Raga Classification and Recommendation for Healing Diseases using Deep Learning

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***Abstract*—Indian classical music, and specifically ragas, have been used for centuries with respect to healing. This research presents an artificial intelligence-based method for the automatic classification of Indian classical ragas along with mapping each of the classified raga to potential health benefits, with the aid of state-of-the-art deep learning methods. The framework uses Mel-Frequency Cepstral Coefficients (MFCCs) for feature extraction and incorporates data augmentation methods to improve the robustness of the model. A few machine learning models, namely Random Forest, K-Nearest Neighbors (KNN), and Convolutional Neural Networks (CNN), are used, with the outputs of all combined in a Voting Classifier. The top-performing model, a custom CNN, performs with an accuracy of 98.64%. Even though this work investigates the overlap of AI and music therapy, the claims of therapeutic uses rest on conventional believes and not scientific proofs. Major constraints include the lack of deployment in real-world situations and clinical proof. Future research will involve testing the system with real-users, scientifically proving therapeutic claims using clinical studies and investigating other deep learning architectures for better performance.**

Keywords – Machine Learning, Deep Learning, Mel-frequency Cepstral Coefficients (MFCCs), Random Forest Classifier, K-Nearest Neighbour (KNN), Convolutional Neural Network (CNN), Voting Classifier

I. INTRODUCTION

Interest in the point of convergence between music and health has been on the rise. A special interest has been awakened, especially in Indian classical music, where a belief exists that there are specific ragas that may cause stimulation in the emotional and psychic effects of a range of medical conditions, towards developing a systematic framework for the automatic classification of Indian classical ragas by way of exploration of their therapeutic potential using machine learning and deep learning technologies [1]. The research is imminent in view of filling this gap with the use of advanced computational methods in traditional musical practices for modern health applications. The proposed work shall focus on the automatic classification of Indian classical ragas, coupled with a special linked feature wherein each classified raga will link to a disease it is traditionally believed to cure. In the therapeutic and healing elements associated with it, different ragas affect physical and mental health in particular ways in the Indian classical music tradition. In this work, advanced machine learning and deep learning for raga identification are done. Feature extraction from the different ragas in the audio files forms the backbone of the work [2]. The features are extracted to achieve the pre-processing, which represents one of the most common features in the pre-processing of an audio signal. MFCCs represent the short-term power spectrum of an audio signal and thus are well suited for capturing the peculiarities of different ragas. The data set of this work includes audio recordings of Indian classical ragas with fine-grained labeling for every raga name [3]. It is capturing the various interpretations of each raga performed by different artists and differences in tempo, pitch, and instrumentation. The data set is enriched further with methods such as pitch shifting and the introduction of background noise to make it more diverse and models more robust [4]. These detailed data sets are used as the basis for the train models and derive features for raga classification and therapeutic associations discussion.

The models used are VGGish SVM, YAMNet Random Forest, OpenL3 KNN, VGG16 Gradient Boosting, CNN with Attention Layers, CNN and Voting Classifier, where the hyperparameters are tuned with GridSearchCV to find the optimal number of estimators, maximum depth, and minimum sample split. Key strengths of Random Forest are its robustness and handling non-linear complex data well. A K-Nearest Neighbors model is also implemented for the classification of ragas with respect to the similarity of their MFCC features. The KNN model can be used here because the KNN model is quite simple and works effectively for problems of small scale [5]. In this work such models will be combined using a Voting Classifier that leverages the strengths of these different models. It will make use of both Random Forest and KNN classification. This is a classification approach whereby an ensemble increases performance in the classification based on diversity in decision processes between individual models. Voting Classifier will make use of soft voting, in that the models generate more accurate predictions based on their outputs regarding probabilities [6]. An important contribution of this work is the inclusion of raga-based music therapy by connecting each categorized raga to a disease that it strategically has traditionally been known to cure. When the system recognizes a raga, it will output a related disease for which the raga may be used to possibly treat, such as lowering stress, insomnia, or high blood pressure. This feature introduces a new therapeutic [20] dimension to artificial intelligence and holistic health practices. Generally, the work implementation of several machine learning and deep learning techniques, such as data augmentation, Random Forest, KNN, CNN [2][10], and a Voting Classifier.

The novelty of the work is as follows: This work identifies the ragas of Indian Carnatic music using deep learning techniques in an efficient way and for each raga identified, the disease that can likely be cured is suggested as a recommendation.

The remaining sections of this paper is organized as follows: Section II describes related work, Section III discusses the proposed methodology, Section IV elaborates results and analysis and conclusion is presented in Section V.

II. Related Works

B. R. and A. M. B., proposed a method that applies HMMs to discover a given raga in Carnatic Music, based on pitch contours. HMMs describe the specific melodic movement of each raga with 89.25% accuracy if applied to 16 different samples. The final results indicate HMM is very robust for complex melodic structures, and thus, it is possible to apply computational techniques to analyse and preserve cultural music heritage [1]. N. Ananth et.al, proposed a method that discusses AI/ML methods for the identification of ragas in Indian Classical Music. After conducting the literature survey, the authors designed the methodology with the focus on data pre-processing and applied KNN and CNN on Hindustani and Classical music datasets. The objective of the research is to extend the dataset to include all 5040 ragas and make the system more efficient and accurate. It throws light on how data sets may be improved and how AI/ML techniques can be applied for optimal raga recognition [2]. S. John, et. al, discusses automatic raga identification in Carnatic music using audio signal processing and Convolutional Neural Networks (CNN). It attempts to improve the efficiency of raga classification, which is otherwise challenging in the time and frequency domains by extracting pitch contour as a key feature. The proposed method is applicable to various fields and areas, including music synthesis, dataset management, as well as music therapy. It approaches the classical methods more accurately but with the support of better performance in raga recognition by using neural networks [3]. N. R. Rajalakshmi, et.al, found an approach to the problem of raga classificationhat considers a CNN that was trained on 70 classes to classify the raga into three categories in Indian Classical Music. It utilized an input of audio spectrogram of the raga songs used for classification, demonstrating improved precision upto 97.9% using different metrics like precision, recall, F-1 Score and AUC-ROC, and is capable to outperform traditional classifiers as well [4]. S. Pahadsingh, et. al, presented a paper that presents a Stacked Ensembled Learning Model for the identification of raga in Carnatic music, integrating classifiers like MLP, SVM, KNN and Random Forest. This model is trained on features like MFCC, Spectral Centroid, and Chroma STFT, where the ensemble achieves a higher accuracy of 97.812% compared to individual classifiers [5].

K. R and P. S. S explored the use of RNN for classifying audio of Carnatic ragas. Features such as MFCCs, Spectral Rolloff, Zero Crossing Rate, Spectrograms and Spectral Centeroids, which can be obtained from audio recordings with signal processing techniques. In the context of the Bidirectional LSTM model, a comparison is done in terms of its precision with 97.63% and its accuracy with 92.13% compared to the model by LSTM [6]. P. M, et. al, developed a system based on CNN for detection of ragas using flute concert audio samples with initial accuracies of 52.4% on mel spectrograms. Data augmentation techniques improve these accuracies to as much as 83% [7]. Anand. A proposed the use of CNN based approach for the automatic identification of ragas in Indian classical music, unlike previous methods that use feature engineering. The proposed CNN model learns the characteristics of ragas from dominant pitch values. The model is evaluated on Carnatic music datasets with 5 and 11 ragas, showing the accuracies of 96.7% and 85.6% [8]. D.C Shubhangi, et. al, explored the problem using deep learning approach specifically to Indo-Western genres by using the classifier that bases its classification based on music classification using the convolutional neural network applied via MFCCs with two datasets GTZAN for the Western part. Research would also discuss the identification of classical ragas and their therapeutic effects by suggesting a machine learning algorithm with MFCC, pitch, and Chroma features to improve raga classification, which is directed toward the demonstration of specific ragas associated with the treatment of illness [9]. U. Farooq, et. al, proposed a method that aims to precisely predict ragas in Indian classical music by using DL and ML techniques. A system is developed that incorporates CNN and RNN, which process audio recordings of ragas. The approach is tested extensively against existing methods, and its capabilities in music analysis, archiving, recommendation systems, and education are discussed as possible applications [10]. P. Kavitha, et.al, introduces the concept of identifying the Janya Ragas of Carnatic music that are drawn from the Melakarta Ragas using deep learning techniques. It solves a problem on identifying the Melakarta Raga, given the Janya Raga for better music recommendation systems, by using classification-based supervised deep learning models with 1D CNN, LSTM, and a hybrid 1D CNN-LSTM, using MFCCs as features. The best result was yielded by the 1D CNN-LSTM model with an an accuracy of 82.0% and using Siamese networks for further improvement to get the best out of as minimal use of labeled data [11]. Y. P. Pingle analyses the therapeutic effects of Indian classical ragas on diabetes, hypertension, and thyroid disease patients. Applying a LightGBM classifier to a 417 entry dataset showed that health indicators were highly affected by the presence of classical ragas. The Kappa score was 0.7319, meaning that agreement is moderate, and the model has an accuracy of 86.90%. These findings therefore suggest potential with music therapy as an exciting complementary treatment and in assessing the capabilities of machine learning in evaluating health outcomes on music [12]. This S. Sreejith, et.al, describes a CNN-based approach to Carnatic music rāga recognition based on Mel-spectrograms that apply sliding window analysis. There is no need for pitch extraction or metadata, allowing the CNN to learn representations of the rāgas directly from the patterns found in Mel-spectrograms. The aggregation-based VGG16 model is tested with ten rāgas from the CompMusic dataset and Ramanarunachalam's YouTube collection at a macro F1 measure of 0.61, similar to traditional sequence classification methods [13]. A review by P. Govindarajan, et.al, takes one through the Indian classical music rāga recognition area, with special focus on recent automation and AI progressions. The existing studies on classification approaches in carnatic classical music are discussed in a critical manner and the traditional approaches along with automated ones are brought into the light. The overall comprehensive model with minimum errors is envisioned, which is capable of identifying a wide variety of rāgas, with gaps for further research. The synthesis of traditional and modern approaches is the way to go for advancing automated music recognition systems [14]. B. S Gowrishankar, et. al, proposed a deep learning LSTM-based system for automatic music transcription in Carnatic music to solve the problem of detection of varied note frequencies. It identifies note detection as an image classification problem using modified VGGNet with the use of modified VGGNet, so the sequences are classified into 72 Melakartha ragas with much higher accuracy than the state-of-the-art methods. This approach would significantly strengthen applications like music mixing, recommendations, and retrieval [15].

A. K Sharma, et. al, discusses the classification of Hindustani and Carnatic music by two different methods. Features were taken in terms of MFCCs for various models such as DNN, CNN, RNN-LSTM, and SVM. Features from MFCC, Spectrogram, and Scalogram merged into VGG-16 and ResNet-50 architectures. The best performances in Indian classical music classification are provided by the 3-layer CNN and RNN-LSTM models [17]. The study by S, Adhikary, et. al, explores the use of Wasserstein Generative Adversarial Networks for generation based on raga for Indian classical music. Training WGAN on dataset recordings of Indian classical using MIDI piano music as the input produced results that newly generated music was close to stylistic and acoustic qualities of training data. The experiment results indicate the generated compositions are as good as those created by human musicians, and it is in this genre that potential exists for WGANs [18]. Anuraj, K., S. S. Poorna, and S. Renjith proposed an integrated method for music genre classification based on different audio features like spectral, rhythmic, and tonal features. The study employed a range of machine learning and deep learning methods to improve the accuracy of the classifier. The results indicated that merging multiple sets of features greatly enhances the detection of genres compared to single-feature-based methods [19]. Pushparajan, M., et al. examined data augmentation techniques to enhance raga classification performance. Authors employed time-stretching, pitch-shifting, and noise injection techniques to generate diverse training samples, reducing problems of data sparsity [20].

Despite the developments, this area still faces a lot of research gaps. A key limitation is that there is insufficient diversity in the datasets as most studies depend on a few small collections concentrating on certain ragas or regional styles and are not generalizable [21]. It discusses the therapeutic benefits of ragas but does not give complete frameworks for incorporating raga recognition with validated health outcomes for music therapy. Most studies have been done on Carnatic or Hindustani music, and fusion or Indo-Western genres are hardly touched upon. There is also a dearth of comparative studies between manual feature engineering and end-to-end deep learning methods. Real-time implementation of raga recognition [22] systems for live performances, music education, or therapy applications is also under-addressed. The theoretical linkage between ragas and their therapeutic benefits lacks empirical validation, which necessitates studies based on health datasets. Challenges still exist for more complex ragas involving improvisations or subtle changes and require more advanced models. Data augmentation [23] is used in a few studies, but there are still unexploited benefits from transfer learning for improving the performance on smaller datasets [24]. Deep learning models also suffer from low interpretability, where one can hardly understand why particular ragas are recognized or what therapeutic effects they produce. In summary, though there is a rhetoric on cultural heritage preservation, practical frameworks towards incorporating raga recognition systems within digital archiving tools are underdeveloped.

III. METHODOLOGY

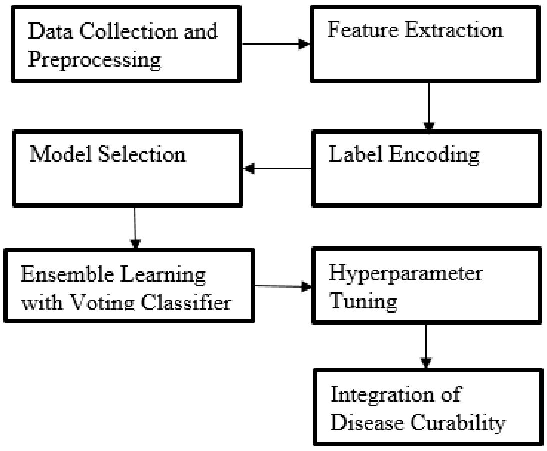

Fig-1: The flowchart describing the proposed Methodology

The methodology of this work is multi-stepped and interdependent; that includes data preparation, feature extraction, model selection and training, hyperparameter tuning, model evaluation, and finally the integration of disease curability based on the classified Indian ragas. The objective of the work is to classify the ragas with better accuracy based on a variety of machine learning and deep learning models; it also maps each of the classified ragas with the respective diseases for which the ragas are commonly believed to cure.

The collection contains audio samples of eight unique Indian classical ragas: Asawari, Bageshree, Bhairavi, Boopali, Darbari Kanada, Malkauns, Vrindavani Sarang, and Yaman. The files for all of each raga are archived in their raga folder at high-fidelity WAV format and 44.1 kHz sampling rate. The length of recordings can vary from 30 seconds to 2 minutes. Such a structured organization makes it easy enough to allow efficient processing through feature extraction and automated classification. The dataset is vital to continue furthering music recognition systems and exploring the subtleties of Indian classical music through machine learning and deep learning techniques.

A. Data Collection and Preprocessing:

The dataset consists of Indian classical raga audio files, which are divided into folders. Every folder represents a specific raga. Data preparation starts with the loading of the audio files found in the folders. Audio files potentially have different sampling rates; thus, such files are standardized during their loading using the librosa library.

Audio signals are augmented with data augmentation to make the models more robust and to improve their generalization ability. Data augmentation includes two primary techniques:

- Pitch Shifting:
  It shifts the pitch of the audio by a random number of semitones between -2 and +2 without affecting the duration. This slightly modifies the original audio while keeping its structures, thus increasing the diversity of the training set.
- Noise Addition:
  Some amount of random noise is added to the audio file to mimic realistic conditions where the recording may include some background noises.

The processed audio files can be used for feature extraction after augmentation, both from the original and augmented dataset.

B. Feature Extraction using MFCCs:

Features need to be extracted from these audio files. Since the cores of the MFCCs indicate the timbral texture in an audio context, MFCCs have been chosen here because they are important for the identification of ragas. In this project, librosa is used to extract 13 MFCC coefficients from each audio file. Further, these MFCC features are averaged across time frames in order to get a fixed-size feature vector for every audio sample, thereby reducing its dimensionality and retaining important information. Therefore, every audio file results in two feature vectors: one corresponding to the original audio and another for the augmented audio. This obviously makes the size of the dataset larger, which pertains to every machine learning model training.

C. Label Encoding:

Categorical labels are considered in this work. As the machine learning algorithms take the numerical input in case of labels, the LabelEncoder from the library scikit-learn has been used to convert the names of the raga into an integer-encoded labels. Such one-hot encoding labels are used in deep learning models like CNN, which need categorical output for a multi-class classification.

D. Model Selection:

To classify the ragas, three different models are developed:

- Random Forest Classifier:
  It is an ensemble learning method that generates multiple decision trees and then combines them to predict in a more accurate and stable way. Random Forest has been chosen for overfitting issues and is robust for classification. For hyperparameter tuning it uses GridSearchCV to determine the number of estimators, the maximum depth of trees, and minimum samples split. Finally, the tuned model will train on the MFCC features and the encoded labels.
- K-Nearest Neighbors (KNN):

The KNN is a simple, yet effective classifier, which classifies the class of a data point based on majority class amongst its k-nearest neighbor in the feature space. The KNN classifier learns from the MFCC features for classifying raga by proximity to another samples of raga in the feature space. In this work, after experimenting, k is chosen as 5.

- Convolutional Neural Networks (CNN):

CNNs are the deep learning model developed to handle grid-like data such as images but also do very well on 1D data, such as audio features. The architecture of the network consists of the following:

1. An input layer that reshapes the MFCC features into a 2D grid (13 MFCCs).
2. Two convolutional layers of 32 and 64 filters followed by the max pooling layers to reduce the dimensionality.
3. A flattening layer to convert the 2D output of the convolution into a 1D vector.
4. Fully connected layer with an output layer to avoid overfitting.
5. Output layer with softmax activation to classify the audio as belonging to one of the raga categories.

E. Ensemble Learning with Voting Classifier:

This project also uses an ensemble model that consolidates the result of Random Forest and KNN classifiers in ensemble form using a Voting Classifier. It utilizes soft voting in the Voting Classifier's setup, aggregating the probability predictions of every individual classifier in making a single prediction. The ensemble learning process utilizes the capability of both Random Forest and KNN to make more accurate classification than the models independentl.

F. Hyperparameter Tuning:

GridSearchCV is a utility for hyperparameter tuning of a Random Forest classifier. The parameters tuned in this case are:

- n_estimators: is the number of trees in the forest;
- max_depth: maximum depth of each tree.
- min_samples_split: The minimum number of samples required to split the node in an inner mode.

Thus, the random forest model does classification optimally, using an exhaustive search algorithm.

G. Model Evaluation:

The model is evaluated with 80-20 split testing data obtained from the dataset. The metrics used for the evaluation are:

- Accuracy: Manual correction of raga predictions vs all predictions.
  Accuracy =
  (Number of Correct Predictions) ÷ (Total Number of Predictions)

- Precision: Weighted precision; this is the ratio of the correct positive predictions against the total correct predictions made for each class.
  Precision=
  True Positives ÷ (True Positives + False Positives)

These measures are utilized to estimate the performance of each model, thus determining which of them is the best and may be applicable to raga classification.

H. Integration of Disease Curability:

Finally, the system will introduce a new attribute: each categorized raga will be assigned to one disease it is generally presumed to cure. For that, once a raga is categorized, predefined directories may link it to its proper disease. For example, "Raga Darbari" might cure anxiousness, and "Raga Bhairav" can help to calm oneself and improve sleep quality. Since this system will output not only the classified raga but also the associated disease, it will deliver therapeutic suggestions in tandem with musical classification.

IV. Results and Analysis

The results of this work combines different uses of machine learning and deep learning in this project, applied for the classification of Indian classical ragas based on their audio features and the healing properties developed from them. The strengths and weaknesses are depicted through the performance of the models in the test dataset.

A. Random Forest Classifier (YAMNet Pre-Trained Model):

With GridSearchCV for hyperparameter tuning, the performance of the Random Forest classifier looked like:
Accuracy: 84.25% accuracy was obtained, which means classification was correctly done for 84% of the dataset.
Precision: In this regard, the system reported 83% precision, meaning a very low rate of false positives.
The Random Forest classifier works well with high-dimensional data, so it might be definitely used to classify the features of MFCC. Overfitting is common with small datasets, but with several trees, overfitting gets minimized. Another reason the model got better was due to tuning its hyperparameters by the further fine-tuning of depth and estimators.

B. K-nearest Neighbor Classifier (KNN Classifier) (OpenL3 Pre-trained model):

Configured with 5 neighbors (K=5), results from the KNN classifier were as follows:
Accuracy: An accuracy of 87.47% was achieved while applied to the test dataset.
Precision: The precision score was obtained to be 84.63%.
KNN depends on the distance metric utilized and the number of neighbors selected. It resulted in higher accuracy for small dataset but the amount of noise and augmented data in the feature space means that it is not something to rely highly on. KNN acts as a good baseline model.

C. Convolutional Neural Network (CNN):

The best-performing model of all models is the CNN, that has been trained on reshaped MFCC features.

Accuracy: The CNN obtained an accuracy of 98.64% this is an indication that it can learn audio features into good patterns.

Precision: A high precision value of 95% is obtained which therefore highly classifies ragas with very minimal false positives.

CNN has a deep learning nature to allow the model to self-learn complex feature representation from MFCCs, thereby including several convolutional layers with max-pooling can improve the models ability to capture both temporal and spectral variations of audio signals, while dropout layers make the models less prone to overfitting and make them more generalizable on new data.

D. Voting Classifier (Ensemble Learning):

The following is the output of the Voting Classifier, which simply combines both the predictions of the Random Forest and the KNN classifiers with soft voting:
Accuracy: The accuracy of the voting classifier is 92.57%.
Precision: The precision score is 88.63%.
The ensemble approach improved the performance of the stand-alone KNN model through the strength of the classifier, which is the Random Forest. However, the voting classifier outperformed CNN, since that CNN was able to capture from MFCCs the complex features involved better. In general, ensemble learning can pay off when the models that are involved by it are somewhat comparable. It had limited gains in the problem of interest due to the disparity in the performance of the used models.

E. Disease Curability Integration:

Following this step of classification, it can identify and map the relevant information to each raga. In other words, according to the assigned diseases being cured by their music therapy, it mapped to
Raga Darbari: Relieving anxiety; having mental calmness.
Raga Bhairav: Associated with soothing sleep and assuaging worries.
The integration of this feature adds a practical dimension to the raga classification by linking the cultural and therapeutic values of Indian classical music with machine learning models. This feature can prove to be highly valuable for music therapists and practitioners of traditional medicine who use ragas as a form of treatment.
Table 1: Comparison of Accuracy and Precision of all the models.

Model Name	Accuracy	Precision
VGGish SVM	65.96%	63.63%
YAMNet Random Forest	84.25%	83.00%
OpenL3 KNN	87.47%	84.63%
VGG16 Gradient Boosting	73.00%	68.72%
CNN with Attention Layers	83.35%	81.05%
CNN	98.64%	95.36%
Voting Classifier	92.57%	88.63%

The results in Table 1 shows that CNN outperforms other ML models Forest and KNN in complex audio feature extraction. The ability to learn from raw feature inputs with minimal pre-processing further shows the superiority of its performance, as the scores for accuracy and precision are higher. Hence, it is suitable for high-dimensional data due to its nature of being an ensemble method.

V. Conclusion and Future Scope

The Voting Classifier turned out to be very successful at combining several models and could do no worse than CNN largely due to the huge gap in performances of base models. So, it follows that ensemble learning does well only when base models all have similar accuracies.

The disease-curability mapping successfully depicts the real application of the project by fusing AI-driven classification with the traditional knowledge of raga therapy. This unique dimension adds an additional value to the work by applying it to the field of music classification but also in music therapy and health care.

The future works includes real-time testing on users, validating the therapeutic claims mentioned in the paper through clinical studies, or exploring alternative deep learning architectures.

References

[1] B. R and A. M. B, "Machine Learning Based Indian Raga Classification and Detection," 2024 Asia Pacific Conference on Innovation in Technology (APCIT), MYSORE, India, 2024, pp. 1-5, doi: 10.1109/APCIT62007.2024.10673605.

[2] N. Ananth, R. M. Bharadwaj, S. S. Shekar, S. Jain and V. R. Srividhya, "Investigation into the Identification of Ragas: A Detailed Analysis," 2024 4th International Conference on Data Engineering and Communication Systems (ICDECS), Bangalore, India, 2024, pp. 1-6, doi: 10.1109/ICDECS59733.2023.10503571.

[3] S. John, M. S. Sinith, S. R. S and L. P. P, "Classification of Indian Classical Carnatic Music Based on Raga Using Deep Learning," 2020 IEEE Recent Advances in Intelligent Computational Systems (RAICS), Thiruvananthapuram, India, 2020, pp. 110-113, doi: 10.1109/RAICS51191.2020.9332482.

[4] A. Singha, N. R. Rajalakshmi, J. Arun Pandian and S. Saravanan, "Deep Learning-Based Classification of Indian Classical Music Based on Raga," 2023 6th International Conference on Information Systems and Computer Networks (ISCON), Mathura, India, 2023, pp. 1-7, doi: 10.1109/ISCON57294.2023.10111985.

[5] A. Paul, S. Pahadsingh, T. Kar and Shruti, "Carnatic Classical Raga Identification Using Stacked Ensemble Learning Model," 2024 1st International Conference on Cognitive, Green and Ubiquitous Computing (IC-CGU), Bhubaneswar, India, 2024, pp. 1-6, doi: 10.1109/IC-CGU58078.2024.10530796.

[6] K. R and P. S. S, "Classification Of Carnatic Music Ragas Using RNN Deep Learning Models," 2023 14th International Conference on Computing Communication and Networking Technologies (ICCCNT), Delhi, India, 2023, pp. 1-6, doi: 10.1109/ICCCNT56998.2023.10308122.

[7] P. M, K. T. Sreekumar, K. I. Ramachandran and C. S. Kumar, "Data Augmentation for Improving the Performance of Raga (Music Genre) Classification Systems," 2024 5th International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India, 2024, pp. 1407-1412, doi: 10.1109/ICESC60852.2024.10690091.

[8] A. Anand, "Raga Identification Using Convolutional Neural Network," 2019 Second International Conference on Advanced Computational and Communication Paradigms (ICACCP), Gangtok, India, 2019, pp. 1-6, doi: 10.1109/ICACCP.2019.8882942.

[9] D. C. Shubhangi, B. Gadgay and M. Moolbharathi, "Machine Learning Based Indo-Western Music Identification, Classification and Disease Healing," 2023 IEEE 5th International Conference on Cybernetics, Cognition and Machine Learning Applications (ICCCMLA), Hamburg, Germany, 2023, pp. 454-458, doi: 10.1109/ICCCMLA58983.2023.10346746.

[10] U. Farooq, K. K. S. Reddy, K. S. Shishira, M. G. Jayanthi and P. Kannadaguli, "Comparing Hindustani Music Raga Prediction Systems using DL and ML Models," 2024 International Conference on Emerging Technologies in Computer Science for Interdisciplinary Applications (ICETCS), Bengaluru, India, 2024, pp. 1-6, doi: 10.1109/ICETCS61022.2024.10543647.

[11] OingleP. Kavitha, J. Charles and L. S. Lekamge, "A Deep Learning Based Approach for Janya Raga Classification in Carnatic Music," 2022 6th SLAAI International Conference on Artificial Intelligence (SLAAI-ICAI), Colombo, Sri Lanka, 2022, pp. 1-6, doi: 10.1109/SLAAI-ICAI56923.2022.10002700.

[12] Y. P. Pingle and L. K. Ragha, "Accuracy Prediction for Music Therapy Data using Kappa Model," 2024 11th International Conference on Computing for Sustainable Global Development (INDIACom), New Delhi, India, 2024, pp. 240-246, doi: 10.23919/INDIACom61295.2024.10498965.

[13] S. Sreejith and R. Rajan, "Rāga Recognition in Indian Carnatic Music Using Transfer Learning," 2021 Fourth International Conference on Microelectronics, Signals & Systems (ICMSS), Kollam, India, 2021, pp. 1-5, doi: 10.1109/ICMSS53060.2021.9673599.

[14] P. Govindarajan, S. M. Mothi and A. Tesfahun, "An AI Model for Recognization of Raagas in Indian Classical, Carnatic Music – A Review Article," 2023 IEEE International Conference on Cloud Computing in Emerging Markets (CCEM), Mysuru, India, 2023, pp. 110-119, doi: 10.1109/CCEM60455.2023.00025.

[15] B. S. Gowrishankar and N. U. Bhajantri, "Deep Learning Long Short-Term Memory based Automatic Music Transcription System for Carnatic Music," 2022 IEEE International Conference on Distributed Computing and Electrical Circuits and Electronics (ICDCECE), Ballari, India, 2022, pp. 1-6, doi: 10.1109/ICDCECE53908.2022.9792867.

[16] A. K, P. B D and Kiran, "Fisher-Jenks Classification Technique for Music Raaga Identification," 2023 International Conference on Ambient Intelligence, Knowledge Informatics and Industrial Electronics (AIKIIE), Ballari, India, 2023, pp. 1-6, doi: 10.1109/AIKIIE60097.2023.10390162.

[17] A. K. Sharma et al., "Classification of Indian Classical Music With Time-Series Matching Deep Learning Approach," in IEEE Access, vol. 9, pp. 102041-102052, 2021, doi: 10.1109/ACCESS.2021.3093911.

[18] S. Adhikary, M. S. M, S. S. K, S. Bhat and K. P. L, "Automatic Music Generation of Indian Classical Music based on Raga," 2023 IEEE 8th International Conference for Convergence in Technology (I2CT), Lonavla, India, 2023, pp. 1-7, doi: 10.1109/I2CT57861.2023.10126388.

[19] Anuraj, K., S. S. Poorna, and S. Renjith. "Music Genre Classification-A Holistic Approach Employing Multiple Features." 2024 15th International Conference on Computing Communication and Networking Technologies (ICCCNT). IEEE, 2024.

[20] Pushparajan, M., et al. "Data Augmentation for Improving the Performance of Raga (Music Genre) Classification Systems." *2024 5th International Conference on Electronics and Sustainable Communication Systems (ICESC)*. IEEE, 2024.

[21] Joby, Ashwin P., et al. "Teaching Indian Classical Music Using Web-Based Interactive Platform and Real-Time Audio Analysis." *2024 32nd European Signal Processing Conference (EUSIPCO)*. IEEE, 2024.

[22] Trisha, Kariveda, et al. "Deep Learning-Enhanced Emotion-Based Music System with Age and Language Personalization." *2024 15th International Conference on Computing Communication and Networking Technologies (ICCCNT)*. IEEE, 2024.

[23] Sinith, M. S., K. V. V. Murthy, and Shikha Tripathi. "Raga recognition through tonic identification using flute acoustics." *International Journal of Advanced Intelligence Paradigms* 15.3 (2020): 273-286.

[24] Kulkarni, Varun Vinod, and Dr Beena BM. "Cloud Based Music Recommendation System." SSRN 4814206 (2024).