



SAM Meets
STEM

Analysis of Music Using Chromagrams and Recurrence Matrices

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In the modern day, music analysis is no longer done by hand, but rather by computers. Digital musical analysis leverages computational techniques to extract meaningful insights from audio recordings.

- Converting raw sound into data
- Can analyze elements like pitch, timbre, rhythm, tempo, etc.

Waltz beat output:
Estimated Tempo: [75.99954044] BPM
Beat times: [2.04335601 2.83283447 3.59909297 4.36535147 5.15482993 5.94430839
6.73378685 7.45360544 8.28952381 8.98612245 9.77560091 10.51863946
11.261678 12.00471655 12.7477551 13.49079365 14.28027211 15.04653061
15.83600907 16.4861678 17.2524263]

Nocturne beat output
Estimated Tempo: [92.28515625] BPM
Beat times: [2.73995465 3.59909297 4.2492517 4.92263039 5.59600907 6.26938776
6.94276644 7.63936508 8.26630385 8.89324263 9.49696145 10.14712018
10.79727891 11.42421769 12.05115646 12.63165533 13.2121542 13.81587302
14.46603175 15.13941043 15.78956916]

Utilizing chromagrams and recurrence matrices, we can analyze the chord structures and progressions within various kinds of audio signals. Here, we utilize these tools to analyze two pieces, Chopin's Nocturne Op. 9 no. 2 and Waltz Op. 64 no. 2.



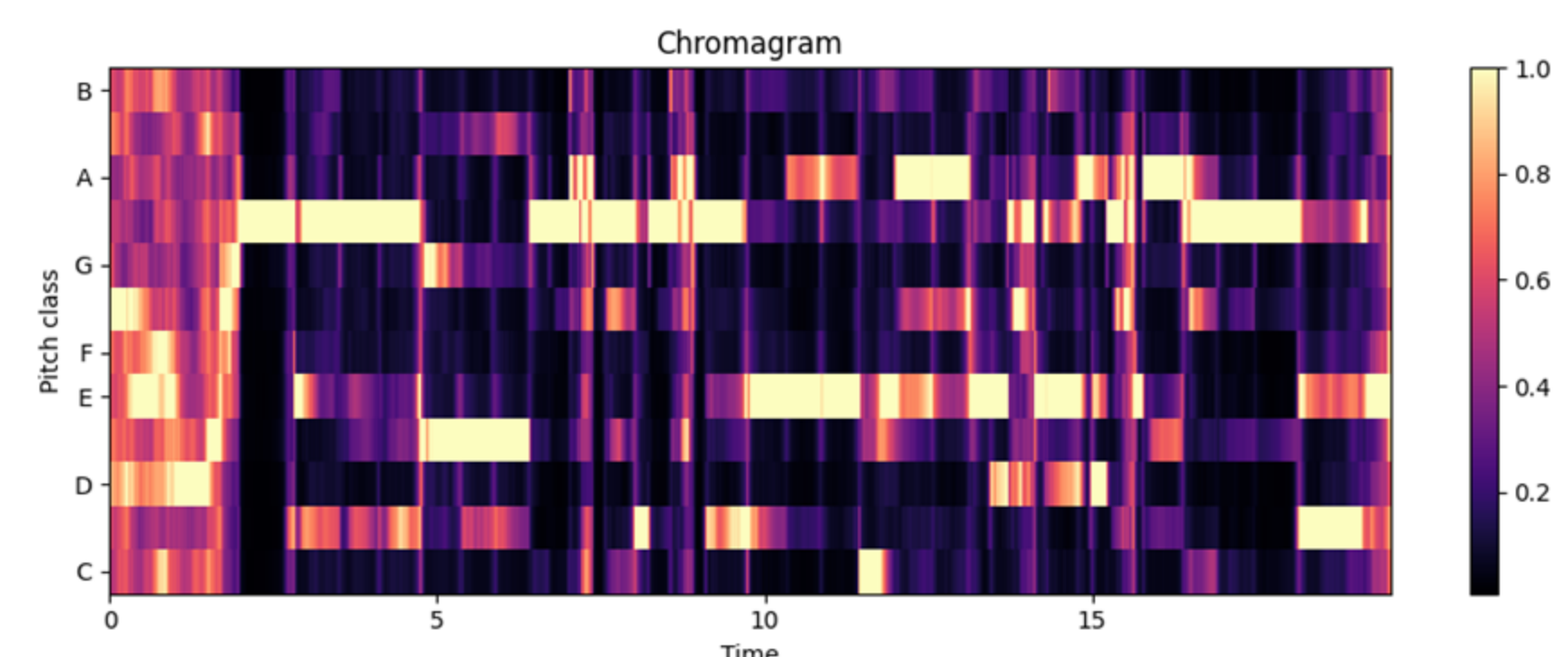
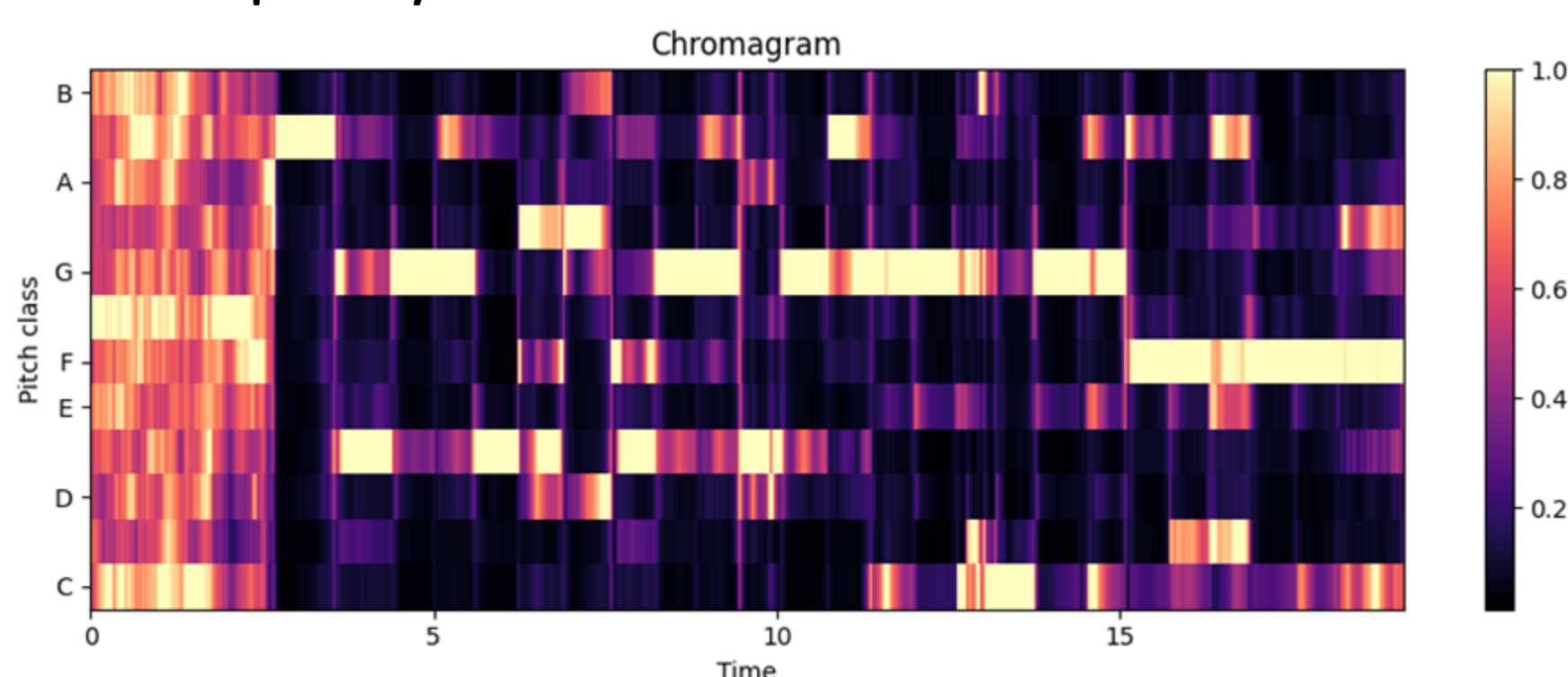
Bio:

- Brady Zhang is a junior at Chattahoochee High School
- 5 time AIME Qualifier, Perfect Score on 2021 AMC 8, 2023 All-State Concert Band Bassoonist, 6-time GMAT Piano Solo Finalist
- President of the CHS Math Team, Vice President of Math Honor Society and Physics Olympiad Team, and participates in community service activities including tutoring and musical performances.



Chromagrams provide a similar viewpoint to the music as looking at the sheet music itself.

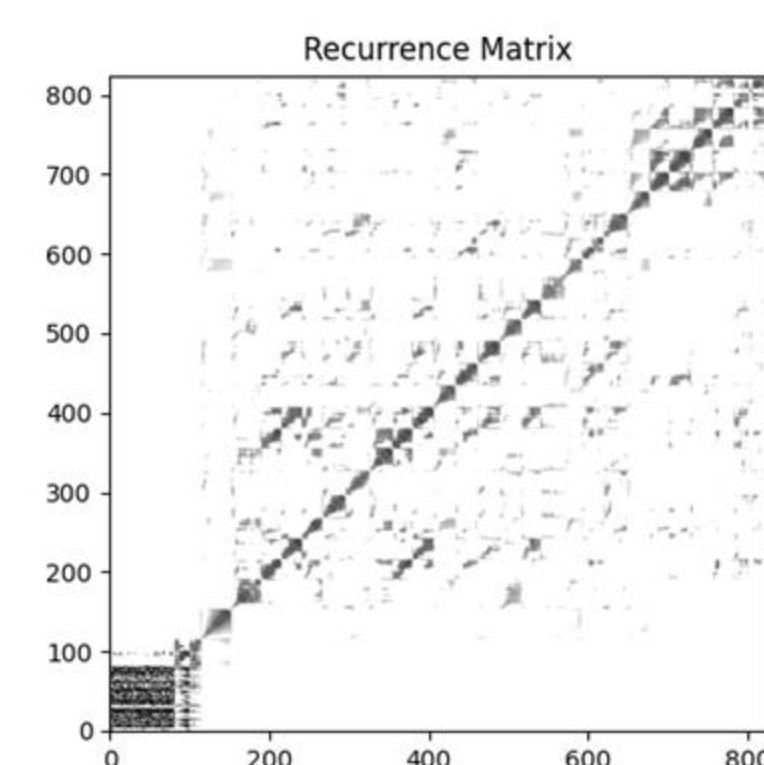
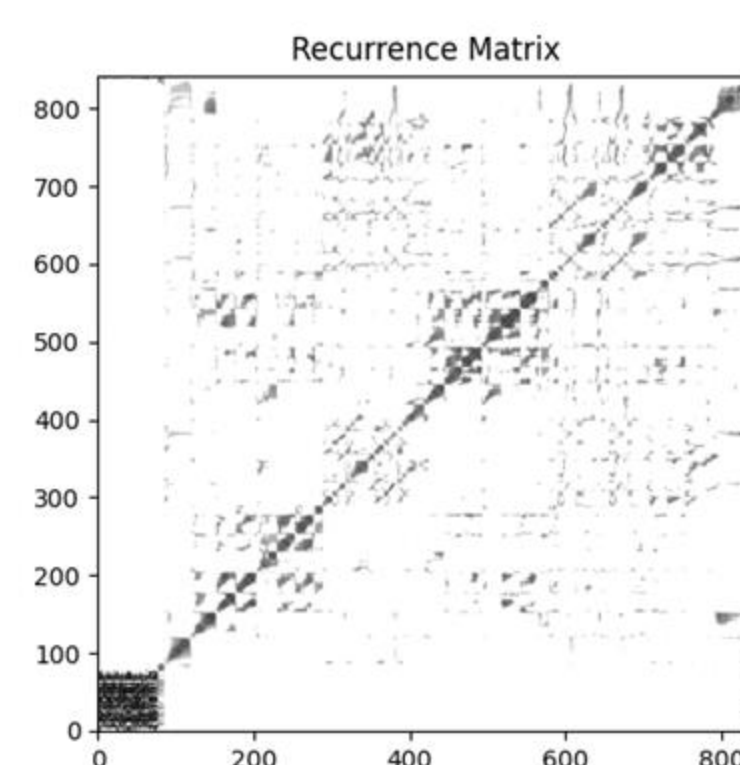
- Y-axis: Pitch
- X-axis: Time
- The color represents the intensity of the frequency



- Both the waltz and the nocturne are in 3/4 time, and they both begin with a note followed by a long sustained note.
- However, the waltz has a very rigid pulse, while the nocturne has a flowing, fluid rhythm.

Recurrence Matrices are another tool used to visualize and interpret structural similarities within a musical piece.

- Marked point on a recurrence matrix: indicates that two segments of music are similar.
- Diagonal line of identity (LOI): indicates self-similarity within the sample.



- **Waltz:** Embellished and ornamented notes, leading to weak diagonal line and random patterns.
- **Nocturne:** Long sustained notes, less embellishments, leading to a more consistent diagonal line.