# MIDI Feature Extraction of Representative Mexican Vocal Melodies

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## I. Introduction and Background

### A. Research Objectives and Significance

The primary objective of this study is to provide a comprehensive analysis of Mexican vocal melodies through MIDI feature extraction, focusing on ambitus, pitch-class entropy and interval distribution. The research focuses on critical questions designed to explore the intrinsic qualities of Mexican folk melodies: How do the variations in pitch range, as measured by ambitus, reflect the diversity of melodic expression in Mexican folk music? What insights can be gained about the complexity of these songs through the analysis of pitch-class entropy? And lastly, what are the discernible patterns in interval distribution within Mexican folk music, and how do they contribute to its melodic essence?

Another exploratory goal of this research is to probe whether there is a correlation between the musical characteristics of entropy and ambitus and the song's popularity, as measured by Spotify play counts. This part of the study explores new perspectives in MIDI feature extraction, particularly the intersection between technical musical analysis and audience engagement in a digital era.

These objectives are to contribute to the broader knowledge of musicology, computational music analysis, and digital musicology, providing insights and data that may be useful for future research and practical applications in these fields.

### B. Review of Recent Methods

A detailed search was conducted in various academic databases, including Google Scholar, to review recent methodologies in the extraction of MIDI features. This search specifically focused on studies in the Music Information Retrieval (MIR) field, emphasising MIDI feature extraction in folk music. Through this process, Anna Maria Christodoulou's 2022 thesis, "Computational Analysis of Greek Folk Music of the Aegean Islands"[1], emerged as a study of particular relevance.

The analysis of Christodoulou's study was based on its direct relevance to MIDI feature extraction in folk music and its comprehensive methodological approach. Examining Christodoulou's approach offered another perspective before researching Mexican Vocal Melodies.

In her thesis, Christodoulou utilised a methodical approach to music analysis, beginning with selecting Greek folk music from the Aegean islands. This selection was pertinent to ensure a proper scope for analysis, enabling a concentrated examination of the musical elements unique to this region's folk music.

The primary methodological step in Christodoulou's research involved extracting musical features from MIDI and WAV files, employing tools such as the MIDI Toolbox. This phase is critical in computational music analysis, as it allows for systematic identification and quantification of various musical elements, including pitch, rhythm, and melody patterns. The extraction laid the groundwork for the subsequent pattern discovery phase.

In this phase, Christodoulou focused on identifying recurring motifs and structural patterns within the selected music. The objective was to uncover the underlying patterns and structures of Aegean island folk music.

Christodoulou also applied advanced Machine Learning techniques, such as Self-Organizing Maps and t-distributed Stochastic Neighbor Embedding, for the unsupervised clustering of the extracted features. This method facilitated the systematic grouping of similar musical elements, contributing to a more organised analysis and revealing broader musical relationships and trends.

Finally, an essential aspect of her methodology included a comparative analysis with existing studies in the field. By situating her findings within the larger scope of musicological research, Christodoulou added context to her approach and contributed new perspectives on Greek folk music compared to other regional music traditions.

### C. Succinct Introduction to the Chosen Approach

This study utilised a MATLAB-based pipeline to analyse MIDI vocal melodies representative of Mexican folk music, incorporating the MIDI Toolbox for data processing and analysis. MIDI files, normalised using Pro Tools, were imported into MATLAB. The MIDI Toolbox was used to extract features such as ambitus, pitch-class entropy, and interval distribution from these files.

In addition to feature extraction, MATLAB was employed to generate plots and conduct statistical analyses. This approach facilitated a streamlined workflow, allowing for the visual representation of data and analysis of the extracted features. The use of MATLAB's statistical tools aided in examining patterns and trends within the dataset.

Overall, this methodology enabled the examination of the characteristics of Mexican folk music as represented in the MIDI vocal melodies, combining the functionalities of MATLAB and the MIDI Toolbox.

## II. Methodology and Implementation

### A. MIR Pipeline Design

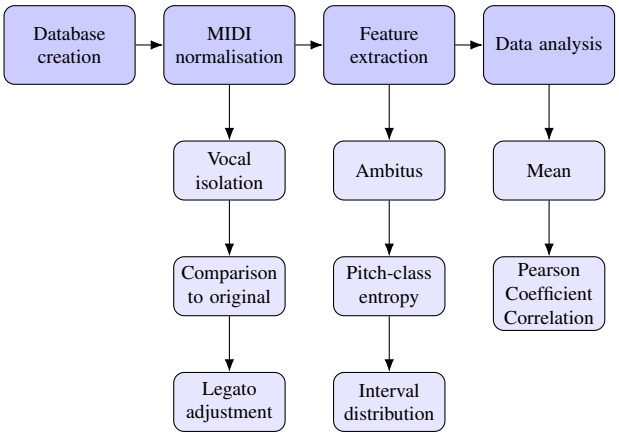


Fig. 1. Schematic Overview of the Music Information Retrieval Process

This study's Music Information Retrieval (MIR) pipeline was carefully structured to analyze MIDI vocal melodies of Mexican folk music. The study's design included the development of a pipeline for efficient data processing and analysis, which comprised the following key stages:

The initial phase of the study involved the meticulous selection of MIDI files for Mexican folk songs that are emblematic of the genre. Each song was chosen for its cultural significance and its impact on the tapestry of Mexican music. Factors such as the song's historical importance, its role in cultural and national events, its presence in popular media, and its recognition by prestigious institutions and in global music charts were considered. This approach ensured a diverse and culturally rich sample representing Mexican folk music's essence. The MIDI files, sourced from reputable online databases, were chosen with an emphasis on their accuracy and fidelity to the original melodies.

After collection, the MIDI files underwent preliminary processing in the digital audio workstation Pro Tools to prepare them for the feature extraction phase of the analysis. This preparatory stage was instrumental in ensuring the MIDI files were in the appropriate format to facilitate the subsequent extraction of musical features.

The core of the MIR pipeline, this phase involved extracting specific musical features from each MIDI file using MATLAB. The features extracted included ambitus, pitch-class entropy and interval distribution. This selection was guided by their relevance to a comprehensive understanding of Mexican folk music's musical structure and characteristics.

The pipeline's final stage focused on analysing and interpreting the extracted features. This study stage involved employing various analytical tools and methods to synthesize the data and identify patterns and trends within the melodies. This included using graphical methods and statistical analysis to interpret the findings and draw conclusions about the musical elements that define Mexican folk music.

### B. Feature Extraction and Normalisation

The project utilised MATLAB for a detailed feature extraction and normalisation process, focusing on ambitus, pitch-class entropy, and interval distribution in vocal melodies. This process included the integration of automated text file generation and data visualisation within the MATLAB code.

The ambitus calculation was performed using the MIDI Toolbox's `ambitus` function. The MATLAB script began by identifying the MIDI file folder and iterating through each file to read it into a note matrix (nmat). For each MIDI file, the script used the `ambitus` function to calculate the musical range in semitones. The script was programmed to create and write a text file to document these calculations, ensuring systematic recording of the ambitus data.

Using MATLAB's plotting functions, the script generated a bar graph to represent the ambitus values visually. This graph was a direct output from the analysis process, visually comparing the musical ranges across the dataset.

Entropy analysis involved processing each MIDI file to calculate the pitch class distribution, subsequently feeding this data into a custom `entropy` function. This function calculated the entropy value by normalising the pitch class distribution and applying logarithmic calculations. The script automatically recorded the results in a text file and generated a bar plot to compare entropy values across different melodies visually.

Finally, the interval distribution analysis used the `ivdist1` function to calculate the frequency of melodic intervals for each song. The script aggregated and normalized these distributions and automatically generated a plot to display the normalized aggregate interval distribution, offering a comprehensive view of common interval patterns.

### C. Selection of Features

The MIDI Toolbox offers a variety of functions for extracting musical features from MIDI files. This study selectively focused on features aligning with the analytical goals of Mexican vocal melodies. The decision was influenced by the fact that many functions in the MIDI Toolbox, like pitch distribution, are key-specific and less relevant for this study. Considering Mexican songs are often performed in various keys, depending on the singer's preference, a key-specific analysis is less pertinent for a holistic understanding of the genre.

Therefore, the features selected for this study — ambitus, pitch-class entropy, and interval distribution — are critical for analyzing melodic aspects that are not dependent on key variations. This approach enables a more objective analysis of the musical elements consistent across different key interpretations within the genre.

*1) Ambitus:* The ambitus function quantifies the pitch range in a given MIDI file, ascertained by the difference between the highest and lowest notes, and serves as an objective metric for analyzing melodic scope. In analyzing folk Mexican vocal melodies, this measurement is vital for identifying the range of pitches chosen by composers and the ensuing vocal demands placed on performers. This dual perspective enhances our understanding of the technical complexity and range required in Mexican music, contributing to a deeper appreciation of its rich vocal traditions.

*2) Pitch-class Entropy:* Pitch-class entropy is a statistical measure used to quantify the diversity in pitch distribution of a musical composition. This measure is derived by calculating the Shannon entropy of the pitch class distribution, yielding a numerical value that reflects the level of predictability or unpredictability in pitch usage. High entropy values indicate compositions with varied and complex pitch patterns, whereas low values suggest more straightforward, repetitive pitch sequences.

In the study of Mexican vocal melodies, pitch-class entropy is applied to assess the complexity of the compositions objectively. Through this method, it can be determined whether these melodies are characterized by a broad range of pitch variations or by more consistent and uniform pitch patterns.

*3) Interval Distribution:* The interval distribution function, as described in the MIDI Toolbox manual by Tuomas Eerola and Petri Toiviainen[2], calculates the frequencies of various musical intervals from a sequence of notes. It presents these frequencies in terms of semitones, providing a clear profile of interval usage within a piece.

For the study of Mexican vocal melodies, interval distribution is a crucial tool for examining the patterns of interval usage in these compositions. Understanding the prevalence and variety of intervals provides a clearer comprehension of the compositional characteristics that define Mexican vocal music.

### D. Statistical Analysis Methods

This study employed descriptive and inferential statistical methods to analyze features extracted from Mexican vocal melodies. The initial phase involved calculating the mean for the ambitus and entropy of the melodies, which helped establish the central tendencies within the dataset.

The study then utilized inferential statistics, particularly the Pearson correlation coefficient, to investigate the relationship between musical features—ambitus and entropy—and song popularity, as reflected by Spotify play counts. The Pearson correlation coefficient was used to measure the strength and direction of the association between these musical features and song popularity.

Further, the significance of these correlations was assessed using p-values. This step was crucial for determining whether the correlations were statistically significant or could have occurred by chance, thereby evaluating musical features' potential influence on the songs' popularity within the digital landscape.

## III. Experimentation and Results

### A. Dataset Creation

The compilation of representative Mexican songs in this study is characterized by their widespread recognition and cultural significance. These songs have been selected based on thorough research to establish their representative status. Detailed information about each song, including factual evidence of their cultural importance and relevance within Mexican society, can be found here[3].

### B. Dataset Pre-processing

The dataset employed for this study underwent a systematic process to ensure data accuracy and suitability for the analysis of ambitus, pitch-class entropy, and interval distribution. Initially, MIDI files corresponding to the selected songs were gathered from online sources. These files were then imported into Pro Tools, a Digital Audio Workstation, for further refinement.

Since MIDI files typically include multiple instrument tracks, the primary goal was to isolate the vocal melodies. To verify the accuracy of the extracted vocal melodies, a meticulous comparison with the original song recordings was conducted. Additionally, legatos within the vocal melodies were adjusted to prevent note overlap, as MIDI Toolbox analysis requires non-overlapping monophonic data.

Following these necessary pre-processing steps, the modified MIDI files, now containing isolated and non-overlapping vocal melodies, were exported. These processed MIDI files were seamlessly integrated into the dataset, ensuring that the dataset accurately represented the vocal melodies of the selected songs. The procedures undertaken during dataset preparation guarantee the reliability of subsequent research findings.

### C. Presentation of Results

*1) Ambitus:* The ambitus results for the analyzed Mexican vocal melodies, as detailed in Table I, are as follows: "Guadalajara" has an ambitus of 27 semitones. "Cielito Lindo" and "Mexico Lindo y Querido" both have an ambitus of 17 semitones. "Besame Mucho" and "El Rey" are each characterized by an ambitus of 15 semitones. "La Cucaracha" has an ambitus of 14 semitones. The ambitus for "Somos Novios" is 13 semitones, followed by "Sabor A Mi", with an ambitus of 12 semitones. "La Bamba" shows an ambitus of 10 semitones. Finally, "El Son De La Negra Low Lead" and "El Son De La Negra High Lead" have ambitus values of 9 and 8 semitones, respectively. As displayed in Figure 2, the average ambitus for the representative Mexican songs was 14.27 semitones.

The correlation between the ambitus of these vocal melodies and Spotify plays is illustrated in Figure 3. The analysis determined a Pearson correlation coefficient of approximately -0.476, with a p-value of approximately 0.165.

TABLE I
AMBITUS OF SELECTED MEXICAN VOCAL MELODIES

| Song Title | Ambitus (Semitones) |
|---|---|
| Guadalajara | 27 |
| Cielito Lindo | 17 |
| Mexico Lindo y Querido | 17 |
| Besame Mucho | 15 |
| El Rey | 15 |
| La Cucaracha | 14 |
| Somos Novios | 13 |
| Sabor A Mi | 12 |
| La Bamba | 10 |
| El Son De La Negra Low Lead | 9 |
| El Son De La Negra High Lead | 8 |

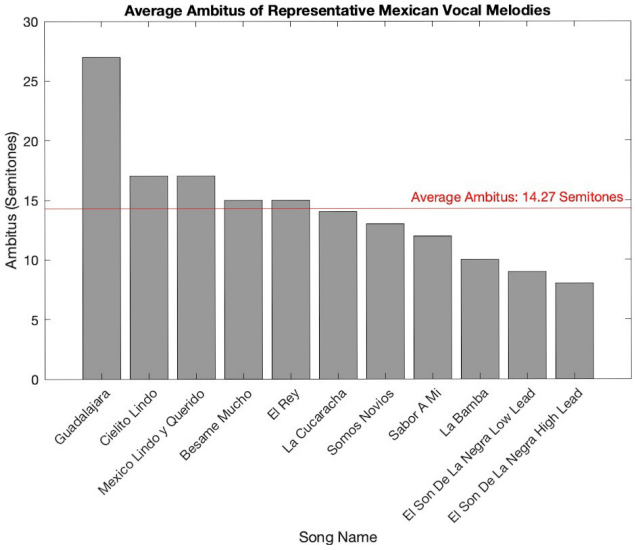


Fig. 2. Average Ambitus of Selected Mexical Vocal Melodies

*2) Entropy:* The pitch class entropy analysis of the selected Mexican vocal melodies yielded the following results, as seen in Table II: "Somos Novios" showed the highest pitch class entropy with a value of 0.854020. It was followed by "Guadalajara" at 0.778169, "Sabor A Mi" at 0.741163, "El Rey" at 0.737659, "La Cucaracha" at 0.724993, "Mexico Lindo y Querido" at 0.722081, "Besame Mucho" at 0.717530, "Cielito Lindo" at 0.706387, "El Son De La Negra" at 0.699415, and "La Bamba" at 0.682210. The average entropy of the database of representative mexical vocal melodies is 0.73, as displayed in Figure 4.

Figure 5 visualizes the correlation between entropy and Spotify plays, with a Pearson correlation coefficient of approximately -0.0775 and a p-value of approximately 0.843.

*3) Interval Distribution:* As seen in Figure 6, the interval distribution graph for the representative Mexican vocal melodies dataset indicates that the prime interval (P1) is the most common interval. This is followed by the major second (M2) and minor second (m2) intervals. The major third(M3) and perfect fourth (P4) are also present but to a lesser extent. The remaining intervals are observed with significantly lower frequencies compared to the more prevalent

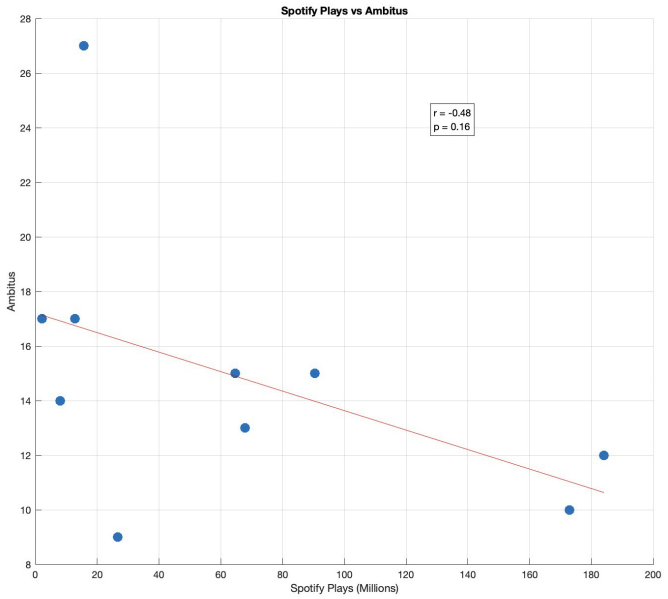


Fig. 3. Correlation Between Spotify Plays and Ambitus of Representative Mexican Folk Songs

TABLE II
PITCH CLASS ENTROPY OF REPRESENTATIVE MEXICAN VOCAL MELODIES

| Song Title | Entropy |
|---|---|
| Somos Novios | 0.854020 |
| Guadalajara | 0.778169 |
| Sabor A Mi | 0.741163 |
| El Rey | 0.737659 |
| La Cucaracha | 0.724993 |
| Mexico Lindo y Querido | 0.722081 |
| Besame Mucho | 0.717530 |
| Cielito Lindo | 0.706387 |
| El Son De La Negra | 0.699415 |
| La Bamba | 0.682210 |

intervals mentioned earlier.

## D. Interpretation of Results

The ambitus analysis of Mexican vocal folk melodies showcases a remarkable range of compositional styles and vocal demands. At one end of the spectrum, songs like "Guadalajara" have an ambitus of 27 semitones, suggesting a need for advanced vocal skills similar to those required in operatic singing. This implies that some Mexican folk melodies are compositionally complex, requiring skilled vocalists for their expressive execution. On the other end, pieces like "El Son De La Negra High Lead," with an ambitus of just eight semitones, demonstrate the genre's inclusivity, accommodating a broader array of vocal abilities. This contrast within the genre exemplifies Mexican folk music's rich diversity, encompassing intricate compositions for trained singers and more straightforward melodies accessible to a broader audience.

In examining the relationship between the ambitus of vocal melodies in representative Mexican songs and their Spotify

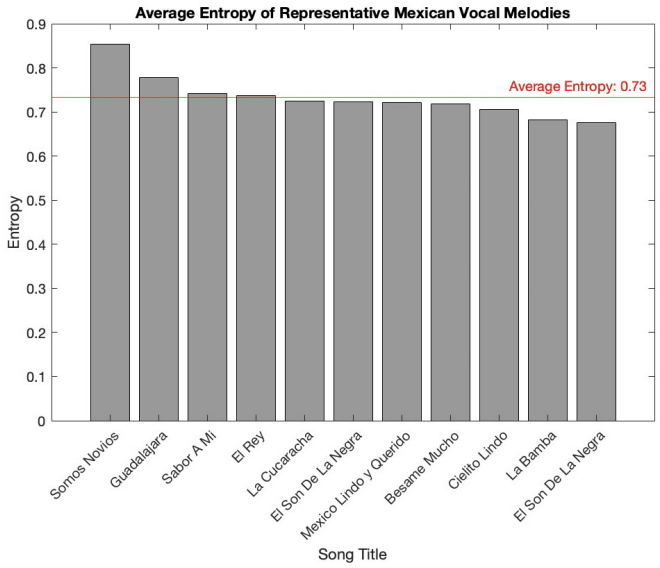


Fig. 4. Average Pitch Class Entropy of Representative Mexical Vocal Melodies

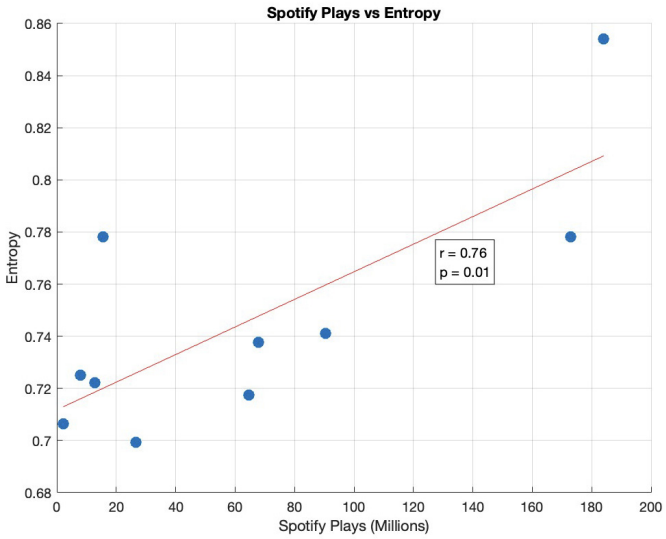


Fig. 5. Correlation Between Spotify Plays and Pitch-class Entropy of Representative Mexican Folk Songs

plays, the statistical analysis revealed a moderate negative Pearson correlation coefficient of approximately -0.476. This coefficient suggests a slight tendency for songs with a larger ambitus to receive fewer plays on Spotify. However, it is crucial to understand the significance of the p-value in this context, which was found to be around 0.165.

A p-value measures the probability that an observed difference could have occurred just by random chance. The standard threshold for statistical significance is a p-value of 0.05 or less. The p-value exceeds this threshold, which implies that the correlation observed might not be statistically meaningful and could be due to random variation in the

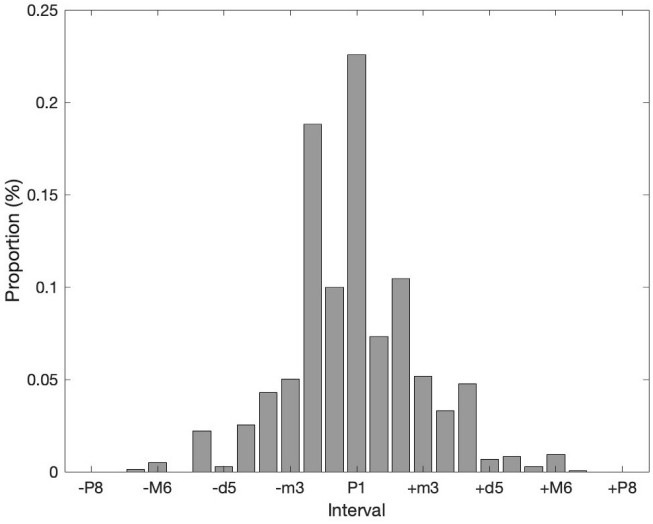


Fig. 6. Intertval Distribution of Representative Mexican Vocal Melodie

data. Therefore, despite the initial indication of a correlation between larger ambitus and fewer Spotify plays, the lack of statistical significance (as shown by the p-value higher than 0.05) means a meaningful link between these two variables cannot be confidently asserted.

In the entropy analysis of Mexican vocal melodies, the composition of Armando Manzanero, "Somos Novios," displayed notably high entropy, ranking first. This observation is consistent with Manzanero's status as one of the most prominent and acclaimed Latin music composers[4]. His sophisticated approach to melody is evident in this song's varied and complex nature. In contrast, "La Bamba," rooted in traditional Mexican folk music, showed the lowest entropy, highlighting its simpler, more repetitive structure. This range in entropy values from "La Bamba" to Manzanero's work illustrates the diverse melodic complexity within Mexican music.

The Pearson correlation coefficient between Spotify plays and entropy for the selected songs is approximately -0.0775. This value indicates a weak negative correlation, suggesting no significant linear relationship between the entropy of a song's vocal melody and its number of Spotify plays.

The p-value associated with this correlation is approximately 0.843, which is well above the expected threshold of 0.05 for statistical significance. This high p-value indicates that the weak correlation observed is likely due to random chance rather than a meaningful relationship.

In summary, the statistical analysis does not support a relevant connection between the entropy of vocal melodies in the selected Mexican songs and their popularity on Spotify, as measured by the number of plays.

The interval distribution analysis of the selected Mexican vocal melodies provides valuable insights into their compositional makeup. The prevalence of the prime interval (P1) and major second (M2) in these songs suggests a composition style that favours close, contiguous intervals. This pattern con-

tributes to creating intimate and approachable melodies, resonating with listeners through their simplicity and directness. The inclusion of minor second (m2) intervals introduces a subtle complexity, adding depth to the melodies without overwhelming their fundamental character. The occasional use of major third (M3) and perfect fourth (P4) intervals, though less common, enhances the melodic diversity within each piece. This nuanced approach to interval choice reflects a thoughtful balance between simplicity and musical richness, characteristic of the songs in this analysis. The overall tendency towards smaller intervals in these Mexican vocal melodies highlights their unique charm and accessibility, making them appealing and relatable to a broad audience.

## IV. Conclusion

The analysis of Mexican vocal melodies through MIDI feature extraction in this study has provided a detailed understanding of several key aspects: ambitus, pitch-class entropy, and interval distribution.

The ambitus analysis demonstrated the wide range of vocal demands within the genre, highlighting the diversity from pieces requiring significant vocal prowess to those more accessible for communal singing. However, the statistical correlation between ambitus and Spotify plays was not significant, indicating that melodic complexity does not necessarily equate to increased digital platform popularity.

In terms of entropy, the study quantified the complexity of these melodies. High entropy values indicated more intricate melodies, but again, there was no significant correlation with Spotify plays. This finding suggests that the unpredictability of pitch class distribution is not a primary factor in determining a song's popularity.

The interval distribution analysis revealed a tendency towards smaller intervals, contributing to the accessibility and appeal of these melodies. The inclusion of varied intervals added to the melodic diversity within the genre.

In conclusion, this study's findings indicate that while ambitus, entropy, and interval distribution are critical in defining the structural characteristics of Mexican vocal melodies, they do not directly correlate with popularity on Spotify. These insights contribute to a more nuanced understanding of the genre and highlight the need for further research that might include a broader dataset and integrate qualitative factors to capture the full spectrum of influences on musical preference and consumption.

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