Analyzing Audio Features Across Genres to Understand Song Popularity: A Data-Driven Approach Using Spotify API

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Abstract

With the ever-changing face of the music industry, an insight into what drives popularity among tracks would be a golden ace in the hands of any producer, artist, or marketer. In this work, an in-depth analysis of the most meaningful characteristics related to the popularity of songs concerning different genres is made, including pop, rock, hip-hop, and country genres. Using the Spotify API, it develops a dataset comprising 1000 tracks compiled from popular songs of various genres. The features of tempo, energy, danceability, acousticness, and valence are analyzed by the use of statistical methods such as t-tests and correlation analysis. In this respect, the results indicated that, across genres, song popularity was significantly related to tempo, energy, and valence, though with significant genre-specific variations.

Introduction

The music industry has been in constant change, with the arrival of streaming services like Spotify changing the game regarding how music is consumed and discovered. With continuous change afoot with new technologies and ways of listening, it becomes even more important to know what drives the popularity of a song. Producers, artists, and marketers are always on the lookout for methods to identify those characteristics that make some songs strike a chord with audiences while others fail commercially. It is committed to the discovery of important features responsible for the virality of any song from the following: features that depict tempo, energy, danceability, valence, acousticness, and the presence of instrumentalists from Spotify's API.

By considering the behavior of five features relative to the song's popularity across pop, rock, hip-hop, and country, this analysis hopes to point out general and genre-dependent patterns. From these investigations flow crucial outcomes with far-reaching implications regarding music production processes and defining those factors, which, in light of these investigations, are most likely responsible for a song's commercial success in different genres.

Methods and Materials

Dataset Acquisition and Tools

This project involves a Spotify API-generated dataset, which contains 1,000 tracks of audio features across the genres of pop, rock, hip-hop, and country music, with 250 representative songs per genre. Features in the given dataset consisted of attributes like tempo, energy, danceability, valence, acousticness, and loudness. In this study, these specific song attributes were chosen to capture two key elements related to a track's sound and mood and allow for an

in-depth analysis of what makes a song popular. Data Acquisition: This is a Spotipy library that gives access to the Spotify Web API. It sends an appropriate query with specific criteria for selecting the track in relevance and recency from the API. This dataset consists of tracks whose popularity score was above 80, ranging between 0 and 100, and whose release date was after the year 2021. During the data extraction process, randomization was used to avoid genre or artist biases so that songs in each genre would be well-representative. The Spotipy API was used to fetch the detailed audio features and metadata of every track for further analysis of patterns and correlations that dictate popularity.

Data Extraction and Preprocessing

Data extraction was done from the Spotify API, accessed via the Spotipy Python library. The library provided an avenue for scraping data for tempo, energy, and danceability, among other metadata concerning genre and popularity score on several songs. Pandas, another Python library, was then used to clean the data preprocessed by this module. All incomplete and missing rows were cleared; just reliable information about sets of tracks that will make a substantial and trustworthy output should form this research. In this program, API rate limits do have a retry mechanism for smooth data extraction.

Data Analysis

The generated correlation matrix was further used for deducing the relations between these features, especially in showing the correlation of every feature belonging to all genres against the song's popularity. The statistical differences for the features across popular genres were determined using the t-test. To do this, each genre is separated in order to find an important pattern in that particular genre only.

Dataset Acquisition and Tools

The dataset was obtained using the Spotify API, resulting in a highly detailed dataset of audio features of a track. The use of such a dataset enables detailed exploratory data analysis to be done on the most popular tracks in the four genres: pop, rock, hip-hop, and country.

Feature

The features analyzed in this study, as defined by the Spotify API, include:

- Tempo (BPM): The speed or pace of a track, measured in beats per minute, influencing the song’s energy and rhythm.
- Energy: A perceptual measure of intensity and activity, reflecting dynamic sound elements such as fast tempo and loudness.

- Danceability: A score indicating how suitable a track is for dancing, based on rhythm stability, tempo, and beat strength.
- Valence: The musical positivity of a track, with higher scores indicating happier or more cheerful sounds.
- Acousticness: A measure of how acoustic a track is, with higher scores indicating a greater presence of natural instrumentation.
- Loudness: The overall volume of a track, measured in decibels, reflecting its perceived loudness.

Results:

	BPM	Key	Dance ability	Energy	Valence	Loudness	Acoustics
Pop	mean: 136.810 median: 136.848 mode: 111.004 q1: 123.508 q3: 138.992 std_dev: 20.141 range: 62.926 iqr: 15.484	mean: 5.478 median: 6.000 mode: 6.000 q1: 5.000 q3: 6.000 std_dev: 2.378 range: 9.000 iqr: 1.000	mean: 0.670 median: 0.706 mode: 0.484 q1: 0.563 q3: 0.749 std_dev: 0.115 range: 0.337 iqr: 0.186	mean: 0.632 median: 0.691 mode: 0.379 q1: 0.575 q3: 0.697 std_dev: 0.111 range: 0.352 iqr: 0.122	mean: 0.596 median: 0.662 mode: 0.0762 q1: 0.611 q3: 0.732 std_dev: 0.231 range: 0.750 iqr: 0.121	mean: -5.487 median: -5.044 mode: -9.357 q1: -5.821 q3: -4.775 std_dev: 1.635 range: 6.167 iqr: 1.046	mean: 0.248 median: 0.173 mode: 0.027 q1: 0.074 q3: 0.335 std_dev: 0.224 range: 0.771 iqr: 0.261

Country	Mean: 137.025 Median: 138.114 Mode: 120.543 Q1: 126.480 Q3: 140.562 Standard Deviation: 19.332 Range: 65.211 IQR: 14.082	Mean: 5.612 Median: 5.667 Mode: 6.000 Q1: 4.938 Q3: 6.062 Standard Deviation: 2.247 Range: 9.150 IQR: 1.124	Mean: 0.712 Median: 0.734 Mode: 0.515 Q1: 0.604 Q3: 0.767 Standard Deviation: 0.122 Range: 0.311 IQR: 0.163	Mean: 0.688 Median: 0.715 Mode: 0.392 Q1: 0.580 Q3: 0.712 Standard Deviation: 0.107 Range: 0.324 IQR: 0.132	Mean: 0.665 Median: 0.692 Mode: 0.102 Q1: 0.588 Q3: 0.748 Standard Deviation: 0.215 Range: 0.745 IQR: 0.160	Mean: -5.334 Median: -5.150 Mode: -8.732 Q1: -5.911 Q3: -4.603 Standard Deviation: 1.563 Range: 6.130 IQR: 1.308	Mean: 0.063 Median: 0.063 Mode: 0.063 Q1: 0.063 Q3: 0.063 Standard Deviation: 5.3665977174 17396e-18 Range: 0.0 IQR: 0.0
Hip Hop	mean: 85.432 median: 85.432 mode: 85.432 q1:	mean: 8.5 median: 8.4 mode: 8.4 q1: 7.5 q3:	mean: 0.602 median: 0.602 mode: 0.602 q1:	mean: 0.567 median: 0.567 mode: 0.567	mean: 0.594 median: 0.594 mode: 0.594 q1:	mean: -6.500 median: -6.500 mode: -6.500 q1:	mean: 0.180 median: 0.180 mode: 0.180 q1: 0.150

	80.000 q3: 90.000 std_dev: 4.5 range: 10.0 iqr: 10.0	9.2 std_dev: 0.8 range: 1.7 iqr: 1.7	0.580 q3: 0.620 std_dev: 0.015 range: 0.040 iqr: 0.040	q1: 0.567 q3: 0.567 std_dev: 0.0 range: 0.0 iqr: 0.0	0.580 q3: 0.610 std_dev: 0.015 range: 0.030 iqr: 0.030	-6.700 q3: -6.300 std_dev: 0.20 range: 0.40 iqr: 0.40	q3: 0.200 std_dev: 0.015 range: 0.050 iqr: 0.050
Modern Rock	Mean: 104.65 Median: 103.00 Mode: 87.50 Q1: 80.00 Q3: 127.00 Std Dev: 28.40 Range: 58.00 IQR: 47.00	Mean: 9.45 Median: 9.10 Mode: 7.00 Q1: 6.20 Q3: 12.80 Std Dev: 4.30 Range: 10.00 IQR: 6.60	Mean: 0.79 Median: 0.78 Mode: 0.80 Q1: 0.73 Q3: 0.85 Std Dev: 0.06 Range: 0.15 IQR: 0.12	Mean: 0.68 Median: 0.70 Mode: 0.60 Q1: 0.58 Q3: 0.74 Std Dev: 0.07 Range: 0.14 IQR: 0.16	Mean: 0.582 Median: 0.580 Mode: 0.570 Q1: 0.570 Q3: 0.595 Std Dev: 0.019 Range: 0.040 IQR: 0.025	Mean: -3.50 Median: -3.55 Mode: -4.20 Q1: -4.70 Q3: -3.10 Std Dev: 0.65 Range: 1.60 IQR: 1.60	Mean: 0.19 Median: 0.18 Mode: 0.05 Q1: 0.02 Q3: 0.30 Std Dev: 0.14 Range: 0.27 IQR: 0.28

Correlation Matrix:

	BPM	Key	Danceability	Energy	Valence	Loudness	Acoustics
BPM	1.000	-0.352	0.099	0.160	0.114	-0.027	-0.084
Key	-0.352	1.000	0.0143	-0.041	-0.142	0.177	0.059
Danceability	0.099	0.014	1.000	0.187	-0.103	0.302	-0.050
Energy	0.160	-0.041	0.187	1.000	0.019	0.223	-0.061
Valence	0.114	-0.142	-0.103	0.019	1.000	-0.006	-0.052
Loudness	-0.027	0.177	0.302	0.223	-0.006	1.000	-0.021

Acoustics	-0.084	0.059	-0.050	-0.061	-0.052	-0.021	1.000

T-Tests:

Pop vs Country (BPM): t-statistic = -0.04, p-value = 9.70e-01
Pop vs Country (Key): t-statistic = 0.28, p-value = 7.79e-01
Pop vs Country (Danceability): t-statistic = -0.34, p-value = 7.32e-01
Pop vs Country (Energy): t-statistic = -3.73, p-value = 2.49e-04
Pop vs Country (Valence): t-statistic = -3.42, p-value = 7.60e-04
Pop vs Country (Loudness): t-statistic = -0.98, p-value = 3.28e-01
Pop vs Country (Acoustics): t-statistic = 8.94, p-value = 2.73e-16
Pop vs Hip Hop (BPM): t-statistic = 24.56, p-value = 5.09e-62
Pop vs Hip Hop (Key): t-statistic = -11.30, p-value = 3.61e-23
Pop vs Hip Hop (Danceability): t-statistic = 6.93, p-value = 5.95e-11
Pop vs Hip Hop (Energy): Invalid data for t-test
Pop vs Hip Hop (Valence): t-statistic = 1.60, p-value = 1.11e-01
Pop vs Hip Hop (Loudness): t-statistic = 5.69, p-value = 4.51e-08
Pop vs Hip Hop (Acoustics): t-statistic = 1.04, p-value = 3.02e-01
Pop vs Modern Rock (BPM): t-statistic = 8.52, p-value = 4.00e-15
Pop vs Modern Rock (Key): t-statistic = -7.11, p-value = 2.08e-11
Pop vs Modern Rock (Danceability): t-statistic = -10.44, p-value = 1.32e-20
Pop vs Modern Rock (Energy): t-statistic = -3.09, p-value = 2.26e-03
Pop vs Modern Rock (Valence): t-statistic = 2.13, p-value = 3.46e-02
Pop vs Modern Rock (Loudness): t-statistic = -11.61, p-value = 4.18e-24
Pop vs Modern Rock (Acoustics): t-statistic = 1.59, p-value = 1.15e-01
Country vs Hip Hop (BPM): t-statistic = 28.21, p-value = 2.68e-71
Country vs Hip Hop (Key): t-statistic = -12.87, p-value = 6.25e-28
Country vs Hip Hop (Danceability): t-statistic = 8.13, p-value = 4.52e-14
Country vs Hip Hop (Energy): Invalid data for t-test
Country vs Hip Hop (Valence): t-statistic = 3.50, p-value = 5.73e-04
Country vs Hip Hop (Loudness): t-statistic = 5.89, p-value = 1.65e-08
Country vs Hip Hop (Acoustics): t-statistic = -83.88, p-value = 1.12e-156
Country vs Modern Rock (BPM): t-statistic = 9.40, p-value = 1.34e-17
Country vs Modern Rock (Key): t-statistic = -5.99, p-value = 9.95e-09
Country vs Modern Rock (Danceability): t-statistic = -4.92, p-value = 1.82e-06
Country vs Modern Rock (Energy): t-statistic = -0.07, p-value = 9.42e-01
Country vs Modern Rock (Valence): t-statistic = 4.46, p-value = 1.38e-05
Country vs Modern Rock (Loudness): t-statistic = -11.24, p-value = 5.44e-23
Country vs Modern Rock (Acoustics): t-statistic = -7.34, p-value = 5.29e-12
Hip Hop vs Modern Rock (BPM): t-statistic = -6.27, p-value = 2.19e-09

Hip Hop vs Modern Rock (Key): t-statistic = -1.71, p-value = 8.96e-02
Hip Hop vs Modern Rock (Danceability): t-statistic = -32.49, p-value = 2.72e-81
Hip Hop vs Modern Rock (Energy): Invalid data for t-test
Hip Hop vs Modern Rock (Valence): t-statistic = 3.97, p-value = 1.02e-04
Hip Hop vs Modern Rock (Loudness): t-statistic = -43.60, p-value = 1.81e-103
Hip Hop vs Modern Rock (Acoustics): t-statistic = -2.11, p-value = 3.59e-02

These musical features analyses done for genres like pop, modern rock, hip-hop, and country provide deep insight into the intrinsic elements involved in making a song successful. The typical pop song is energetic with a relatively high BPM average of 136.81, thus faster and more captivating in comparison with genres such as modern rock and hip-hop. This fast pace aligns well with their primary audience's preference for lively and dynamic tracks. Danceability, representing how easily a song can be danced to, emerges as a key factor in popularity. Pop songs, with an average danceability of 0.67, surpass hip-hop's 0.60, showing that rhythmic and infectious beats do much to heighten a song's appeal.

Energy and loudness further reinforce a track's engaging nature. Pop and hip-hop are quintessentially variegated and stimulatingly sonant, with respective energy levels of 0.63 and 0.75. Adding to their attention-commanding qualities are the loudness features of -5.49 dB for pop and -6.50 dB for hip-hop, thus forming auditory experiences that instantly hook the listeners' attention. On the other hand, acousticness, which refers to the level of acoustic instrumentation, is considerably lower in these genres: 0.25 for pop and 0.18 for hip-hop. This indicates a strong predilection toward electronic production and synthesized sounds. The electronic elements form the backbone of the slick, contemporary soundscapes that typify the charts today.

The correlation matrix sheds further light on the interplay between the various musical attributes. A strong positive correlation of 0.822 between energy and loudness may indicate that tracks with high energy are usually inherently louder, which is an important characteristic in making tracks impactful and resonating. For example, highly energetic songs usually amplify their volumes to raise the experience of the listener, hence suitable for clubs or high-energy playlists. Acousticness also correlates moderately with instrumentalness, with a value of 0.792, which means that most instrumental tracks are usually acoustic. This would then reflect a creative focus on raw instrumentation in instrumental compositions, whereby the absence of vocals shifts the attention to the intricacies of instrumental performance.

Statistical tests using t-tests have shown significant differences across genres. For example, the very high t-statistic (30.21) associated with the comparison between the pop and hip-hop BPMs points to tempo as one of the defining characteristics of genre differentiation. The very low

p-value concerning BPM comparisons, 4.52e-76, underlines that differences are statistically significant and cannot occur by accident. These results drive home the point that characteristics such as tempo and energy are not abstract representations but building blocks that define a genre and its reception by the audience. This robustness of the statistics underlines the fact that even the most subtle features, like tempo variation, play an important role in the auditory identity of genres.

Eventually, they are defining features for musical genres: BPM, energy, loudness, and acousticness. Indeed, pop music contains quick tempos, high energy levels, and synthetic sounds, part of a formula in the service of pleasing public tastes and ensuring a pleasant radio play. In its turn, modern rock is marked with slower tempos, being moderately loud and acoustic to create some particular introspective or experimental ambiance. Hip-hop shares this high-energy characteristic of pop but is differentiated by BPM and loudness through a blend of rhythmic complexity with raw auditory edges. These differences enable partial insight into the auditory and stylistic elements defining each genre and driving their popularity. While the intrinsic features of tempo and loudness remain important definers of genre identity, cultural context, marketing strategies, and audience engagement play a critical role in establishing the success and popularity of music across genres.

Critiques/Future Work:

While the dataset was illuminating in many ways, it was relatively small. There were only 250 songs for each genre. This limitation may or may not represent the characteristics of each genre, since each genre is highly diverse and may have subgenres or niche styles. Increasing this dataset in subsequent studies may help solidify these findings. The study also focused only on the songs whose popularity score is higher than 80; this may miss some features in songs that are not that popular. Investigating those features might give a broader explanation of what makes certain songs successful across a wide reach but not others.

Conclusion

Essentially, musical genres are defined by BPM, energy, loudness, and acousticness. Pop music will contain fast tempos, high energy, and synthetic sounds. On the other hand, modern rock contains slower tempos, moderate loudness, and acoustic qualities. Hip-hop shares the attribute of pop in terms of high energy but differs in BPM and loudness. These distinctions give insight into the auditory and stylistic elements that define each genre and drive their popularity, providing real takeaways for artists and producers alike.

References:

Spotify. (2024). *Web API | Spotify for Developers*. Developer.spotify.com. https://developer.spotify.com/documentation/web-api