

## Question 2: Experimenting with Spectrograms and Windowing Techniques

### Task A

#### A.3: Windowing Techniques and Spectrograms

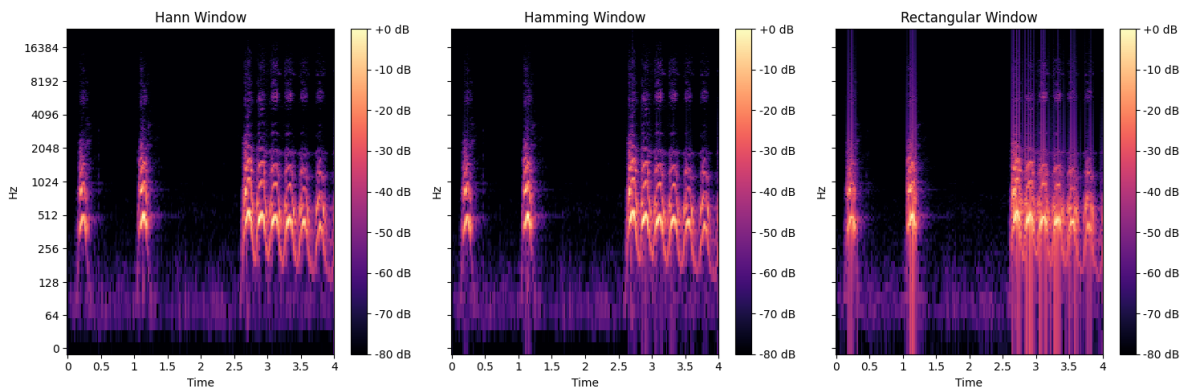


Figure 1: Spectrograms of the sample audio using Hann, Hamming, and Rectangular windows.

### Analysis

The spectrograms reveal the following observations:

#### Hann Window

The Hann window shows a smooth frequency representation with reduced spectral leakage. The transitions between frequency bands are clear, making it suitable for most audio analysis tasks.

#### Hamming Window

The Hamming window also provides a smooth representation but retains slightly more energy near the edges compared to the Hann window. This may result in minor spectral leakage but enhances amplitude retention.

## Rectangular Window

The rectangular window exhibits noticeable spectral leakage due to the lack of tapering at the edges. The frequency components overlap more, leading to less distinct transitions between bands.

## A.4: The Classifier

A simple neural network classifier was used for the task. The network architecture consisted of two fully connected layers: an input layer with 256 units, activated by ReLU, followed by an output layer with 10 units (corresponding to 10 classes) activated by a LogSoftmax function. This compact architecture effectively transforms high-dimensional spectrogram features into class predictions.

The model was trained on spectrogram features extracted using the Hann windowing technique. During training, the model's loss decreased steadily across 10 epochs, indicating effective learning of patterns in the data. However, the accuracy achieved on the test dataset was 10.88%. This relatively low performance highlights the need for more sophisticated feature extraction, additional data preprocessing, or deeper architectures to improve classification results.

## Task B: Spectrogram Analysis of Songs from Different Genres

### Songs and Genres

The four songs selected for analysis belong to distinct genres:

- **Garaj Garaj Jugalbandi** - Indian Classical
- **Jhoom Barabar Jhoom** - Bollywood
- **On Top** - Karan Aujla - Punjabi Pop
- **Shree Krishna Govind Hare Murari** - Devotional/Bhajan

## Observations

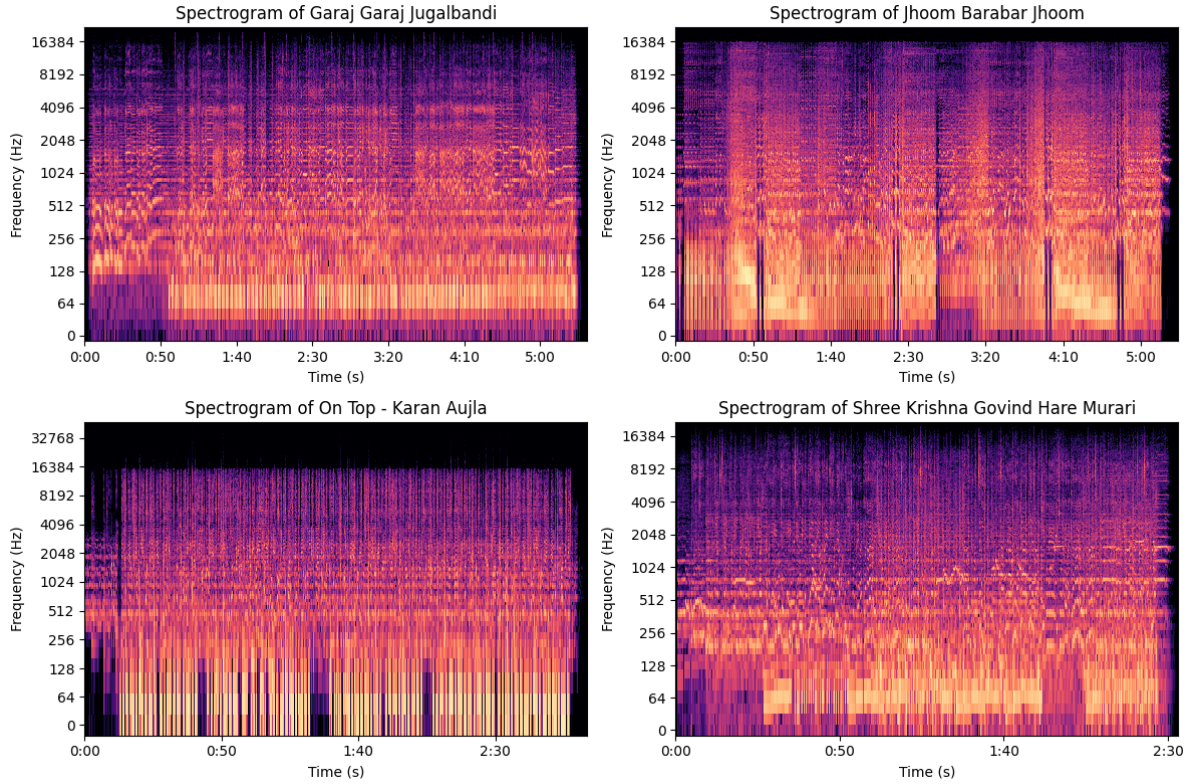


Figure 2: Combined Spectrograms of All Songs

### Garaj Garaj Jugalbandi (Indian Classical)

The spectrogram shows a wide frequency range, indicative of complex harmonics typical of classical music. Noticeable variations over time are due to the improvisational nature and instrumental interplay, with consistent bright bands suggesting continuous drones or fundamental notes like a tanpura.

### Jhoom Barabar Jhoom (Bollywood)

The spectrogram highlights strong low and mid-frequency components, typical of Bollywood tracks with pronounced rhythmic elements. The periodic patterns signify a regular beat structure, and sharp intensity changes align with transitions between vocal and instrumental sections.

### On Top - Karan Aujla (Punjabi Pop)

The spectrogram is dominated by low frequencies, reflecting the prominence of basslines characteristic of Punjabi pop. The repetitive structure and sharp bursts in intensity correspond to beats and chorus sections, emphasizing rhythm over harmonic complexity.

### Shree Krishna Govind Hare Murari (Devotional/Bhajan)

The spectrogram focuses on low to mid frequencies, with smooth transitions over time. This reflects the meditative quality of devotional music, characterized by sustained in-

tensity in chant-like vocals and accompaniment by harmonium or tabla.

## Comparative Observations

- **Frequency Range:** "Garaj Garaj Jugalbandi" exhibits the widest frequency range, while "Shree Krishna Govind Hare Murari" is concentrated in low to mid frequencies.
- **Harmonic Complexity:** Indian classical music shows the highest harmonic complexity, whereas Punjabi pop and devotional music are simpler.
- **Rhythmic Patterns:** Bollywood and Punjabi pop emphasize strong, regular beats, while devotional music features smoother rhythms.
- **Intensity Changes:** Classical music has dynamic intensity variations, Bollywood has periodic changes, Punjabi pop has repetitive bursts, and devotional music maintains sustained intensity.

## Conclusion

The spectrogram analysis highlights the unique frequency, rhythmic, and harmonic characteristics of each genre. Additionally, the application of windowing techniques shows how the choice of window impacts the spectrogram representation, with the Hann and Hamming windows offering better clarity than the Rectangular window.