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Advanced Machine Learning Techniques for Raga Classification

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Abstract

Indian classical music is one of the most ancient and purest form of music. Indian classical music is a highly intricate art form that is characterized by its use of ragas. Ragas are melodic frameworks that define the melodic structure, tonality, and mood of a composition. Ragas are the soul of Indian classical music. Raga identification is a crucial task in Indian classical music analysis and retrieval systems. In this paper, we proposed a novel approach for raga identification in Indian music using stack ensemble model. We ensemble five models based on the prediction accuracy of Indian ragas. CatBoost, XGBoost, Random Forest, LightGBM and Decision Tree. Our approach achieves state-of-the-art performance on the task of raga identification, outperforming existing methods by achieving accuracy of 94%. Our proposed work has the potential to improve the performance of Indian music retrieval systems. This will contribute to the understanding, preservation and refinement of this rich cultural heritage.

Keywords:*Raga, Raga classification, Audio Feature Extraction, Mel Frequency Cepstral Coefficient,CatBoost.*

1. Introduction

Traditional Indian society has always been pivotal to music in its customs, celebrations and spirituality. The culture has always revolved around music production and other forms of entertainment. Therefore, there has always been an expert class of musicians who have continued to pass the generational heritage of the style and the tone of Indian music throughout the years in its original and modified forms both. With a population of about 1.42 billion people, Indian society is not just diverse in terms of cultural heritage but as well as concerning the type of music that they play. The music and songs in Indian traditional society are often classified based on the raga which they do belong to. At the heart of this musical tradition lies the concept of ragas — melodic frameworks that serve as the foundation for improvisation, composition, and emotional expression. Ragas are not merely scales or melodies; they embody a complex interplay of musical notes, intervals, and emotional nuances. Raga is an important aspect of a song and it determines specifically how and when a song is played. After noting the importance of the raga and its great significance in Indian society and even culture, it is also interesting to note that traditional Indian society has always embodied the concept of raga specialists. These experts have knowledge and experience to differentiate between these ragas and then eventually identify one from another based on the context of the song and the play patterns. These expert musicians have the onus to preserve the indigenous traditional knowledge of various forms of music in diverse societies. For many years, people believed that there could never be a system so efficient that it can eventually classify the songs into an appropriate raga based solely on studying the bits and other related patterns in the song. Identifying ragas accurately is a crucial task for musicians, musicologists, and enthusiasts, as it forms the cornerstone of understanding and preserving this cherished heritage. Traditionally, raga identification has been a manual and experiential endeavor, passed down through generations of musicians. However, in the digital age, the merging machine learning and musicology offers a transformative approach to this age-old practice. Over the recent years, however, a shift in favour of machine learning and artificial intelligence has suddenly ignited a new debate whether it is possible to achieve greater precision and accuracy in raga detection through leveraging cutting-edge technologies. This paper proceeds to discuss such possibility and shows how it is possible to use advanced computer sciencies in detecting the raga of a given creative piece through the use of machine learning efficiently.

In this introductory section, we will outline the overview and significance of how machine learning can revolutionize this field. We will also provide a brief roadmap of the paper, outlining the key areas and contributions that will be explored in subsequent sections. Section 2 reviews the literature related to raga identification using machine learning technologies. Section 3 explains the feature engineering and data preprocessing for the proposed model. Section 4 represents the proposed model for raga identification and section 5 shows the experimental results. Section 6 summarizes the conclusion of the paper.

2. Literature Review

It is pertinent to mention that this paper is not a first in the quest for accuracy and precision when it comes to the detection and classification of the raga dataset. Perhaps, the most promising records of an attempt to classify the raga from the songs was an experiment by Shetty and Arhary [1] in which the researchers managed to achieve a training accuracy of around 94% and a test accuracy of 75% using Artificial Neural Network and a meagre sample of 90 songs. The problem with such an approach was its small dataset.

In a similar experiment, Dandawate et al. [2] tried data mining and information extraction approaches in an attempt to achieve a significant increase in accuracy compared to their predecessors. In their approach, the researchers considered old-age approaches such as K-Nearest and Support Vector Machine in an attempt to answer the question of whether it is possible to use machine learning and related artificial intelligence approaches and automatically detect a raga from a music file. In their approach, the researchers considered different features of the audio file ranging from onset to energy levels, centroid, and even roll off to determine what makes a specific raga unique. After the training and the classification, the researchers concluded that the average training accuracy of the two models was 87% and 93% respectively and hence indicating no improvement in the training accuracy score when compared to the first experiment done over 6 years ago.

Bidkar et al. [3] proposed raga recognition methodology using pitch,mean and centroid MFCC variants.The model proposed was tested using ensemble KNN classification algorithms and ensemble bagged tree with 95.83% and 96.32% accuracy. Lele and Abhyankar [4] identified raga of Hindustani classical music using swar of raga.They used different methods like chromogram, spectrogram and Fourier transform on the database of santoor samples and some light music.

Joshi et al. [5] used KNN and SVM classifiers on the raga Yaman and Bhairavi dataset for classification and identification of raga. Dodia et al. [6] identified Indian raga using chromogram feature of audio files. KNN and SVM were used for identifying Bhimpalasi and Yaman raga achieved accuracy of 92% and 91% respectively. Sharma and Bali [7] worked with Hindustani raga identification on dataset of live performances of ragas. Their work showed accuracy of 93.38% with K-star algorithm. Anand [8] identified raga using convolutional neural network and attained accuracy of 96.7%. Kumar et al. [9] proposed raga identification and classification using non-linear SVM framework with n-gram distribution of notes and pitch-class profile. They captured temporal information of raga notes by calculating n-gram histogram. Sharma et al. [10] worked with soft computing for raga identification of Hindustani music. Some of ragas features like dirga swara, vadi swara, distance, samay of raga for identifying raga. John et al. [11] classified Indian classical musical ragas using deep learning. They used pitch contour of ragas as a key feature to improve the accuracy. Madhusudhan and Chowdhary [12] classified ragas using long short term memory based on recurrent neural network. They achieved an accuracy of 88.1% on comp music carnatic dataset. Kavitha et al. [13] used deep learning approach for classifying janya raga. They used Mel-Frequency Cepstral Coefficients (MFCCs) of audio samples and attained accuracy of 82%. Singha et al. [14] proposed convolutional neural network for raga classification. They used spectrograms of audio note for identifying raga's note. Shah et al. [15] proposed an approach based on deep learning and signal processing. They attained accuracy of 98.98% on compMusic dataset. Dighe et al. [16] developed a method using random forest classifier based on swara histograms. They achieved accuracy of 94% through the experiment. Dodia et al. [17] identified raga using chromogram feature. They attained 91% acuuracy with SVM classifier and 92% accuracy with K-NN classifier. It is also very important to note that the subject area of raga classification especially concerning Indian music has been very contentious over the past couple of years and hence many researchers have come forward to propose different solutions that have significantly led to improvements when it comes to precision and accuracy. It is important to acknowledge that the works of other researchers that have led to increased interest and the need to push the limit. For that, this research study continues on the path to improving accuracy and precision by building on the studies before it.

Table 1: Work done by various authors for classifying ragas using machine learning

Year	Authors	Dataset	Classifier	Accuracy
2009	Shetty and Arhary [1]	Small dataset (90 songs)	Artificial Neural Network	75%
2015	Dandawate et al. [2]	Data mining Bhairav, Bhairavi, Todi and Yaman	K-Nearest and Support Vector Machine	87% and 93%
2021	Bidkar et al. [3]	12 ragas played by 4 musical instruments	Ensemble KNN, Ensemble bagged tree	95.83% and 96.32%
2021	Joshi et al. [5]	Yaman and Bhairavi raga	KNN and SVM	94% and95%
2020	Dodia et al. [6]	Bhimpalasi and Yaman raga	KNN and SVM	92% and 91%
2015	Sharma and Bali [7]	Live performance dataset	K-star algorithm	93.38%
2019	Anand [8]	Carnatic music consisting of five and eleven ragas	Convolutional Neural Network (CNN)	96.7%
2014	Kumar et al. [9]	60 tunes, 5 artists, 4 ragas, 2 instruments	pitch- class profile and n-gram distribution of notes. With n-gram distribution	83%
2020	Dighe et al. [16]	8 Ragas	Random forest classifier	94%
2019	Lele and Abhyankar [18]	Santoor samples and few light music	MIR Toolbox	70%-80%

3. Feature Engineering And Data Preprocessing

Within the scope of this experiment, our foremost objective is to identify the most predictive features within the songs, assemble them, and harness their power for raga prediction. The one and most important tool in the entire process was Librosa. Librosa is used for primary data extraction and feature engineering package.Librosa is a suitable choice for both, the modeling and the data preparation, due to its versatility and the ability to scale well.

For this experiment, the most important part of the investigation was to find the most predictive features of the song. The features selected include chromagramo power spectrogram (chroma_strf,), spectral centroid(spec_cent), spectral bandwidth (spec_bw), rolloff, zero crossing rate,(zcr), melspectogram and root mean square of the spectrogram (rmse). These features are selected for our wor as they define the tonal nuances and distinct ragas present in the music. Consequently, our machine learning models' training and the resulting mappings are exclusively built upon these carefully curated features.

3.1 Evaluating Feature Importance

A pivotal aspect of the feature engineering process centers around the assessment of each feature's relative importance, particularly in terms of their predictive ability. Features that exhibit weak or negligible correlations with the target variable hold minimal sway in shaping the final model's design and development. In light of this, our study places a strong emphasis on a thorough investigation into the relative importance of these features within the dataset and their contributions to the overall model-building process.

It is paramount to acknowledge that different features boast varying degrees of predictive potential. As illustrated in Figure 1, no feature registers an absolute lack of predictive value. Therefore, there is presently no compelling reason to eliminate any feature based solely on its predictive capabilities.

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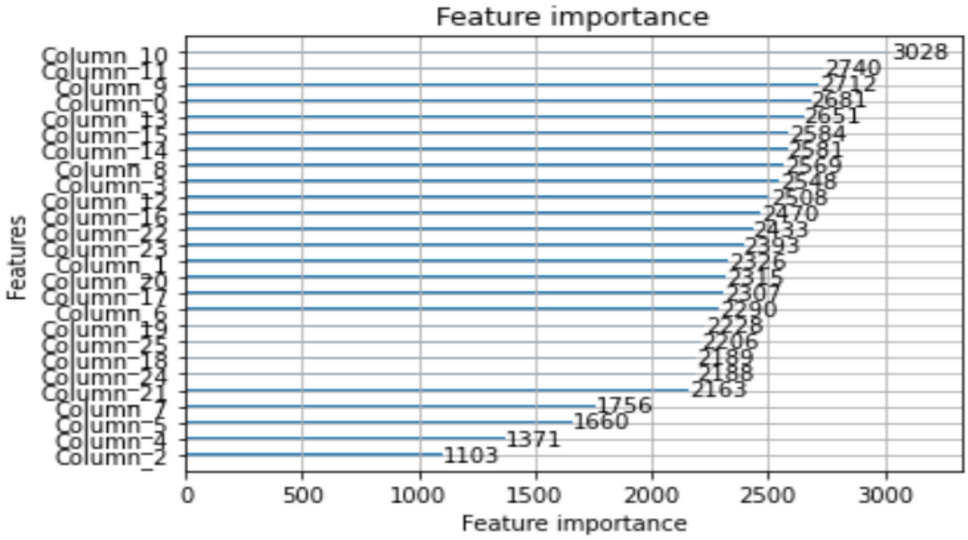

Figure 1: Feature importance of dataset

4. The Proposed Model

The core of this research study is the idea of the wisdom of the stack ensemble of the models when it comes to predictions. Based on the features selected above, there were many models selected and tested for prediction including Logistic Regression, Random Forests, Decision Trees, LightGBM, CatBoost, XGBoost, Naïve Bayes, Support Vector Machine, and even Nearest Neighbor Algorithm. After all these models were fitted individually and their accuracies determined, CatBoost was the best performing model followed by the XGBoost, Random Forest and LightGBM respectively. The decision Tree also had decisively accurate results. While the models such as the Support Vector machine had low decisively accurate result in traditional research in this area. Hence, only 5 models above were selected for stack ensembling.

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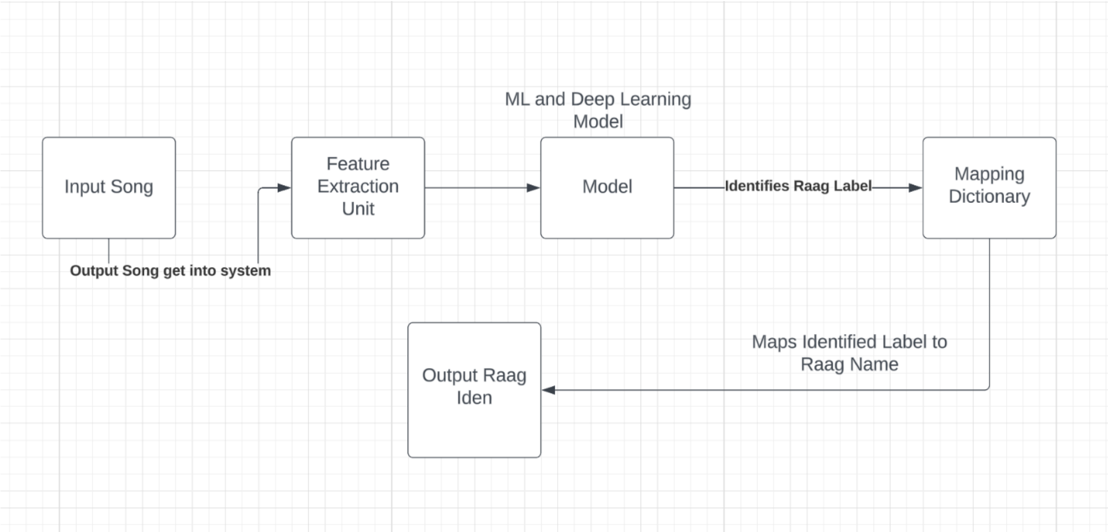

Figure 2: Proposed Model for Raga Classification

The entire machine learning system above is a highly complex system that resulted from work and prioritization on performance and accuracy. Steps included in the proposed model are:

I. User Input: Users upload content, typically songs, for which they want to identify the raga.

II. Feature Extraction: A complex feature extraction system processes the uploaded content to extract relevant features. These features are extracted from the audio data and are used to represent different aspects of the music, which are important for raga identification. These features are saved for later use.

III. Machine Learning Model: The extracted features are used as input to a machine learning model. This model has been trained to take these features and predict the raga associated with the input music. The training process likely involved a dataset of songs with known raga labels, and the model learned to map the extracted features to these labels. It's mentioned that the labels are converted to numerical values for training, which is a common practice in machine learning.

IV. Mapping Dictionary: After the machine learning model makes a prediction, the output is in the form of numerical labels. A mapping dictionary is used to convert these numerical labels back into human-readable raga names. This step is essential for presenting the results to users in a user-friendly way.

V. User Interface: The system likely includes a user interface where users can upload music samples and receive the associated raga predictions in a convenient and understandable format.

VI. Hyperparameter Tuning: Before arriving at the final ensemble model, hyperparameter tuning and parameter optimization were performed. This involved techniques like GridsearchCV to search for the best set of hyperparameters for the machine learning models. Tuning hyperparameters is crucial for achieving the best model performance.

VII. Ensemble Model: The final model is a stacked ensemble, which means it is a combination of multiple machine learning models. Stacked ensembles often outperform individual models by leveraging the strengths of each base model. The hyperparameters of these models have been optimized to ensure the best possible performance.

Overall, this system appears to be a well-designed pipeline for raga identification in music, with a focus on accuracy and performance. It takes user input, extracts relevant features, uses a machine learning model for prediction, converts the results into a user-friendly format, and incorporates hyperparameter tuning to optimize model performance.

5. Experiment and Results

In this section, we delve into the varying predictive power of different features within the context of the raga dataset.

5.1 Feature Importance Visualization

Understanding the predictive power of features is crucial for our analysis. Figure 3 illustrates the average importance of features during model training, shedding light on the differential capabilities of these features.

```
mfcc0          0.469654
spec_bw        0.457474
spec_cent      0.443226
mfcc1          0.439163
rolloff        0.431935
rmse           0.427196
mfcc4          0.424864
mfcc2          0.416729
zcr            0.414261
mfcc7          0.413180
mfcc6          0.401216
mfcc3          0.400495
mfcc12         0.389147
mfcc17         0.387121
mfcc8          0.384854
mfcc10         0.384349
mfcc5          0.381350
mfcc15         0.380746
mfcc11         0.378887
mfcc19         0.377460
mfcc18         0.375290
chroma_stft    0.373438
mfcc16         0.371836
mfcc9          0.370377
mfcc14         0.366787
mfcc13         0.360225
dtype: float64
```

Fig. 3: Importance of various features

We observe notable differences in the predictive power of features. For instance, features like "mfcc" carry more weight in terms of accuracy than features such as "mfcc13."As seen above, the average importance of features in the model training is different. So, there are ways to determine the type of raga that are more accurate than the others depending on the features under consideration. Here follows a visualization of the feature's importance using a pie chart:

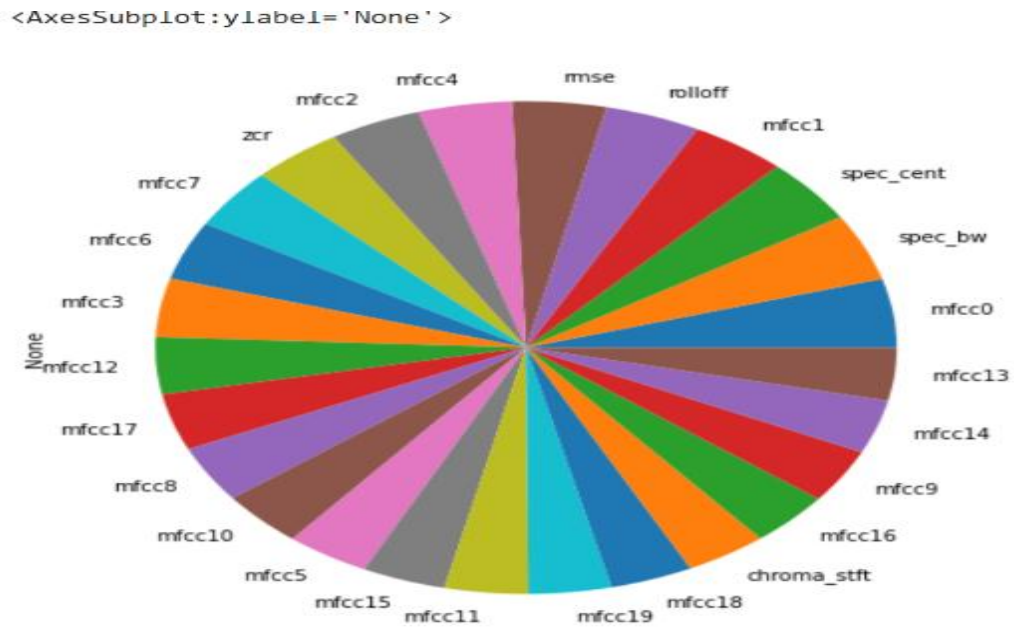

Figure 4: Features used for raga identificaton

From above, we can see that the features such as mfcc have more weight in terms of predictive power than other features like mfcc13.

5.2 Training Progress

To gain insight into the model's training progress, we examine the error rate throughout the training process. Figure 5 demonstrate the error rate for the training data.The error rate initiates at a relatively high level at the onset of the analysis. However, as the training process unfolds, there is a marked reduction in the error rate. Eventually, as the training nears completion, the error approaches zero.

This systematic reduction in error attests to the effectiveness of our approach and the learning capacity of our model.

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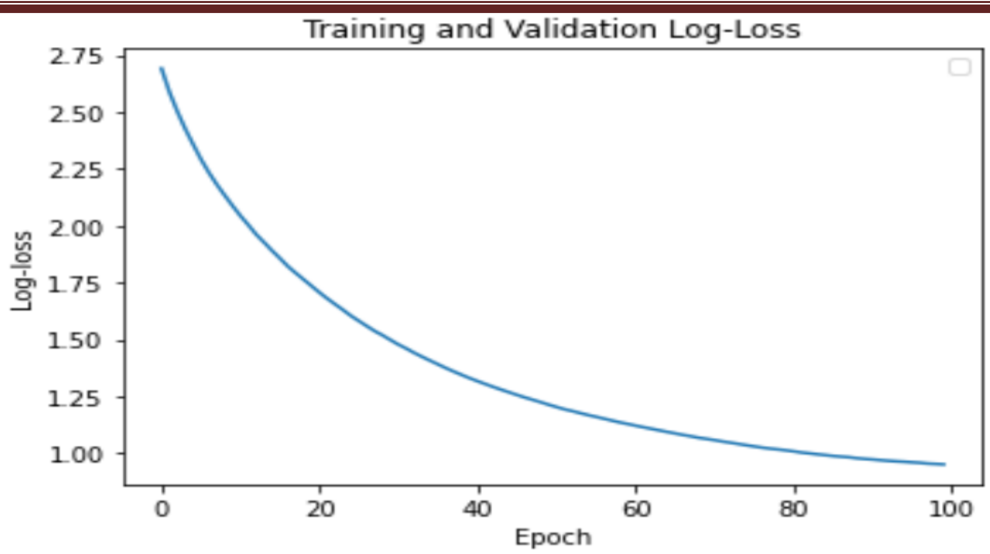

Figure 5: Error for training data

6. Conclusion

In nutshell, raga identification is an important area of research in the field of Indian classical music. With the growing availability of digital music recordings and the development of computational methods for music analysis, there is a need for accurate and efficient algorithms for raga identification. In this paper, we have reviewed some of the existing approaches for raga identification and presented our own method based on a combination of melodic and rhythmic features. Our results indicate that this approach can achieve high accuracy in identifying ragas from audio recordings. Our work has focused on developing more sophisticated algorithms that can handle various challenges and contribute to the ongoing efforts to preserve and promote the rich heritage of Indian classical music. We proposed an identification method that employs MFCC variants as features. Our study worked with stack ensemble of the models. The proposed model was tested, trained and achieved over 94% testing accuracy. Hence, this experiment perhaps is the most successful of all others that have been conducted especially with regards to raga detection from any piece of music.

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