**Comparative Analysis of Spectrograms for Different Music Genres**

**1. Introduction** This report presents a comparative analysis of spectrograms generated for four different music genres: Classical, Rock, Hip-Hop, and Electronic. Spectrograms visualize the frequency content of audio signals over time, helping to analyze musical structures and differences across genres.

**2. Dataset and Methodology**

* **Audio Files:** Four different music genres were selected: Classical, Rock, Hip-Hop, and Electronic.
* **Preprocessing:** The audio files were loaded using librosa, converted to a uniform sampling rate, and processed using Short-Time Fourier Transform (STFT) to generate spectrograms.
* **Visualization:** The spectrograms were plotted using librosa.display.specshow() with a logarithmic frequency scale to highlight frequency variations over time.

**3. Spectrogram Analysis**

**3.1 Classical Music**

* **Observation:** The spectrogram shows distinct harmonic structures with well-defined frequency bands and longer sustain.
* **Interpretation:** Classical music typically features long, sustained notes and complex harmonic structures, leading to clear and separated frequency bands.

**3.2 Rock Music**

* **Observation:** Rock music spectrograms contain dense frequency components across a broad range, with visible rhythmic patterns and sudden transitions.
* **Interpretation:** Rock music has a mix of percussive and instrumental sounds, contributing to a spectrogram with high-energy bursts and frequent variations.

**3.3 Hip-Hop Music**

* **Observation:** The spectrogram exhibits a strong presence of bass frequencies, repetitive beats, and prominent rhythmic structures.
* **Interpretation:** Hip-Hop often emphasizes percussive beats and rhythmic vocal delivery, leading to lower frequency dominance and distinct patterns of speech-like energy.

**3.4 Electronic Music**

* **Observation:** The spectrogram displays a structured and repetitive frequency pattern, with synthesized tones and modulated frequencies.
* **Interpretation:** Electronic music features synthesized sounds, leading to consistent and periodic frequency patterns with clear repetition over time.

**4. Comparative Insights**

| **Genre** | **Key Spectrogram Features** |
| --- | --- |
| **Classical** | Harmonic, well-separated frequency bands, slow transitions |
| **Rock** | Dense frequency spread, fast transitions, percussive bursts |
| **Hip-Hop** | Low-frequency dominance, rhythmic energy bursts |
| **Electronic** | Repetitive, structured patterns, consistent frequency modulations |

**5. Conclusion** Spectrogram analysis provides valuable insights into the characteristics of different music genres. Classical music exhibits sustained harmonic structures, rock music has dynamic frequency variations, hip-hop emphasizes rhythmic patterns, and electronic music shows repetitive frequency modulations. This study highlights the importance of spectrograms in understanding musical structures and distinguishing genres based on frequency-time representations.

**6. Future Work**

* Expanding the dataset to include more sub-genres.
* Applying machine learning models for automatic genre classification based on spectrogram features.
* Exploring more advanced time-frequency analysis techniques like wavelet transforms.

**Output:**

