Smart Techno (Smart Technology, Informatic, and Technopreneurship)
Volume 08, Number 01, 2026 pp. 132-141
E-ISSN : 2541-0679
Open Access: https://lppm.primakara.ac.id/jurnal/index.php/smart-techno/

Analysis of the Effect of Spectral Feature Dimensionality on Audio Classification Performance

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ARTICLE INFO
Article history:
Initial submission
22-12-2025
Received in revised form
23-01-2026
Accepted 23-01-2026
Available online 27-02-2021

Keywords:
Dangdut Music, Spectral Feature, Classification, MIR, K-NN

DOI:
https://doi.org/10.59356/smart-techno.v8i1.196

ABSTRACT

This study examines the impact of spectral feature quantity on the classification performance of dangdut music sub-genres, namely classical dangdut, dangdut rock, and dangdut koplo. Previous studies reported relatively low classification accuracy, which is presumed to be influenced by spectral features with small numerical values and dense feature distributions. To address this issue, two feature configurations were evaluated six and five spectral features using the K-Nearest Neighbor (KNN) algorithm and a Genetic Algorithm-optimized KNN (GA-KNN). Model performance was assessed using accuracy, precision, recall, and F1-score, supported by confusion matrix analysis. The results show that the six-feature configuration consistently outperforms the five-feature configuration for both methods. GA-KNN achieved the best performance with six spectral features, yielding an accuracy of 71.53%, precision of 0.7147, recall of 0.7153, and an F1-score of 0.7140, outperforming conventional KNN, which achieved an accuracy of 62.50% and an F1-score of 0.6135. When reduced to five spectral features, performance declined for both methods; GA-KNN reached an accuracy of 66.67% with an F1-score of 0.6611, while conventional KNN dropped to 52.08% accuracy with an F1-score of 0.5121, accompanied by increased misclassification between sub-genres with similar spectral and rhythmic characteristics. These findings indicate that spectral features with small numerical values still contribute meaningful discriminative information and should be carefully evaluated before applying feature reduction in music genre classification tasks.

1. INTRODUCTION

Dangdut music is a popular music genre in Indonesia that consists of various sub-genres with distinct musical characteristics, such as classic dangdut, dangdut rock, and dangdut koplo. These differences can be observed in rhythm patterns, tempo, the use of musical instruments, and overall musical structure (Hananta, 2023). This diversity of characteristics makes the classification of dangdut sub-genres an interesting problem in the field of audio signal processing, particularly in efforts to automatically group music based on its acoustic features.

In previous studies on the classification of dangdut music sub-genres based on six spectral analysis features, namely centroid, skewness, roll off, kurtosis, spread, and flatness, the performance of the resulting classification models was still considered suboptimal, as indicated by relatively low accuracy values. One factor suspected to influence this condition is the characteristics of the features used, particularly the presence of features with very small or near-zero values, as well as uneven feature value distributions across classes or categories (Fratiwi et al., 2025). This condition can potentially lead to suboptimal data representation in the feature space and negatively affect the performance of classification algorithms, especially those based on distance calculations.

Spectral analysis features are widely used in audio classification because they can represent frequency, related information associated with the timbre and sound characteristics of music. However, the use of spectral features with an inappropriate number or scale of values can cause problems in the classification process (Sujatha & Prabakeran, 2025). In distance-based algorithms, such as K-Nearest Neighbor (K-NN), the number of features and the

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distribution of their values have a significant influence on the calculation of distances between data points. Adding features that are irrelevant or noisy does not necessarily improve classification performance and, in some cases, can even degrade the results obtained (Ramadhan et al., 2024).

Based on these issues, this study considers the analysis of the number of spectral features to be an important aspect in improving the classification performance of dangdut music sub-genres. This research does not solely focus on the use of classification algorithms but rather emphasizes evaluating the effect of the number of features on model performance. By comparing different feature-number scenarios, specifically the use of six spectral features versus five spectral features, this study seeks to identify whether reducing features with small values can have a positive impact on classification results or instead remove important information needed to distinguish between sub-genres.

Through an experimental approach on a dangdut music dataset consisting of the sub-genres classic dangdut, dangdut rock, and dangdut koplo, this study evaluates classification performance using accuracy, precision, recall, and F1-score metrics. The evaluation results are expected to provide a clearer picture of the relationship between the number of spectral features and audio classification performance. Therefore, the main objective of this study is to analyze the effect of the number of spectral features on the classification performance of dangdut music sub-genres and to provide empirical contributions regarding the importance of selecting an appropriate number of features in machine learning–based audio classification systems.

2. LITERATURE REVIEW

2.1. Music Classification Based on Spectral Feature

Computational based music classification is a central topic in the field of Music Information Retrieval (MIR) and has been extensively studied within audio signal processing and machine learning research. A commonly adopted approach involves extracting spectral features from the frequency domain of audio signals to represent timbral characteristics and the distribution of spectral energy. Spectral features such as spectral centroid, roll off, spread, skewness, kurtosis, and flatness have been shown to be effective in various MIR tasks, including music genre classification, instrument recognition, and timbre analysis (Abrah et al., 2025). In practice, a range of machine learning algorithms has been employed, including K-Nearest Neighbor (KNN), Support Vector Machine (SVM), and decision tree–based methods, with KNN being widely used due to its conceptual simplicity in measuring similarity within the feature space. However, distance-based algorithms exhibit inherent limitations, particularly their sensitivity to the number of features and feature value distributions. The inclusion of irrelevant or low-informative features may degrade classification performance due to the curse of dimensionality, highlighting the importance of careful feature selection and dimensionality control in the development of MIR-based music classification systems.

2.2. Dangdut Music

Previous literature indicates that dangdut is a popular Indonesian music genre that emerged from processes of cultural hybridity and has continuously evolved in response to social dynamics, technological advancements, and shifting market preferences. Early studies identify dangdut as being strongly influenced by Malay musical traditions and Bollywood music, which later underwent transformation through the adoption of electronic instruments and band-based formats, giving rise to variants such as dangdut rock. Alongside the development of music production technologies and remix culture, the dangdut koplo sub-genre emerged, characterized by faster and more dominant rhythmic patterns. Musicological analyses demonstrate that these changes in instrumentation and performance style result in distinct differences in timbre, rhythm, and musical structure within dangdut. In more recent scholarship, dangdut is no longer viewed solely as an expression of popular culture but has also become an object of interdisciplinary academic inquiry, including ethnomusicology, cultural studies, and

music technology. The recognition of dangdut as an Intangible Cultural Heritage by UNESCO further underscores the importance of systematic documentation, mapping, and classification of its sub-genres. Nevertheless, existing studies remain largely dominated by qualitative and descriptive approaches, while research employing computational analysis of dangdut audio signals, particularly for automatic sub-genre classification, remains relatively limited. This gap highlights the potential for further research within the Music Information Retrieval (MIR) framework using quantitative, audio signal-based approaches (Hananta, 2023; Ikhwan, 2023).

2.3. State of the Art

The use of spectral features is a primary approach in music classification within the Music Information Retrieval (MIR) framework due to their ability to represent timbral characteristics and frequency energy distribution. Previous studies have shown that spectral features such as rolloff, centroid, spread, skewness, kurtosis, and flatness exhibit varying discriminative power in distinguishing musical genres and sub-genres. A 2021 study utilizing the spectral rolloff feature successfully differentiated regional music and dangdut with an accuracy of up to 83.3%, although the analysis was limited to two genre classes and a single dominant feature (Ismanto et al., 2021). Subsequent research employing a combination of five spectral features for Balinese gamelan music classification demonstrated improved audio representation across multiple genre classes, highlighting the importance of spectral feature diversity in capturing the complexity of sound characteristics (Harsemadi, 2023). However, studies on dangdut sub-genre classification using six spectral features have still yielded moderate performance, with indications of very low-valued features and uneven feature distributions across classes (Fratiwi et al., 2025). These findings suggest that increasing the number of spectral features does not necessarily lead to proportional improvements in classification performance, underscoring the need for further analysis of the optimal number and contribution of spectral features an aspect that remains insufficiently explored

2.4. Research Gap

Based on the state of the art, it can be identified that music classification research based on spectral features has been widely conducted, both on traditional music genres and on dangdut music sub-genres. However, most previous studies have focused on the utilization of spectral feature types and the selection of classification algorithms, without systematically evaluating the effect of the number of spectral features on model performance. Using a larger number of spectral features does not necessarily lead to improved accuracy, especially when some features have very small values or uneven distributions across classes. In addition, comparative studies that specifically analyze differences in classification performance resulting from variations in the number of spectral features in dangdut music sub-genres are still limited. Therefore, further research is needed to empirically examine the effect of the number of spectral features on the classification performance of dangdut music sub-genres within the framework of Music Information Retrieval (MIR).

3. METHOD

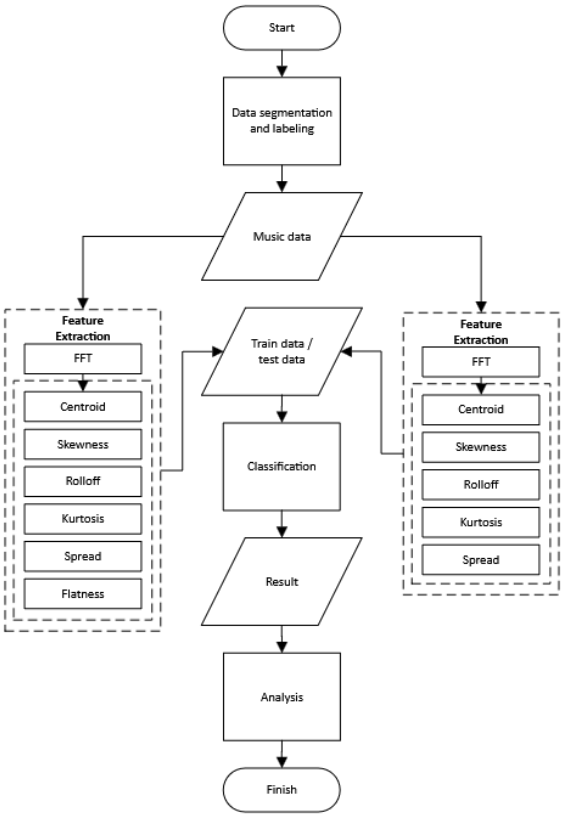

Figure 1. Research method.

3.1. Dataset and Pre-Processing

This study uses a dangdut music dataset consisting of three sub-genres: classic dangdut, dangdut rock, and dangdut koplo. The data were collected from three musicians, each representing one sub-genre: Ellya Khadam (classic dangdut), Rhoma Irama with Soneta Band (dangdut rock), and Denny Caknan (dangdut koplo). All songs were segmented into the most representative 30-second audio excerpts and stored in mono (.wav) format with a uniform sampling rate. Each sub-genre consists of 161 samples, resulting in a total dataset of 483 audio samples.

3.2. Spectral Feature Extraction

Feature extraction was performed in the frequency domain using the Fourier transform. Six spectral features were extracted, namely spectral centroid, spectral roll off, spectral spread, spectral skewness, spectral kurtosis, and spectral flatness. These features were selected because they effectively capture timbral characteristics and the distribution of spectral energy, which are essential for distinguishing sub-genres of dangdut music. In addition to the full feature set, an experimental scenario using five spectral features was conducted by excluding spectral flatness. This decision was based on preliminary statistical analysis, which showed that spectral flatness consistently yielded very low values (close to zero) and exhibited limited variance across samples, indicating a minimal contribution to discriminative power. The comparison between the six-feature and five-feature configurations was intended to evaluate the impact of feature reduction on classification performance and feature space representation.

3.3. Feature Number Scenarios

To analyze the effect of the number of spectral features on classification performance, this study applies two feature scenarios:

a. Six spectral feature scenario, using all extracted features.
b. Five spectral feature scenario, by removing one feature that has very small values or a less informative distribution based on preliminary statistical feature analysis.

The comparison of these two scenarios aims to evaluate whether reducing certain features can improve data representation in the feature space and enhance classification performance.

3.4. Classification Method

Classification was performed using the K-Nearest Neighbor (KNN) algorithm, which was selected due to its simplicity and sensitivity to feature configuration. The distance between data points was calculated using the Euclidean distance metric, and the value of the parameter k was determined through an evaluation process to obtain the best performance on the training data. In addition to conventional KNN, this study also applies a Hybrid K-NN approach in which the k parameter is optimized using a Genetic Algorithm (GA). This optimization process enables the automatic selection of the optimal k value through evolutionary mechanisms, with the aim of improving classification performance compared to manual parameter tuning (Fratiwi et al., 2021, 2025).

3.5. Performance Evaluation

The dataset was divided into training and testing sets using a specific ratio. Classification performance was evaluated using accuracy, precision, recall, and F1-score metrics. In addition, a confusion matrix was employed to analyze classification error patterns among the sub-genres.

$$Accuracy = \frac{TP + TN}{P + N} \quad (1)$$

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

$$Recall = \frac{TP}{P} \quad (3)$$

$$F1 - score = \frac{2 \times precision \times recall}{precision \times recall} \quad (4)$$

TP= True Positive
TN= True Negative
FP= False Positive
FN= False Negative

Table 1. Confusion Matrix.

		Prediction Class		
		Yes	No	Amount
Actual Class	Yes	**TP**	**FN**	Positive
	No	**FP**	**TN**	Negative
	Amount	Positive'	Negative'	P+N

The evaluation results from both feature-number scenarios were then compared to assessing the effect of the number of spectral features on classification performance (Wororomi et al., 2024).

4. RESULT AND DISCUSSION

The results of this study indicate that the number of spectral features has a significant impact on the classification performance of dangdut music sub-genres, namely classical dangdut, dangdut rock, and dangdut koplo. The evaluation was conducted under two feature scenarios, six spectral features and five spectral features, using both conventional K-Nearest Neighbor (KNN) and KNN optimized with a Genetic Algorithm (GA). In the GA-KNN approach, the GA was employed to optimize the KNN parameters using a population size of 15 individuals, a maximum of 15 generations, and a chromosome representation four genes, with the maximum value of k set to 15. The dataset was divided into training and testing sets using a 70:30 ratio to ensure a balanced and representative evaluation process. Model performance was assessed using accuracy, precision, recall, and F1-score, which are widely employed metrics in music classification and pattern recognition research.

In the conventional K-Nearest Neighbor (KNN) approach, a series of experiments were conducted to identify the optimal value of the k parameter within the range of 1 to 10. Under the six spectral feature scheme, the highest classification accuracy of 62.50% was achieved when k was set to 1. However, this result cannot be considered robust, as using a single nearest neighbor introduces a high potential for bias and sensitivity to noise, given that the classification decision relies solely on one closest data point. In contrast, under the five spectral feature scheme, the optimal k value was found at k = 8, yielding the highest accuracy of 52.08%, which indicates a more stable neighborhood-based decision process compared to the six-feature scenario.

Table 2. KNN Classification Accuracy for k = 1–10.

K	Accuracy 5 Spectral (%)	Accuracy 6 Spectral (%)
1	45,83	62,50
2	45,14	59,03
3	49,31	59,03
4	47,92	57,64
5	50,69	57,64
6	51,39	54,86
7	50,69	54,86
8	52,08	59,03
9	51,39	59,03
10	48,61	57,64

In the KNN optimized with a Genetic Algorithm (GA-KNN), the determination of the optimal k value was performed automatically through GA operations. The GA optimization process enabled a more effective search for the optimal parameter configuration, resulting in k values that produced higher classification accuracy compared to the conventional KNN approach. Specifically, under the six spectral feature scheme, the optimal k value identified by GA was k = 5, while under the five spectral feature scheme, the optimal k value was k = 7. These results demonstrate that GA-based optimization is capable of mitigating parameter selection bias and improving classification performance by identifying more balanced neighborhood sizes.

In the six spectral feature scenario, GA-based KNN demonstrated the best performance, achieving an accuracy of 71.53% (k = 5), precision of 0.7147, recall of 0.7153, and an F1-score of 0.7140. These values are higher than those obtained by conventional KNN, which only reached an accuracy of 62.50% with a precision of 0.6591, recall of 0.6250, and an F1-score of 0.6135. This improvement indicates that the combination of a more comprehensive set of features and parameter optimization using a Genetic Algorithm enhances the model's ability to more effectively distinguish spectral characteristics across dangdut sub-genres.

Table 3. Six Spectral Classification Result.

No	Algorithm	Precision	Recall	F1-score	Accuracy
1	K-NN	0,6591	0,6250	0,6135	62,50%
2	K-NN with GA	0,7147	0,7153	0,7140	71,53%

Conversely, in the five spectral feature scenario, a noticeable decline in performance was observed for both methods. GA-based KNN achieved an accuracy of 66.67% (k = 7, precision of 0.6665, recall of 0.6667, and an F1-score of 0.6611, while conventional KNN only reached an accuracy of 52.08%with a precision of 0.5309, recall of 0.5208, and an F1-score of 0.5121. The decrease in precision and recall in this scenario indicates an increase in classification errors, both false positives and false negatives, due to the reduced amount of spectral information used to represent the audio signals.

Table 4. Five Spectral Classification Result.

No	Algorithm	Precision	Recall	F1-score	Accuracy
1	K-NN	0,5309	0,5208	0,5121	52,08%
2	K-NN with GA	0,6665	0,6667	0,6611	66,67%

Confusion matrix analysis provides a more detailed view of the classification error patterns among sub-genres. In the six-feature scenario using conventional KNN, a relatively high level of cross-classification errors was still observed, particularly between dangdut klasik and dangdut rock, as well as between dangdut rock and dangdut koplo. However, after applying optimization using GA, the confusion matrix showed an increase in the number of correct predictions across all classes, indicated by the dominance of diagonal values. The most significant improvement occurred in the dangdut rock and dangdut koplo sub-genres, suggesting that the six spectral features are better able to capture differences in energy characteristics, rhythmic patterns, and musical dynamics when combined with optimal parameter selection.

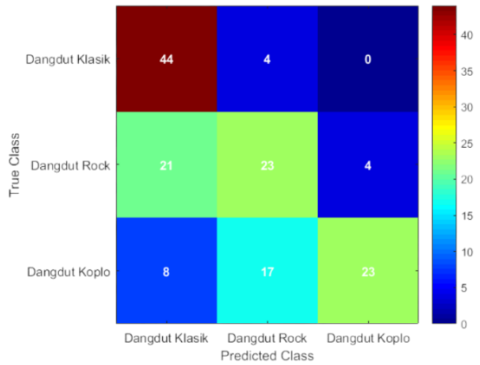

Figure 2. Confusion Matrix of K-NN with Six Spectral.

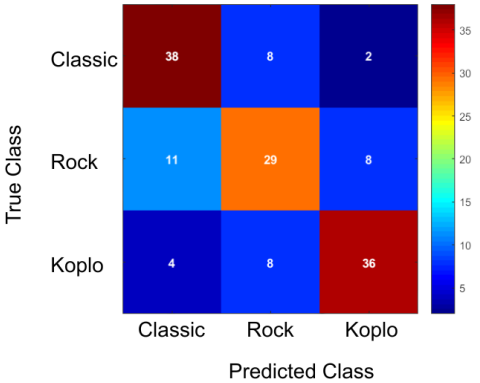

Figure 3. Confusion Matrix of K-NN GA with Six Spectral.

In the five spectral feature scenario, the confusion matrix of the conventional KNN showed a sharp increase in cross-classification errors. The dangdut rock sub-genre was frequently misclassified as dangdut klasik, while dangdut koplo also experienced an increase in misclassification into the dangdut rock class. Although the application of GA with five features was able to improve the prediction distribution and reduce some of these errors, the level of confusion among classes remained higher than in the six-feature scenario. This indicates that parameter optimization alone is not sufficient to fully compensate for the loss of discriminative information resulting from the reduction in the number of features.

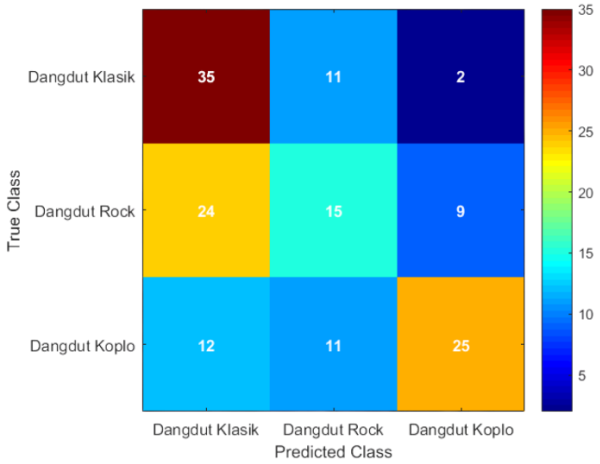

Figure 4. Confusion Matrix of K-NN with Five Spectral.

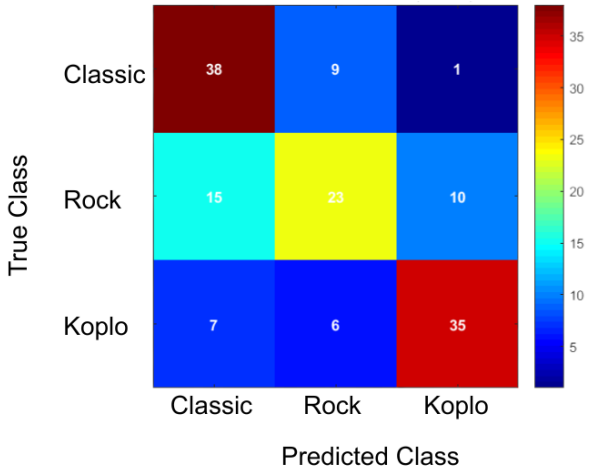

Figure 5. Confusion Matrix of K-NN GA with Five Spectral.

Consistent error patterns across all scenarios indicate that the highest level of classification confusion occurs between the dangdut klasik and dangdut koplo sub-genres. This can be explained by the overlap in their musical characteristics, particularly in terms of basic rhythmic patterns, similar tempos, and overlapping distributions of frequency energy. In the context of complex music signals, low-level spectral features are often insufficient to capture subtle differences between closely related classes, resulting in less distinct class boundaries when the feature representation is incomplete. These findings are consistent with contemporary studies in Music Information Retrieval, which show that the integrated use of multiple spectral features can enhance a model's ability to distinguish overlapping genres, as each feature captures different aspects of the audio signal that are important for accurate music classification. Conversely, relying on a limited number of spectral features tends to increase inter-class confusion among genres or sub-genres with similar spectral or rhythmic characteristics (Li et al., 2025).

In the classification experiments using the Support Vector Machine (SVM) method, the six spectral feature scheme achieved an accuracy of 54.86%, while the five spectral feature scheme obtained an accuracy of 54.17%. Although the difference in accuracy between the two schemes is not statistically significant, the six spectral feature scheme demonstrates slightly better performance than the five spectral feature scheme. This finding further confirms that the spectral attributes used in this study, despite having relatively low values and being close to zero, still contribute to the overall performance of the classification system. Therefore, the inclusion of additional spectral features remains beneficial in enhancing the model's ability to discriminate between dangdut music sub-genres.

Overall, the results of this study confirm that reducing the number of spectral features without a comprehensive analysis of their individual contributions can negatively affect classification performance. Features with small statistical values or low variability, although often assumed to be less informative, may still contain discriminative information that is necessary for separating acoustic similar classes. The removal of such features can lead to the loss of important cues related to musical nuances, particularly in complex and highly correlated audio datasets. These findings indicate that the effectiveness of a classification model depends not only on algorithmic optimization, but also on the completeness and adequacy of the selected spectral features in representing the underlying characteristics of the music signals.

5. CONCLUSION

This study concludes that the number of spectral features has a significant influence on the classification performance of dangdut music sub-genres. The use of six spectral features results in higher accuracy, precision, recall, and F1-score compared to the five-feature scenario and demonstrates more stable classification patterns based on confusion matrix analysis. Reducing the features to five leads to an increase in inter-class misclassification, particularly among sub-genres with similar musical characteristics, indicating the loss of important information even when the removed feature has a small numerical value. In addition, KNN optimization using a Genetic Algorithm improves classification performance; however, it does not fully replace the role of informative features, confirming that the selection of an appropriate number of features remains a key factor in dangdut music classification.

6. ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Institut Teknologi dan Bisnis STIKOM Bali for the academic support and facilities provided during the completion of this research.

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