

Quantitative Evaluation of Stylistic Consistency and Acoustic Evolution: A Case Study of Jay Chou's Career from 2000 to 2026

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Abstract. Computational musicology provides a quantitative approach for examining musical style beyond subjective listening impressions. In Mandopop studies, however, long-term acoustic analysis of individual artists remains relatively limited. This study quantitatively examines the acoustic evolution and stylistic continuity of Jay Chou's studio albums from 2000 to 2026. A corpus of 175 locally stored tracks from 16 studio albums was analyzed through digital signal processing. A 27-dimensional analytical feature set was constructed from rhythmic, spectral, dynamic, and timbral descriptors extracted with librosa. Descriptive statistics, statistical comparison tests, Principal Component Analysis (PCA), and K-means clustering were utilized to evaluate whether works released after Jay Chou's Bedtime Stories form an acoustically distinct late-career stage. The results do not support a clear binary rupture between pre- and post-Bedtime Stories works. K-means clustering shows a near-balanced distribution across clusters in both stages, suggesting substantial cross-period overlap. However, significance tests reveal localized differences in selected spectral-textural features, particularly zero-crossing rate and spectral-centroid variation. Album-level PCA further indicates that Children of the Sun occupies a position distinct from Greatest Works of Art and closer to several earlier or mid-career albums, suggesting partial acoustic repositioning rather than a straightforward continuation of recent production patterns. Overall, the findings suggest that Jay Chou's late-career style is better understood as a synthesis of broad acoustic continuity and localized sonic adjustment rather than a definitive stylistic break.

Keywords: Jay Chou, computational musicology, acoustic evolution, PCA, K-means clustering

1. Introduction

Computational musicology and music information retrieval (MIR) have increasingly been utilized to examine musical style through measurable audio features. Previous studies have demonstrated that rhythmic, timbral, harmonic, and spectral descriptors can effectively support the analysis of genre classification, stylistic evolution, and long-term macro-changes in popular music [1-3]. However,

the majority of existing research focuses on large Western music corpora or genre-level evolution, while longitudinal quantitative studies of individual artists in Mandopop remain relatively limited.

Jay Chou provides a highly representative case for such an analysis, as his career spans over two decades and comprises 16 studio albums released between 2000 and 2026. His extensive catalogue is frequently discussed in cultural contexts regarding stylistic continuity, late-career maturation, nostalgia, and potential returns to earlier musical signatures. Yet, these discussions largely rely on subjective listening impressions or public reception rather than systematic, data-driven acoustic evidence.

This study, therefore, investigates whether Jay Chou's works before and after *Jay Chou's Bedtime Stories* exhibit measurable differences in the audio-feature space, and whether his most recent albums constitute a distinct late-career acoustic stage. To address these questions, this study analyzes 175 locally stored tracks using digital signal processing. Rhythmic, spectral, and timbral features are extracted using *librosa*, encompassing metrics such as tempo, RMS energy, zero-crossing rate, spectral centroid, spectral bandwidth, spectral rolloff, and Mel-frequency cepstral coefficients (MFCCs) [4, 5]. Descriptive statistics, significance tests, PCA, and K-means clustering are subsequently applied to evaluate acoustic continuity and change. By doing so, this study provides a transparent, reproducible framework for examining stylistic evolution in Mandopop and offers methodological references for future intra-artist musicological analysis.

2. Methodology

2.1. Corpus and stage definition

The dataset consists of 175 tracks from Jay Chou's 16 studio albums released between 2000 and 2026. Instead of relying on streaming-platform audio indicators, locally stored audio files were used as the primary data source. This design ensures the extraction process remains transparent and reproducible, avoiding the interpretive limitations associated with platform-derived black-box features.

The analysis adopts *Jay Chou's Bedtime Stories* as the primary period boundary. Albums released before and including *Jay Chou's Bedtime Stories* are assigned to the pre-*Bedtime Stories* stage (150 tracks), while *Greatest Works of Art* and *Children of the Sun* are assigned to the post-*Bedtime Stories* stage (25 tracks). This division serves the research objective of examining whether the two most recent albums manifest a measurable acoustic shift relative to the expansive earlier catalog.

2.2. Audio feature extraction

All audio files were converted into mono signals and loaded at a sampling rate of 22,050 Hz. Audio descriptors were extracted using *librosa*, a Python package for audio and music signal analysis [4]. To ensure the reported analysis remains interpretable and robust against the curse of dimensionality, this study constructs a 27-dimensional analytical feature vector for multivariate analysis (PCA and K-means clustering). This vector comprises 14 interpretable base descriptors (temporal, energy, and spectral features) and 13 MFCC mean coefficients (timbral features). This design adheres to common MIR practices, where multifaceted descriptors are utilized to represent recordings as numerical feature vectors [3, 5, 6]. The detailed composition of the feature set is summarized in Table 1.

Table 1. Composition of the 27-dimensional analytical audio feature set

Feature group	Variables included	Dimensions	Acoustic meaning
Temporal	duration_sec; tempo	2	Song length and estimated rhythmic speed
Energy and attack	rms_mean; rms_std; onset_strength_mean; onset_strength_std	4	Average energy, dynamic fluctuation, and rhythmic attack intensity
Spectral texture	zcr_mean; zcr_std; centroid_mean; centroid_std; bandwidth_mean; bandwidth_std; rolloff_mean; rolloff_std	8	High-frequency activity, brightness variation, frequency spread, and spectral boundary
Timbral profile	mfcc_1_mean to mfcc_13_mean	13	Compact representation of overall timbral configuration
Total	Analytical vector used for PCA and K-means	27	Main multivariate representation in this study

2.3. Statistical comparison

Descriptive statistics were calculated for the pre- and post-*Bedtime Stories* stages. Given that the two groups are imbalanced in size and certain variables violate the assumption of normality, the non-parametric Mann-Whitney U test was employed for most feature comparisons. Welch's t-test was utilized when distributional assumptions were met. This step aims to identify whether specific, localized acoustic features differ significantly between the two historical stages.

2.4. Principal component analysis

Principal Component Analysis (PCA) was utilized to reduce the 27-dimensional feature space into a subset of orthogonal components [7]. All features were standardized to have a mean of zero and unit variance prior to transformation. Two analytical perspectives were applied: (1) Track-level PCA, designed to detect outlying tracks and observe within-album variation across the entire dataset; (2) Album-level PCA, where track-level features were averaged within each album before dimensionality reduction. As the core research question pertains to long-term album-stage evolution, this approach serves as the primary visualization tool.

2.5. K-means clustering

K-means clustering was applied as an unsupervised diagnostic to assess the manually defined stage division [8]. The number of clusters was predetermined as $k=2$ to explicitly test whether the acoustic data naturally partitions into two groups corresponding to the pre- and post-*Bedtime Stories* eras. It operates as an exploratory tool for evaluating the validity of a binary evolutionary structure rather than a definitive classification model.

3. Results and discussion

3.1. Descriptive statistics and significance testing

Statistical comparisons reveal that the pre- and post-*Bedtime Stories* stages do not differ significantly across all acoustic dimensions. Instead, statistically significant differences are isolated

to a subset of spectral-textural indicators (Table 2).

Table 2. Statistical comparison of selected acoustic features between pre- and post-bedtime stories stages

Feature	Test	Pre mean	Post mean	p-value
ZCR SD	Mann-Whitney U	0.0642	0.0507	1.11e-04
ZCR Mean	Mann-Whitney U	0.0852	0.0732	0.0055
Centroid SD	Mann-Whitney U	906.47	843.41	0.0153
Duration	Mann-Whitney U	244.32	222.87	0.0396
Centroid Mean	Welch t-test	2142.64	2048.75	0.2311
Tempo	Mann-Whitney U	125.49	129.79	0.3610
RMS Mean	Welch t-test	0.2279	0.2305	0.8076
Onset Mean	Mann-Whitney U	1.3556	1.3848	0.4166

3.2. Principal component analysis results

The track-level PCA (components 1 and 2 explaining 42.30% of total variance combined) reveals substantial overlap between pre- and post-stage tracks. Post-stage tracks do not cluster in isolation, corroborating the hypothesis that late-career works incorporate localized shifts without cleanly detaching from established historical aesthetics.

As shown in Figure 1, the album-level PCA provides a macro-trajectory of this evolution. The first two principal components explain 51.89% of the cumulative variance (PC1: 27.40%; PC2: 24.49%). In the album-level PCA space, *Greatest Works of Art* occupies a strongly positive PC1 position, while *Children of the Sun* occupies a negative PC1 position. The loading structure indicates that PC1 is strongly driven by spectral distribution and timbral profiles (with bandwidth, rolloff, and ZCR loading negatively, counterbalanced by MFCC parameters). This spatial divergence is critical: *Children of the Sun* is situated significantly further from *Greatest Works of Art* than would be expected if the post-stage represented a homogenous "late-period" sound. Instead, *Children of the Sun* shifts towards coordinates occupied by earlier albums like *The Era*, *Capricorn*, and *Opus 12*. However, its Euclidean distance to the debut album *Jay* is not the absolute minimum, implying that *Children of the Sun* executes a partial acoustic repositioning toward mid-career production frameworks rather than a regressive revival of the 2000-era aesthetic.

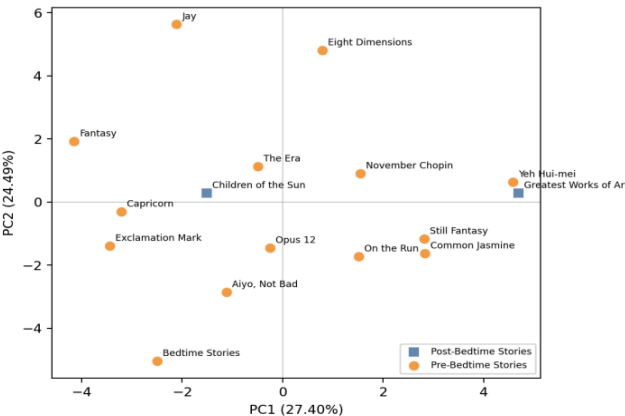


Figure 1. Album-level PCA of Jay Chou's acoustic feature profiles

3.3. K-means clustering

The K-means analysis ($k=2$) provides corroborating evidence against a binary historical rupture. If the post-stage albums formed a distinctive acoustic paradigm, cluster assignments would diverge sharply between periods. However, the cross-tabulation demonstrates a near-balanced distribution: in the post-stage group, 44.0% of tracks belong to Cluster 0 and 56.0% to Cluster 1; comparably, the pre-stage group splits 47.3% to Cluster 0 and 52.7% to Cluster 1.

An analysis of cluster centroids reveals that Cluster 0 is defined by higher ZCR, broader spectral bandwidth, and elevated RMS energy (a brighter, more dynamic texture), whereas Cluster 1 features lower spectral energy but higher average tempo. Because tracks from both chronological stages populate these clusters equally, they should be interpreted as recurring stylistic modes embedded within Chou's foundational musical vocabulary, rather than sequential chronological eras.

3.4. Discussion and limitations

Synthesizing these findings, Jay Chou's late-career productions defy linear, unidirectional evolutionary models. The persistence of shared track-level PCA space and uniform K-means distributions underscores a durable acoustic signature. Concurrent localized changes—such as smoothed spectral textures and stabilized brightness variations—likely reflect shifts in modern mixing, mastering, or arrangement philosophies [2, 9], rather than an abandonment of core stylistic identity. Furthermore, the stark contrast between *Greatest Works of Art* and *Children of the Sun* reveals multidimensional retrospective tendencies.

This study acknowledges certain methodological limitations. The intentional boundary at *Bedtime Stories* results in an imbalanced sample (150 vs. 25 tracks), which may heavily weight the PCA variance structure toward earlier works. Additionally, setting $k=2$ for K-means was a hypothesis-driven choice to test binary periodization; future research could employ silhouette analysis or elbow-method diagnostics to discover the unconstrained optimal clustering structure of the catalogue [10].

4. Conclusion

Through the extraction of a 27-dimensional analytical feature set from 175 locally stored tracks, this study establishes a reproducible, data-driven representation of Jay Chou's 26-year acoustic trajectory. The empirical results do not support the hypothesis of a complete stylistic rupture in his late career. Both unsupervised learning and dimensionality reduction indicate substantial continuity across his discography. K-means clustering shows that pre- and post-*Bedtime Stories* tracks are distributed in highly similar proportions across the two clusters, while track-level PCA reveals considerable overlap between the two historical stages.

At the same time, the findings do not imply that Jay Chou's late-career works are acoustically unchanged. Statistical comparisons reveal localized textural differences, especially in zero-crossing rate and spectral-centroid variation. These results suggest smoother high-frequency activity and reduced brightness fluctuation in recent works. Such changes are better understood as targeted acoustic adjustments rather than evidence of a complete stylistic break.

Album-level PCA further visualizes a non-linear late-career trajectory. *Children of the Sun* occupies a position clearly distinct from *Greatest Works of Art* and moves toward the region associated with several earlier or mid-career albums. However, its distance from the debut album *Jay* does not support a simple revival of the earliest style. Therefore, the most cautious interpretation

is that Children of the Sun demonstrates partial acoustic repositioning within a broadly continuous stylistic framework.

Overall, this study provides an objective basis for discussing stylistic continuity and acoustic change in Mandopop. It also demonstrates how self-extracted audio descriptors can support intra-artist longitudinal analysis. Future research may incorporate lyrical features, vocal-timbre modeling, listener reception data, and comparative samples from other Mandopop artists to further examine how production, performance, and cultural memory interact in long-term artistic evolution.

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