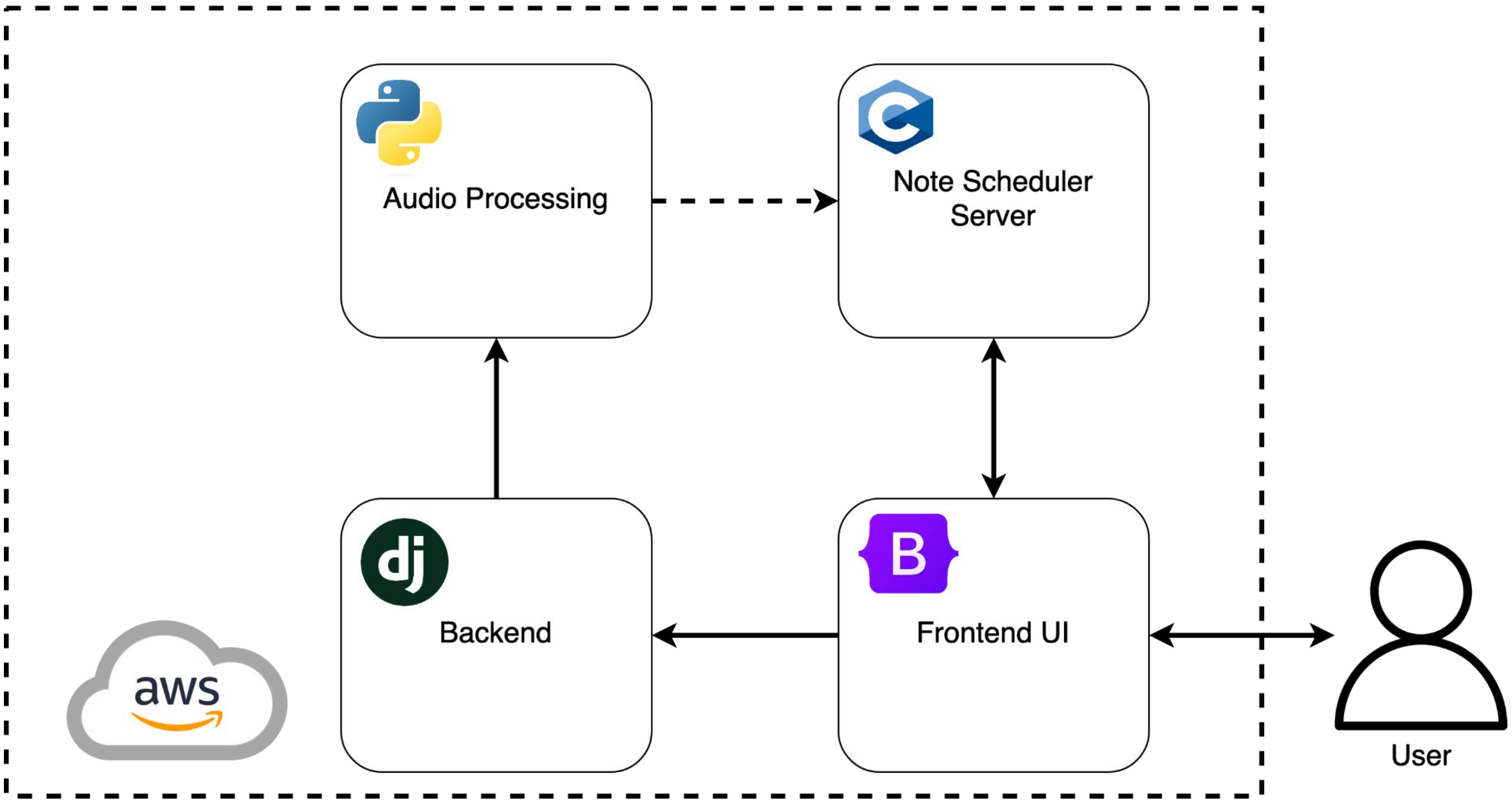
Use-Case and Requirements

Explore music beyond physical constraints by creating human speech on a piano!

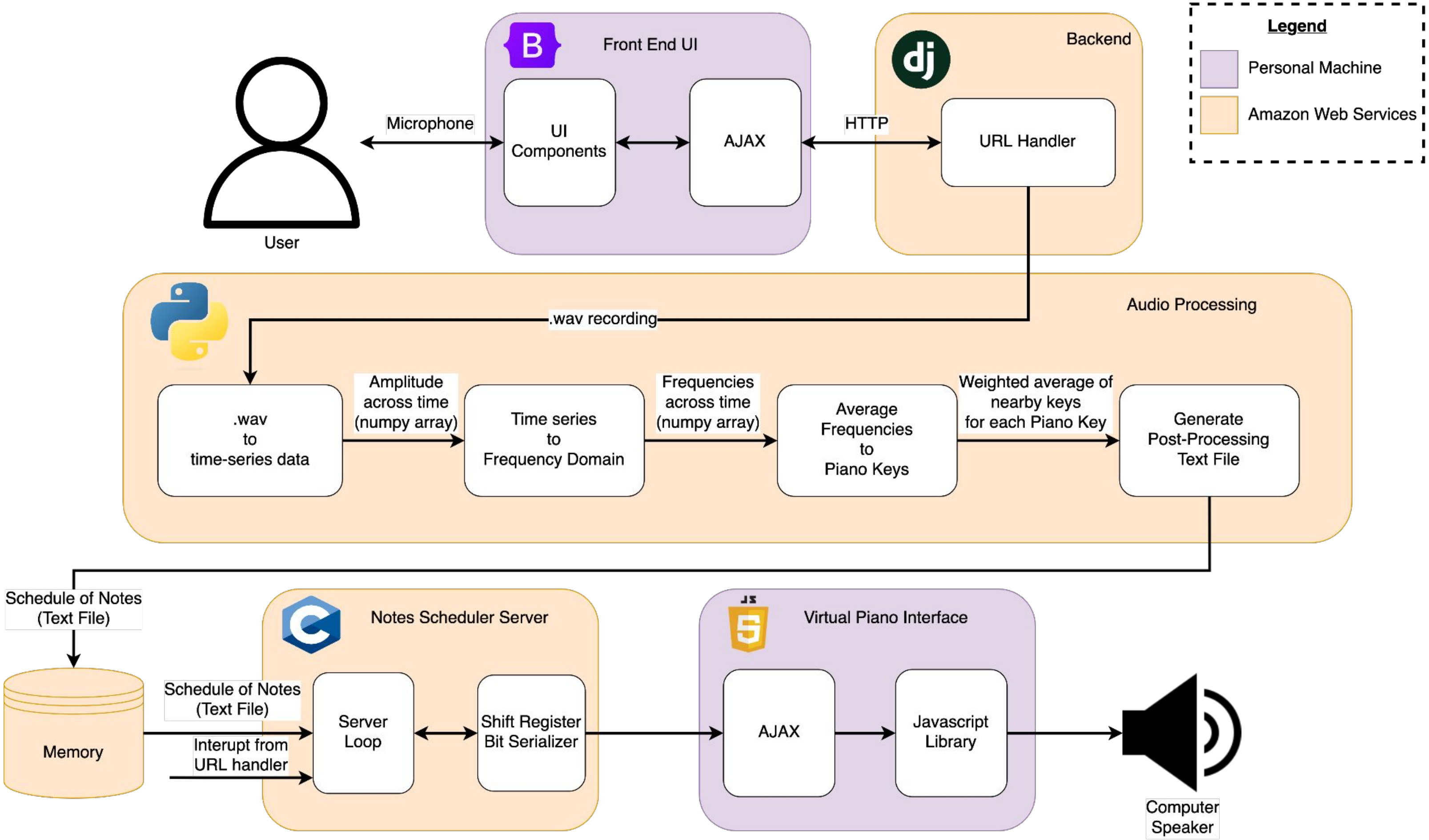
- Record user speech (via UI, that also offers playback features)
  - 200ms end-to-end latency
- Convert input speech into piano notes
  - 80% Frequency extraction accuracy
- Schedule those notes onto a piano
  - <5% of syllables missed (delayed/elongated/sped, not dropped)
- Implement a physical device that can press the keys on a piano
  - 80% Fidelity Rate

ECE Areas: Software Systems, Signals and Signals

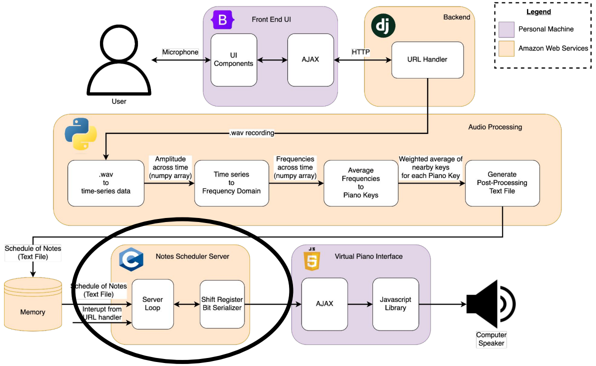
Solution Approach



Complete Solution

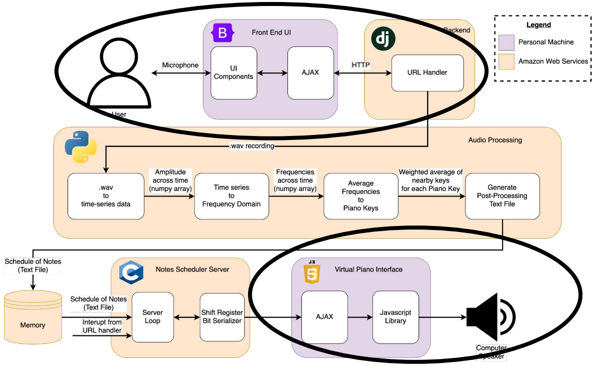


Notes Scheduler



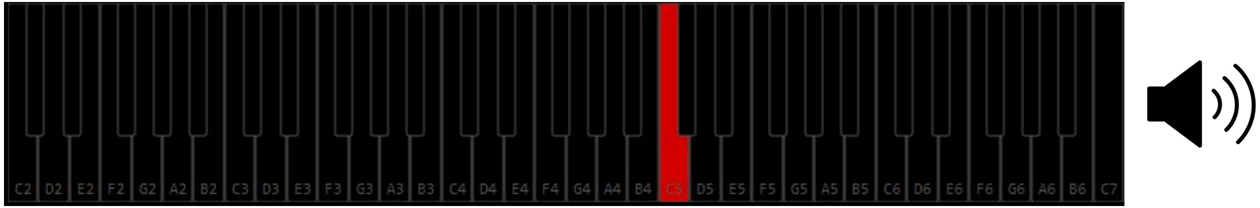
- Input: a 2-dimensional array of frequencies
  - Each row is a timestamp
  - Each column is a key (69 columns)
- Output: a second 2-dimensional array
  - Volumes for keys at each timestamp
- Differentiate between when to re-press keys and when to keep them held down
  - Decay of keys
  - Separation of phonemes and syllables
- Decay modelling: a logarithmic approximation
  - Volume of the virtual piano is controlled by amplitude scaling
  - This makes the decay even across all volumes
  - Phenomenon in physical pianos more complex

Web Application Interface



- Virtual piano plays corresponding audio file for each piano key as described by note scheduler

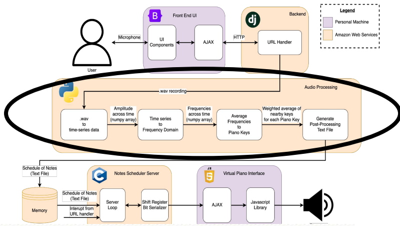
- Run Speech-Text libraries on incoming audio files to provide subtitles for better interpretation of output audio from piano



C5 (523 Hz)

Example of the visualization from 1 note being played

Audio Processing

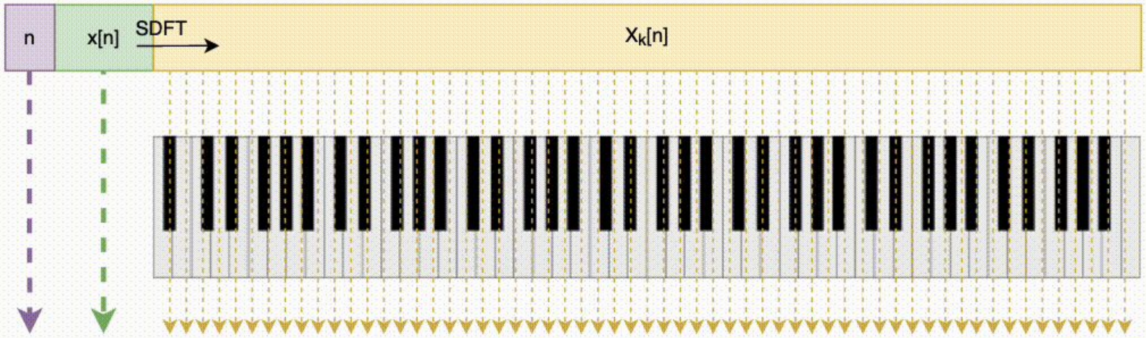


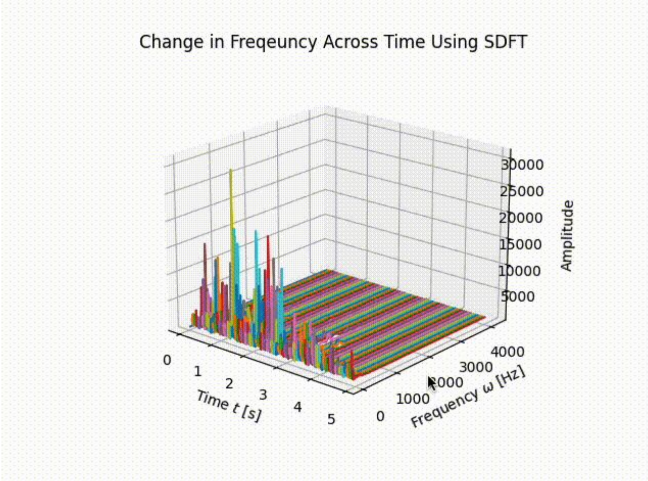
The Sliding Discrete Fourier Transform

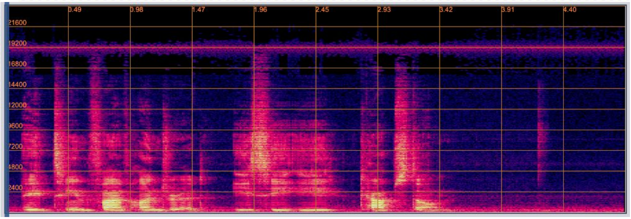
$$X_k[n] = [X_k[n-1] - x[n-N] + x[n]]e^{j2\pi\frac{k}{N}}$$

$$x[n] = [X_k e^{-j2\pi\frac{k}{N}}] - X_k[n-1] - x[n-N]$$

Given a window of N samples, if we'd like to know what the frequency is at frequency bin k, we can use the recursive function for X_k. As new samples come in, we can use the previously calculated frequency, $X_k[n-1]$







Risk Factors and Unknowns

- Building the physical interface
  - ~~Might take longer than expected, therefore we'll build a proof of concept build that only uses ~5 solenoids to press keys~~
- Blurring the audio might not extract enough information
- ~~Upload and Download internet speed between remote server and Raspberry Pi introduce a bottleneck~~
- Our piano play rate may be too high, causing keys to be "spammed"

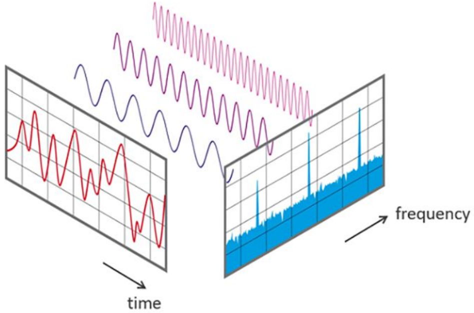
Alternative Design Strategies

- Virtual piano implementation: should our proof of concept for the piano-playing mechanism fail, we will implement a virtual piano solution.
- Near real-time speech-to-piano translation: once MVP is achieved, we hope to allow people to speak and hear their sentence played on the piano once they’re done speaking.
- ~~Lower-latency backend: once fully committed to the physical interface, we can migrate the backend logic onto a Jetson if speed is a concern.~~

Testing, Verification, Metrics

- Web-app physical system latency
  - Use Selenium to mimic clicking on UI components
  - Measure the time between pressing a button on our frontend UI and the appropriate reaction of the system
  - Our goal metric is < 200ms

- Fast Fourier transform accuracy
  - Use an input audio recording we create with known frequencies and amplitudes
    - For each window we will compare the frequencies reported by our system to the known frequencies at that time
  - Accuracy dependent on chosen time window for FFT
    - Shorter Window=> Less Accurate
    - Longer Window => Long wait times
  - Adjust our time window for >80% accuracy.



Testing, Verification, Metrics cont.

- Syllable timing
  - Use recordings with labeled start times for each syllable
  - Record the number of syllables whose start time does not match the original recordings labelled start time

- Fidelity of Output Audio
  - Generate a series of prompts and output piano recordings
  - Survey a group of listeners on whether or not they can understand the prompt given the piano audio
  - Collect data on what percentage of listeners were able to make out what the piano was trying to say

Updated Gantt Chart

PROJECT NAME	Talking Piano	UNIVERSITY CLASS	Carnegie Mellon Univeristy - 18500 Capstone
MEMBERS	Marco Acea, Angela Chang,	DATE	9/15/22