Piano Octave Filtering

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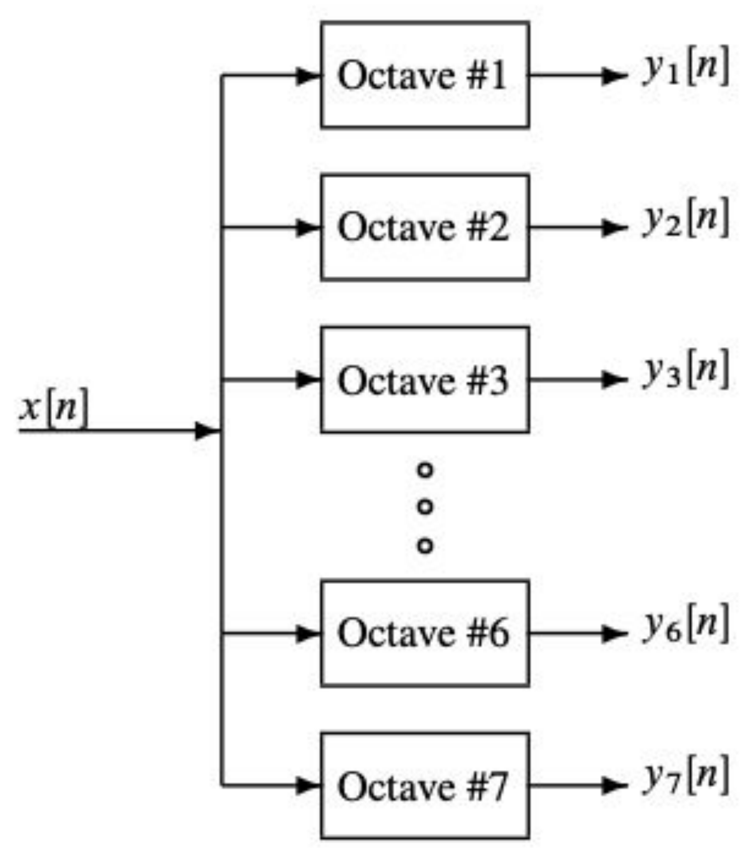
Introduction



Multiple FIR filters can be used to decode piano signals into octaves. Each filter is a bandpass filter with a frequency range of its designated octave. After the filtering would be a detection system to recognize which filters had passed a note from the original signal.

Data

	Starting Freq (Hz)	Ending Freq (Hz)	Starting Freq (dig omega)	Ending Freq (dig omega)	Center Freq (omega c)
Octave 1	32.703	61.735	0.026	0.048	0.037
Octave 2	65.406	123.471	0.051	0.097	0.074
Octave 3	130.813	246.942	0.103	0.194	0.148
Octave 4	261.626	493.883	0.205	0.388	0.297
Octave 5	523.251	987.767	0.411	0.776	0.593
Octave 6	1046.502	1975.533	0.822	1.552	1.187
Octave 7	2093.005	3951.066	1.644	3.103	2.374

Method

Bandpass filtering: In order to decode the octaves on the piano, we used bandpass filtering which filters out the noise from a signal outside of a specific chosen cutoff frequency. This ensure that only the desired frequencies are represented in the output.

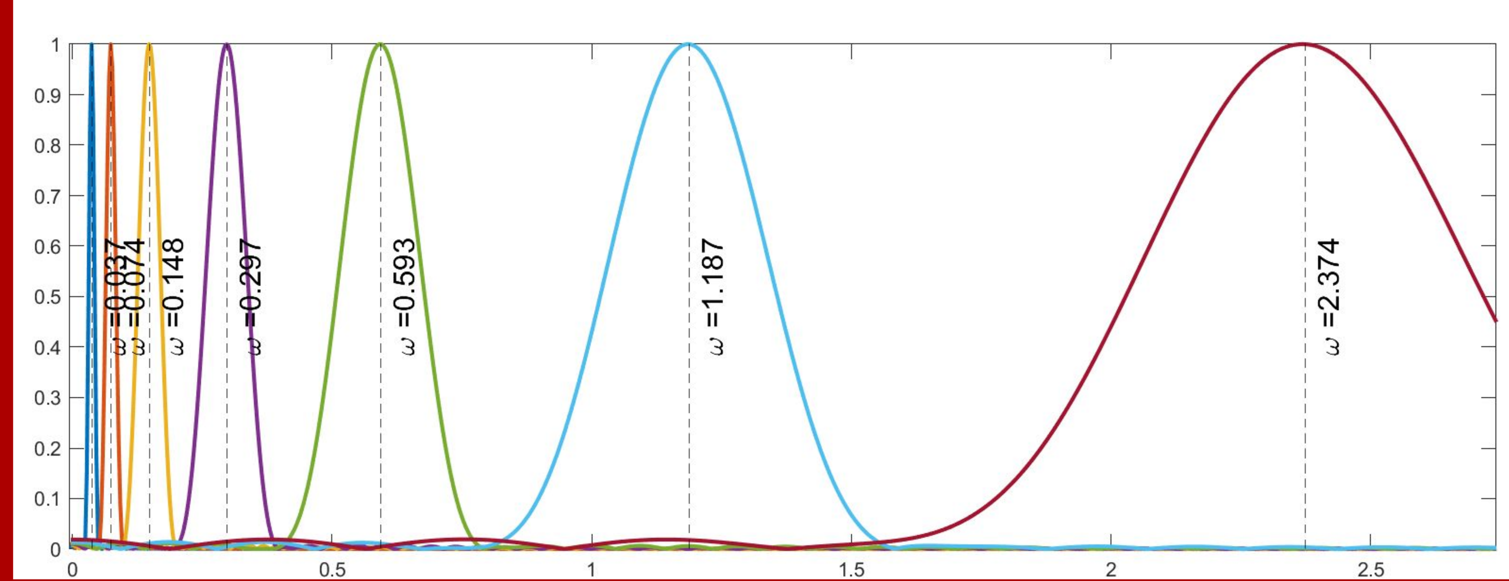
Hamming Window: We used a Hamming window for our filtering method to reduce noise from the side lobes, though windowing like this does increase the width of the passband.

$$h[n] = \beta\,(0.54 - 0.46\cos(2\pi n/(L-1)))\cos(\hat{\omega}_c(n-(L-1)/2))$$

$$\text{for } n = 0, 1, 2, \ldots L-1$$

Bandwidth Tuning: To give each octave the desired bandwidth, we will adjust the filter length (L) of the hamming window. As L gets higher the bandwidth gets narrower.

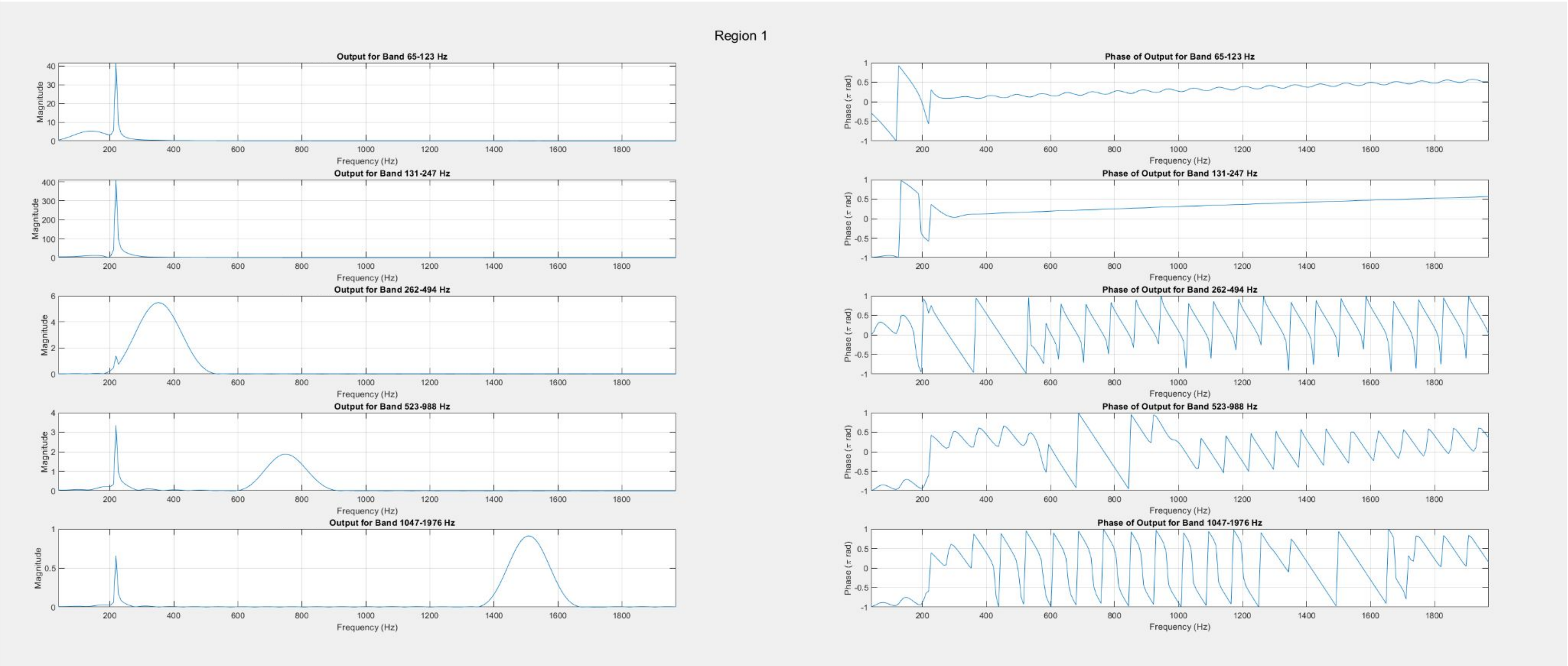
We first scaled each frequency response, H, to have an amplitude of 1 by multiplying the response with the term □, where □=1/max(H). Then we tuned L through trial and error so each filter had the appropriate bandwidth with a 0.01 stopband. For octaves 1-7
L = [943, 546, 246,133, 67, 34, 17]

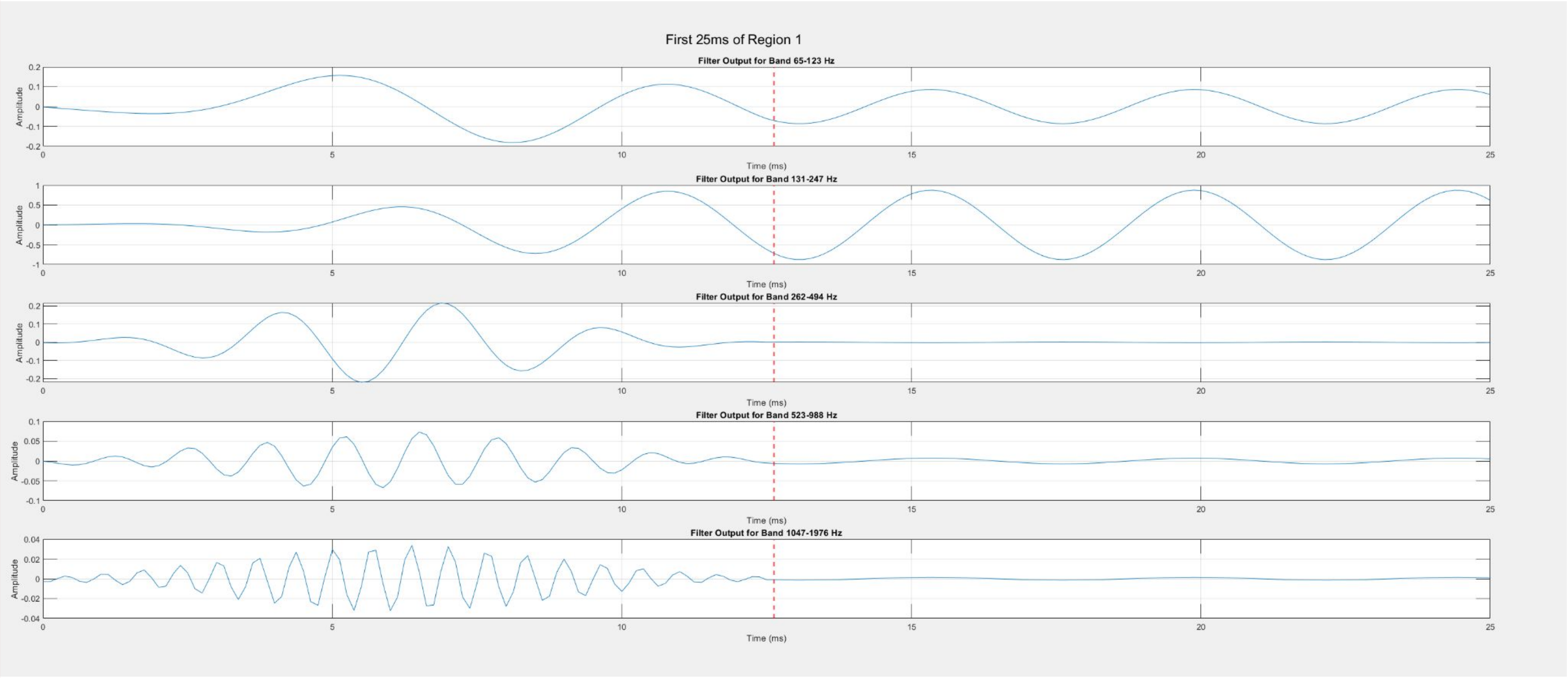


Summary

- **Objective**: Design and evaluate methods to isolate and decode octave bands using bandpass filtering, windowing, and normalization.
- **Approach**:
  - Applied Hamming-based bandpass filters for frequency isolation.
  - Used windowing to minimize spectral leakage.
  - Implemented normalization to improve signal consistency.
- **Results**:
  - Normalized filters demonstrated precise frequency isolation.
  - Reliable decoding of octave bands across diverse input signals.
- **Impact**: Insights into signal processing with applications in audio analysis, communications, and frequency-based data analysis.

Results





References

[1]R. M. Mottola, "Liutaio Mottola Lutherie Information Website," *Liutaio Mottola Lutherie Information Website*, 2024. https://liutaiomottola.com/ (accessed Dec. 02, 2024).