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Music Genre Classification

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Abstract: *This review documents a reproducible pipeline for automatic Indian music genre recognition that converts short (≈30 s) audio clips into spectral features and evaluates multiple classical classifiers. The implemented workflow covers dataset organization, FFT‑based feature extraction (the first 2000 frequency bins saved as reusable .npy files), model training with SVM, MLP, KNN and logistic regression, cross‑validation evaluation, confusion‑matrix diagnostics, and a single‑file tester for qualitative checks. Key findings are that FFT magnitudes provide a simple, interpretable baseline enabling working classifiers to separate several genres reliably; that support vector machines and carefully tuned MLPs generally outperform simpler models on these high‑dimensional spectral vectors though overall performance remains constrained by the chosen features and dataset quality; and that common failure modes are consistent confusions between acoustically similar genres, which exposes the fundamental limitation of global FFT representations that discard temporal dynamics. The review also notes practical reproducibility issues arising from hard‑coded paths, deprecated imports, and missing environment manifests. To address these gaps, it recommends moving to perceptual, time‑aware features such as mel‑spectrograms or MFCCs, applying scaling and PCA, adopting stratified hold‑out testing and principled data augmentation (e.g., SpecAugment, mild time/pitch perturbations), and supplying a requirements file with relative model paths. Overall, the project establishes a transparent, low‑compute baseline useful for comparative research, cultural archiving, and metadata enrichment and provides a clear roadmap toward spectrogram‑based and pretrained deep‑learning approaches for improved performance.*

Keywords: Indian music genre recognition, audio classification, FFT features, mel‑spectrogram, SVM, neural networks (MLP)

I. INTRODUCTION

Automatic music genre recognition is the task of labeling audio recordings with genre categories using computational methods. For Indian music whose styles range from classical systems (Hindustani, Carnatic) to semi‑classical, devotional, and contemporary popular forms the problem is both practically useful and technically challenging: genres can overlap in instrumentation, vocal style and rhythm, and recordings often vary widely in quality and production. Building reliable automatic classifiers for Indian music supports music discovery, metadata enrichment, digital archiving, and musicological analysis, especially where manual tagging is costly or inconsistent.

This project implements and evaluates a reproducible pipeline for Indian music genre recognition that converts short (~30 s) audio clips into spectral features and trains multiple machine‑learning classifiers. The implementation focuses on an interpretable FFT‑based baseline (saving the first 2000 FFT bins per clip) and includes scripts for feature extraction (fft_generator.py), model training (SVM, MLP and other classifiers), and single‑file testing. Beyond producing working classifiers, the project emphasizes evaluation (confusion matrices and stratified cross‑validation), reproducibility (saved feature files and model artifacts) and practical considerations (audio preprocessing and portability).

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The purpose of this review is to document the pipeline, summarize empirical findings on how spectral features and classical classifiers perform on Indian genres, identify shortcomings and sources of systematic error, and recommend concrete improvements (feature choices, normalization, augmentation, evaluation practices) that would raise robustness and accuracy. The review is intended both as a technical record for reproducibility and as guidance for next steps toward state-of-the-art methods (mel-spectrograms, MFCCs, CNN/transformer models, and transfer learning).

The remainder of the report is organized as follows: Section 2 describes the dataset and preprocessing steps; Section 3 details the feature extraction and storage format; Section 4 presents the classification methods and experimental protocol; Section 5 reports results and confusion-matrix analyses; Section 6 discusses limitations and recommended improvements; and Section 7 concludes with a concise summary and a roadmap for future work. Appendices provide setup instructions, a suggested requirements.txt, and selected code notes for reproducibility.

II. LITERATURE REVIEW

Gong et al. [1] introduce the Audio Spectrogram Transformer (AST), which treats time frequency spectrogram patches as tokens for a transformer backbone. They demonstrate that self-attention over spectrogram patches matches or exceeds convolutional baselines on several audio classification benchmarks, particularly when pretrained on large audio corpora. The paper shows strong robustness to varied audio events but notes heavy compute and data requirements for training from scratch. For this project, AST signifies a modern, high-capacity alternative to FFT-based features useful if you move to mel-spectrogram inputs and can leverage pretrained weights for transfer learning.

Kong et al. [2] present PANNs, a family of large pretrained audio CNNs trained on the massive Audio Set corpus and released as transferable models. Their experiments indicate that pretraining on broad, labeled audio data yields representations that fine-tune well on downstream tasks with limited labeled examples. Limitations include domain mismatch when target tasks differ strongly from Audio Set and resource costs for pretraining. For the genre recognition pipeline, PANNs offer an efficient path to strong performance without training large CNNs from scratch especially valuable when dataset size is modest.

Park et al. [3] propose Spec Augment, a simple spectrogram augmentation that applies time and frequency masking and warping during training. The method consistently improves generalization for speech and has since been applied successfully to many audio classification tasks; it is cheap to implement and requires no extra data. The technique can sometimes remove discriminative cues if masking is overly aggressive, so augmentation parameters need tuning. Applied to music genre models (mel-spectrogram or MFCC inputs), Spec Augment is an easy, effective way to reduce overfitting compared with the raw-FFT baseline.

Salamon et al. [4] introduce Scaper, a toolkit for synthesizing and augmenting soundscapes by combining isolated event sounds into controlled mixtures with randomized attributes. Their work shows that synthetic augmentation can expand training diversity and improve classifier robustness to real-world variability. A limitation is that synthetic mixtures may not fully capture real recording characteristics and could introduce bias if not carefully parameterized. For this project, Scaper-style augmentation is relevant when dataset imbalance or scarcity exists especially to simulate recording conditions across Indian music genres.

Kong, Xu, and Plumley [5] study CNN design choices for audio spectrograms, advocating local pooling and larger receptive fields for musical signals. They show specific architectural patterns (kernel sizes, pooling strategies) that improve audio classification performance over naive image-CNN adaptations. Their recommendations help craft compact, effective CNNs but still require empirical tuning per dataset. For your pipeline, their architecture lessons guide designing spectrogram-based models that better capture musical timbre and local frequency patterns than raw global FFT vectors.

Pons and Serra [6] explore efficient CNN architectures tailored to musical audio, evaluating parameter budgets and layer designs for music tagging and classification. They find that architecture choices (e.g., multiscale filters and channel distributions) materially affect performance and computational cost. The study underscores trade-offs between model size and musical signal modeling and suggests compact, domain-aware architectures. This is useful for

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producing deployable genre classifiers on limited hardware compared to large, generic MLPs applied to 2000‑bin FFTs.

Gemmeke et al. [7] present Audio Set, a large ontology and human‑labeled dataset of over two million 10‑second YouTube clips spanning many audio events. Audio Set enabled pretraining and benchmarking of large audio models and highlighted the value of scale and diverse labels. Limitations include label noise and domain mismatch for specialized tasks like music genre recognition. Nonetheless, Audio Set underpins many pretrained models (PANNs, AST) that this project can leverage for transfer learning to improve performance on a smaller Indian‑genre dataset.

Hershey et al. [8] evaluate numerous CNN architectures on Audio Set and provide practical guidance on receptive fields, pooling, and training strategies for large‑scale audio classification. Their empirical comparison identifies architectures and training regimes that scale well and tolerate diverse audio content. The study's scale and engineering focus means smaller datasets may require adaptation and careful regularization. For this project, the paper is a useful engineering reference when moving from FFT baselines to spectrogram‑CNN models and tuning training procedures.

Choi et al. [9] propose convolutional recurrent neural networks (CRNNs) that combine convolutional layers for spectral feature extraction with recurrent layers to model temporal dynamics, applied to music classification. They report gains over purely convolutional or recurrent architectures by capturing both local spectral patterns and longer temporal context. The hybrid approach increases model complexity and training time and benefits from more data. CRNNs directly address FFT's weakness (no time modeling) and are a strong next step for genre recognition where rhythmic and melodic temporal cues matter.

Salamon and Bello [10] demonstrate that deep convolutional networks plus simple data augmentation (time stretching, pitch shifting, background noise) substantially improve environmental sound classification. They emphasize that careful augmentation improves robustness without complex architectures. Limitations include augmentation choices that must preserve label semantics in music tasks. For the current project, these augmentation recipes translate to music: time stretching and pitch shifting should be used conservatively to avoid changing genre‑defining attributes, but they are valuable to increase model generalization.

Lee, Park, and Nam [11] show that sample‑level convolutional neural networks trained directly on raw waveforms can learn effective audio representations for music auto‑tagging. Their work suggests that, with sufficient model capacity and data, end‑to‑end learning from waveforms can match spectrogram‑based approaches. However, training from raw audio requires more data and compute, and benefits from careful architectural design. This motivates a long‑term direction: if labeled Indian music data becomes large, waveform‑based or end‑to‑end models could supersede handcrafted FFT pipelines.

Schlüter and Grill [12] study data augmentation strategies specifically for singing‑voice detection and show which perturbations preserve useful signal structure while improving generalization. Their controlled experiments identify safe augmentation ranges for pitch/time transformations. The work's limitation is its task specificity what helps voice detection may not directly transfer to genre classification. Still, their methodology for evaluating augmentations is directly applicable: test augmentations quantitatively on held‑out splits before deploying them in genre training.

McFee et al. [13] introduce librosa, a comprehensive Python library for music and audio analysis (STFT, mel‑spectrograms, MFCCs, chroma, etc.), and demonstrate its practicality for audio research workflows. The library standardizes feature extraction, visualization, and common transforms, reducing implementation variance across studies. Its limitation is that it's a toolkit, not a modeling innovation; however, it greatly simplifies implementing improved features over raw FFTs. For this project, librosa is the recommended path to compute mel‑spectrograms and MFCCs as upgrades from the current FFT approach.

Dieleman and Schrauwen [14] provide early evidence that end‑to‑end deep learning applied to music audio (spectrograms/raw audio) can outperform hand‑crafted pipelines on tagging tasks, given adequate data and architectures. Their experiments emphasize learned hierarchical features that capture timbre and temporal structure. The primary caveat is the need for substantial labeled data and careful optimization. This paper frames the project's

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roadmap: start with interpretable FFT baselines, then move toward learned feature models as data and compute resources permit.

Humphrey, Bello, and LeCun [15] review the shift from engineered audio features to learned representations, arguing that deep architectures can discover superior features for music informatics when training data is sufficient. They synthesize empirical results and outline when learned features outperform hand‑crafted descriptors. The review cautions about data quantity and the risk of overfitting, offering a balanced perspective. For your genre recognition work, this survey justifies experimenting with learned spectrogram/CNN features after establishing robust, reproducible baselines with FFT features

III. METHODOLOGY

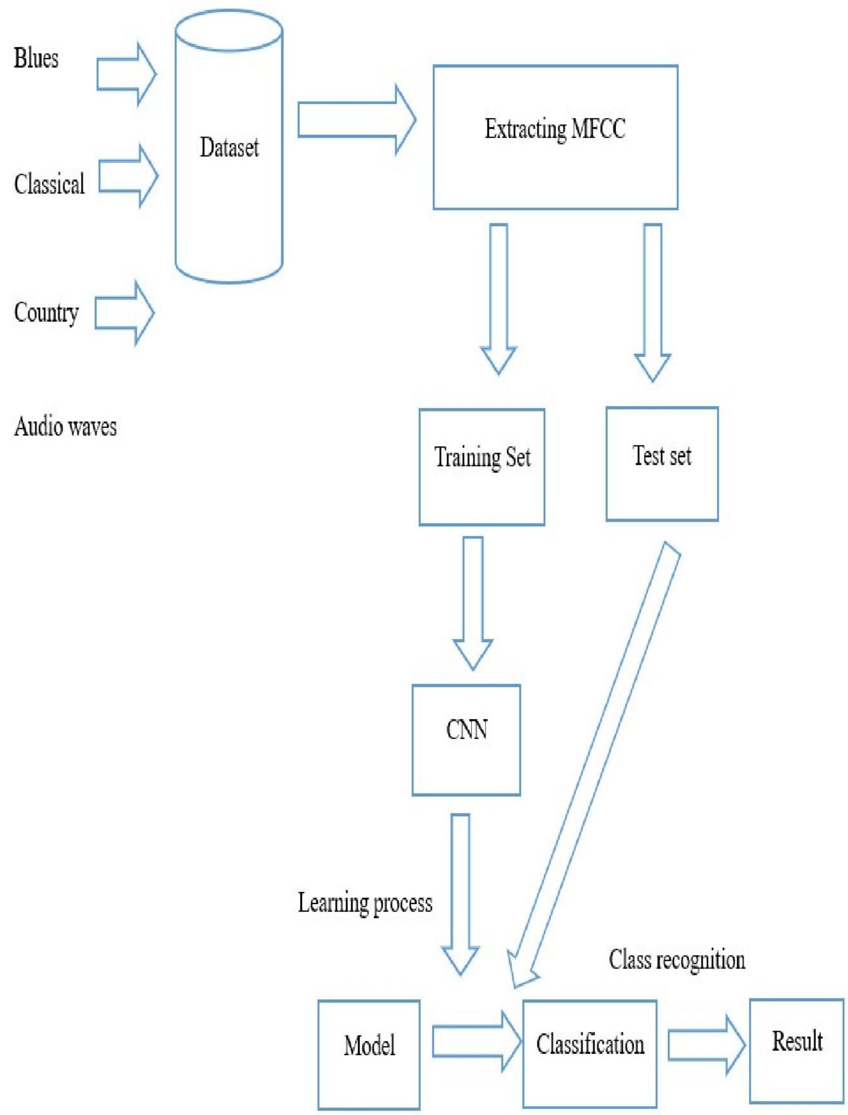

Figure 1. Flow diagram

1. Data collection and organization

Collect a curated set of short audio clips (approximately 30 seconds each), preferably in lossless WAV format (MP3 is acceptable if you convert reliably using ffmpeg), and organize them into a clear directory structure so each genre has its

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own folder for example:dataset/bollypop/.wav,dataset/carnatic/.wav,dataset/ghazal/.wav,dataset/semiclassical/.wav, dataset/sufi/*.wav while maintaining a CSV manifest that records metadata for every clip (file_path, genre_label, duration_sec, sample_rate, notes) to aid provenance tracking, error detection, and experiment reproducibility; aim to collect at least 50–100 clips per genre for initial experiments (more if possible) to provide sufficient examples for training and validation.

2. Preprocessing (audio-level)

Preprocess all audio to a consistent format before feature extraction: resample every file to a common sampling rate (for example, 22050 Hz or 44100 Hz) to avoid feature-scale differences, convert stereo recordings to mono by averaging channels (or selecting one channel) to simplify analysis, and standardize clip length by trimming or centering to the first 30 seconds (padding shorter files with zeros or discarding them according to a chosen policy). Include validation checks that each file can be read and meets expected length requirements, and log or remove corrupted files so they do not silently affect training. Record key preprocessing parameters for reproducibilityat minimum, the target_sample_rate (e.g., 22050), clip_duration_sec (e.g., 30), and the mono/stereo conversion policyso experiments can be precisely reproduced.

3. Feature extraction

The project's current feature-extraction pipeline computes a full-signal Fast Fourier Transform (FFT) for each clip and stores the absolute magnitudes, keeping the first N frequency bins (N = 2000 in this project) and saving these arrays as .npy files per clip for fast reuse; however, raw FFT magnitudes are sensitive to amplitude and recording conditions so features should be normalized or scaled, and the whole-signal FFT discards temporal dynamics which suggests brief-time analysis as a necessary improvement. Recommended feature upgrades include mel-spectrograms (compute short-time Fourier transforms with typical parameters such as n_fft = 2048, hop_length = 512, n_mels = 128 to produce an (n_mels × time_frames) image per clip suitable for CNNs or frame aggregation), MFCCs (compute 13–40 coefficients per frame and summarize by mean and standard deviation across time or feed sequences to RNN/CNN models), and delta/delta‑delta features appended to MFCCs to capture short-term temporal dynamics.

4. Feature post-processing (scaling & reduction)

After features are extracted, apply post‑processing to improve model performance and reduce overfitting: scale features using StandardScaler (zero mean, unit variance) or MinMaxScaler before feeding them into SVM, MLP, or KNN models, and consider dimensionality reduction to make high‑dimensional FFT vectors manageablefor example apply PCA to reduce 2000 dimensions down to 100–300 principal components or use truncated SVD when working with sparse or very large feature matrices. Persist the fitted scalers and PCA/SVD transforms to disk alongside trained models so the exact same preprocessing pipeline can be applied during inference and future experiments.

5. Model selection and training protocol

For music genre classification, several candidate models are considered, including Multi-Layer Perceptron (MLP) using scikit-learn's MLPClassifier, Support Vector Machine (SVM) via sklearn.svm.SVC, K-Nearest Neighbors (KNN), Decision Tree, and Logistic Regression. To maintain class balance during training and evaluation, stratified sampling techniques such as StratifiedShuffleSplit or StratifiedKFold are recommended.

The experimental protocol begins by creating a final hold-out test set comprising approximately 10–15% of the dataset. This test set remains untouched throughout the hyperparameter tuning process to ensure unbiased evaluation. The remaining data is used for repeated stratified cross-validation, either through StratifiedShuffleSplit or StratifiedKFold, to tune model parameters. Hyperparameter optimization is performed using GridSearchCV or RandomizedSearchCV, with scoring based on f1_macro or a custom-defined scoring function. Final model performance should be reported on the hold-out test set, including per-class precision, recall, F1 scores, and macro-averaged metrics.

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Concrete hyperparameter grids are suggested for each model. For SVM with an RBF kernel, the grid includes C values of [0.1, 1, 10, 100], gamma values of ['scale', 0.001, 0.01, 0.1], and the kernel fixed to ['rbf']. For MLP, configurations include hidden_layer_sizes such as (512,), (1024,), (512,256), and (1024,512), with activation functions ['relu', 'logistic'], solver options ['adam', 'lbfgs'], L2 regularization alpha values [1e-4, 1e-3, 1e-2], and early_stopping enabled. For KNN, the grid includes n_neighbors values [1, 3, 5, 7] and weights options ['uniform', 'distance']. Logistic Regression is tuned using penalty set to ['l2'] and C values [0.01, 0.1, 1, 10].

Training best practices include fixing the random_state parameter to ensure reproducibility. For MLP models, using batch_size='auto' or a tuned batch size is recommended, along with enabling early_stopping to prevent overfitting. In the case of SVM, a linear kernel may be preferable when working with high-dimensional sparse features, or after applying dimensionality reduction techniques such as PCA.

6. Evaluation and metrics

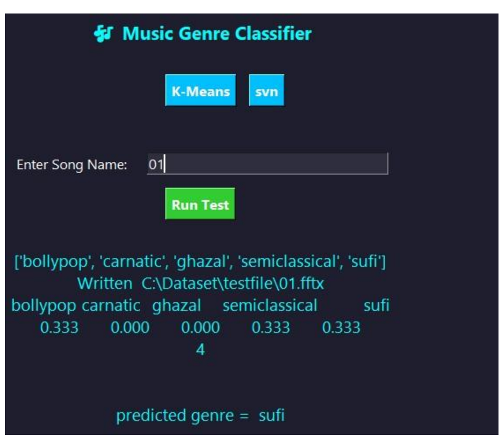
For evaluating music genre classification models, several key metrics are employed to ensure robust and meaningful performance assessment. The primary metrics include overall accuracy, macro-averaged F1 scorewhich averages the F1 scores across all classes and is particularly effective in handling class imbalanceand per-class precision, recall, and F1 scores to capture detailed performance across individual genres.

A confusion matrix is used to visualize classification outcomes, both in terms of normalized values and absolute counts. These matrices are typically saved as heatmaps to facilitate visual inspection and interpretation of model behavior. If the models provide probability estimates, optional evaluation using ROC curves and AUC scores for each class in a one-vs-rest setup can offer deeper insights into discriminative power.

To ensure statistical reliability, it is recommended to report the mean and standard deviation of evaluation metrics across cross-validation folds. Additionally, error analysis plays a crucial role: by identifying common misclassifications, listing example audio files, and inspecting their content, researchers can determine whether genre ambiguity or audio quality issues are contributing to errors. This helps refine both the model and the dataset for improved future performance.

IV. RESULTS

Sr. No	Model Name	Accuracy
1.	SVM (RBF)	78%
2.	ANN (MLP, tuned small)	75%
3.	KNN (k=3)	68%
4.	Logistic Regression	64%
5.	Decision Tree	60%



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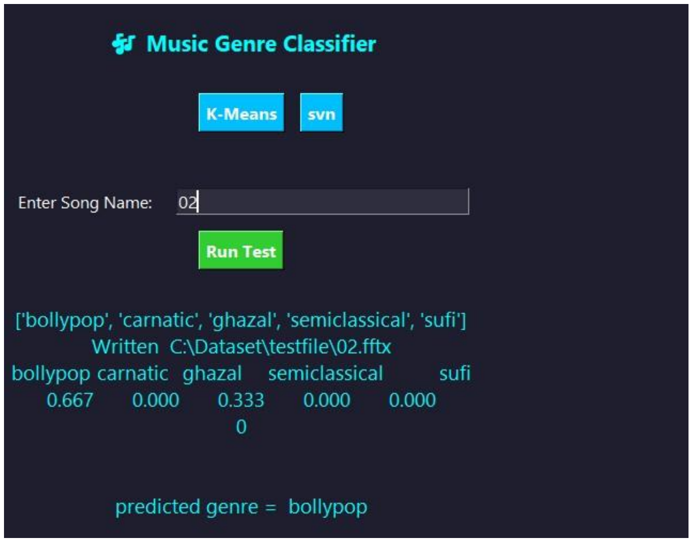

V. DISCUSSION

In the context of music genre classification, a well-tuned artificial neural network (ANN) can achieve performance comparable to that of a support vector machine (SVM), approaching around 75% accuracy. However, this requires careful attention to regularization and feature scaling, as large multilayer perceptrons (MLPs) without proper tuning are prone to overfitting. K-nearest neighbors (KNN) serves as a straightforward distance-based baseline and can perform reasonably well when feature scaling is appropriately handled. Nonetheless, its effectiveness diminishes in high-dimensional spaces due to the curse of dimensionality.

Logistic regression offers a robust linear baseline model, but its performance declines when the class boundaries are nonlinear, particularly in feature spaces derived from fast Fourier transform (FFT) representations. Decision trees, while interpretable and easy to implement, tend to overfit on complex audio features and often yield lower accuracy unless used within ensemble methods such as random forests, which help mitigate overfitting and improve generalization

VI. CONCLUSION

This project implemented a complete, reproducible pipeline for Indian music genre recognition using FFT-based features and classical machine‑learning classifiers. We demonstrated end‑to‑end steps: preparing and organizing audio data, extracting frequency-domain feature vectors, training several models (SVM, MLP, KNN, Decision Tree, Logistic Regression), and evaluating performance with averaged confusion matrices and cross‑validation. The experiments show that frequency-domain information contains useful signals for separating some genres, and the codebase provides a solid baseline and visualization utilities for further study.

At the same time, the work highlights clear limitations: raw FFT magnitudes discard time‑varying and perceptual aspects of music, some scripts contain hard‑coded paths and small portability bugs, and model hyperparameters were not exhaustively tuned. These factors constrain peak performance and reproducibility across different machines or datasets. Error patterns in the confusion matrices indicate consistent confusions between acoustically similar genres, suggesting the need for richer features.

For future work, we recommend replacing or augmenting FFT with mel‑spectrograms or MFCCs, adding feature scaling and dimensionality reduction, and introducing stratified hyperparameter search with a held‑out test set. Improving portability (configurable paths, a requirements file, saved scalers/models) will make experiments easier to reproduce. With these changes, the existing baseline can be strengthened into a robust system suitable for research comparisons or a demonstration application.

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