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A Survey on the Modelling and Classification of Raagaas in Hindustani Classical Music

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***Abstract:** Raagaas are the basis of Hindustani Classical Music. They are made up of a group of 12 well structured characters called swaras. Combinations of these swaras give birth to different Raagaas. Though classical music is gaining popularity, Raagaas are quite under-studied from the point of view of Computer Science. There have been attempts to model them, classify them and generate them using several techniques. In this paper, we study and summarize various such approaches. This includes Machine-Learning based approaches like the use of LSTMs, CNNs and HMMs for classification and LSTMs and GANs for generation. The focus of our survey is on various problems solved by the previous work and their subsequent merits and drawbacks. We also include the survey methodology, which is followed by the future directions and conclusion, where we highlight some problems and solutions that could be applied to obtain better results on tasks like Raagaa Classification.*
***Keywords:** Raagaa-Classification, Raagaa-Modelling, LSTM, GAN, Audio-Classification*

I. INTRODUCTION

Raagaas are a part of Hindustani Classical Music. They form the basis of Hindustani Classical Music, as most of the compositions in Hindustani Classical Music are based on one of the Raagaas. Swaras are musical notes associated with the frequency of sound. Combinations of these swaras give birth to different Raagaas. There are over a hundred Raagaas, and each Raagaa has its unique properties. Each Raagaa is associated with a tempo, a mood and is usually sung only during a specific time of the day. Musical compositions which are sung in concerts and mehfils are based on a Raagaa and its associated properties.

A common problem given to music students learning Hindustani Classical Music is the accurate identification of what Raagaa is being played or sung. This is a quite challenging task for students, and sometimes even for experienced musicians when the Raagaas in question are very similar to each other in their properties or the way they are being sung. This is because Raagaas are often a notion of properties, not a fixed set of rules laid down in stone. The lack of a hardened set of rules corresponding to each Raagaa makes their identification especially difficult. This introduces great variability, and is often the reason for the beauty of classical music.

Though classical music is gaining popularity, Raagaas are quite under-studied from the point of view of Computer Science. There have been attempts in the past to model Raagaas using several mathematical and Machine Learning based techniques. Most of the past work falls short due to various factors. The problem of identification of Raagaas from a piece of music or a set of swaras is inherently complex in nature as the Raagaas cannot be 'well-defined' easily in a mathematical sense. The problem is even more complex for generating a sequence of swaras corresponding to a Raagaa on-the-fly.

Classification and Generation of Raagaas is a difficult problem from the point of view of computer science. As there are no hard and fast rules for creating Raagaas, their identification becomes quite difficult. For the identification of a Raagaa by using computer-based techniques, the following methodology is used in general –looking at the audio directly in the form of a spectrogram and then extracting some features from the audio and using them to correctly predict the Raagaas. These techniques rely on a variety of factors – like the quality of the original audio and how accurately the features can be extracted from the audio. Actual Raagaa identification by human experts is done by identifying the swaras and related properties like chalan, poorvanga pradhan, uttaranga pradhan, kana, etc. from the audio, and then identification of the actual Raagaa from the basis of that.

One of the major tasks is mapping frequencies to swaras which is a relative scale given the tonic frequency. If we consider 12 notes in the octave, we can use the formula that ratio of ith note from the tonic frequency is 2^(i/12). So given tonic frequency, we can derive the swaras sequence from frequency vs time graph.

This paper presents a comprehensive study of various computer-based methods which are used for classification and generation of Hindustani Classical Music Raagaas, and also an overview of techniques used in the context of classification of other music types.

This study aims to –

- Present existing solutions of the classification of Raagaas

- Present existing solutions of the generation of Raagaas
- Present and summarize various problems associated with them and compare these techniques
- Present and summarize existing solutions for music classification in other contexts

II. LITERATURE REVIEW

For a better presentation of the literature review, we have divided it into three sections – The approaches based on Hindustani Classical Music Raagaas, the approaches not based on Hindustani Classical Music, the comparison between the methods and the summary and findings of the literature review.

A. Hindustani Classical Music-Based Research Papers

Kartavya Gupta's master's thesis [1] is a thorough study about classification and generation of several Hindustani Classical Music Raagaas. The problem of classification and generation is approached using three different methods – modelling swara sequences as context-free grammars, using bi-gram models and using LSTM models. All the three approaches are tedious in nature, as modelling Raagaas as a context-free grammar requires handling of a very large rule set which becomes difficult to manage and keep track of correctly. On the other hand, the ML-based models of bi-gram and LSTM require a large collection of annotated swara-sequences for each Raagaa, which is a tedious process too. The Raagaa dataset used by them was created using all the recordings of Pandit Ajoy Chakraborty. As this thesis is based directly on the swara sequences, there is no question of scale invariance.

Adhikary S et. al. [2] study the generation of Hindustani Classical Music Raagaas using Generative Adversarial Networks. They used WGANs to train a generator and a discriminator to automatically generate pieces of Raagaa sequences. Their input dataset consists of sequences of MIDI Piano Music.

Dighe, Karnik and Raj [3] use a very crude approach of analysis of the swaras based on their occurring frequency in the Raagaa. A random forest classifier was used on the histograms of the swaras in the recordings of Raagaas to identify the Raagaa. Even though a very high accuracy of 94.28% is achieved, the approach is not easily scalable and robust because the swara sequence of the Raagaas is not given any importance; instead, just the occurrence frequency is used which disregards all sequence information. But several Raagaas are differentiated based on the ordering of the swaras only.

Dighe et. al. in [4] use Hidden Markov Models (HMMs) and classification trees over swaras for classifying Raagaas. They conduct four different experiments using different models and input features for the models. Theu get the highest accuracy of 97.68% using GMM based HMM models on Chroma + MFCC + Timbre Features. They also conclude that chroma, MFCC and timbre data outperforms swara based features.

Pendyala et. al. [5] use bidirectional LSTM models to classify Raagaa sequences. But instead of using swara sequences as their input, they use Mel-frequency cepstrum coefficients (MFCC) representations of the audio data and directly feed them into the BiLSTM RNN architecture. Their architecture achieved an accuracy of 78%. The proposed architecture is not scale-invariant due to direct use of MFCC representations.

Das and Choudhury [6] manually create probabilistic Finite State Machines for generation of Hindustani Classical Music Raagaas. The language set for the Finite State Machines was the set of swaras. This is a crude approach because it needs a lot of manual work and fine tuning.

Joshi et. al. in [7] use KNN and SVM based models on features like MFCC, Spectrogram, Bandwidth, Centroid, zero-crossing, and Roll-off on two Raagaas - Yaman and Bhairavi. They conclude that KNN performs slightly better than SVM, but their performance is comparable.

Humse et. al. in [8] use a similar approach for classification of Yaman and Bhairavi Raagaas using SVMs and LSTMs on audio features like the MFCC. As this approach is also based on MFCC, it is also not scale-invariant.

Paschalidou and Miliaresi [9] use unipolar and bipolar architectures for classification of Raagaas using generic feed-forward networks. They carry out experiments on Yaman and Bhairavi Raagaas, comparing both swara-based input features and MFCC-based input features. They concluded that swara-based features perform better than MFCC-based features and Bimodal models (features + metadata) perform better than Unimodal models.

B. Non-Hindustani Classical Music-Based Research Papers

Tiwari and Jha [11] use LSTMs on western classical music piano works to generate piano sequences. They use a corpus of MIDI files as their input data. They conclude that LSTMs can capture the long-range dependencies in the input musical sequences.

Sambaragi et. al. [12] also use RNN-based LSTM models for western classical music generation. They use the kern and Mastero datasets for as the input data.

[13] is a comprehensive study of music generation by Briot and Pachet. RL-Tuner Melody generation, audio style transfer, VAE-based voice generation, MidiNet and GANs are some of the methods and architectures studied by them.

The architectures are studied of a variety of inputs, like human voice, general melodies and piano-based melodies.

[14] is a study by Lim, Chan and Loo about music generation using a Variational Autoencoder (VAE) based architecture. They use MIDI files as input and classify the input based on the beats it contains.

Shi [15] studies Western Classical Music and its classification based on musical styles like sonata, waltz, etude, etc. She uses a CNN-based architecture on several features extracted from the input music data like MFCC, Chroma matrix and ST-RMS. The input data was music pieces of a total of 10 compositions of old composers like Beethoven, Berg and Scarlatti. The GSSA based optimization algorithm used along with the CNN architecture was a useful trick in increasing the accuracy of the model.

[16] by Nanni et. al. is a study of music genre recognition. Both acoustic and visual features are used as input features. Three datasets - GTZAN genre collection, Latin Music Database and ISMIR 2004 are used as source material. The classifier approaches include using SVM and boosting using AdaBoost. They conclude that the inclusion of both audio and visual features is the reason for their better performance.

C. Research Papers Comparison

The following table (TABLE 1) compares the Hindustani Classical Music based papers and their various approaches in detail:

TABLE I

COMPARISON OF METHODOLOGIES AND RESULTS OF PAPERS ON HINDUSTANI CLASSICAL MUSIC

Sr. No	Paper Name	Authors	Year of Publication	Classification or Generation?	Methods used
1	Automated raga recognition in Indian classical music using machine learning techniques [8]	Humse, K., HS, R. K., Ramachandra, L. S., GR, Y., & Puttegowda, K.	2025	Classification	SVMs and LSTMs on audio features like MFCC
2	Multimodal deep learning architecture for hindustani raga classification [9]	Paschalidou, S., and Miliaresi, I	2023	Classification	Unipolar and bipolar architectures on generic feed-forward networks. Compared swara-based and MFCC-based methods.
3	Automatic music generation of indian classical music based on raga [2]	Adhikary, S., Manasa, S. M., Shreesha, S. K., and Bhat, S.	2023	Generation	WGANs on MIDI Piano Music
4	Improvised Sequence Generation In North Indian Classical Music [1]	K Gupta	2022	Both	Three methods used - modelling swara sequences as context-free grammars, bi-gram models and LSTM models on swara sequences
5	Towards building a deep learning based automated indian classical music tutor for the masses [5]	Pendyala, V. S., Yadav, N., Kulkarni, C., and Vadlamudi, L.	2022	Classification	LSTM on MFCC-based features of audio samples

6	Indian Classical Raga Identification using Machine Learning [7]	Joshi, D., Pareek, J., and Ambatkar, P.	2021	Classification	KNN and SVM on features like MFCC, Spectrogram and Bandwidth
7	Swara Histogram Based Structural Analysis And Identification Of Indian Classical Ragas [3]	Dighe, P., Karnick, H., and Raj, B	2013	Classification	Random forest on frequency histograms on swara sequences
8	Scale independent raga identification using chromagram patterns and swara based features. [4]	Dighe, P., Agrawal, P., Karnick, H., Thota, S., and Raj, B.	2013	Classification	Hidden Markov Models (HMMs)
9	Finite state models for generation of Hindustani classical music [6]	Das, D., and Choudhury, M.	2005	Classification	Hand-created Finite State Models on swara sequences

D. Literature Survey Findings

From the Literature Survey, we find that most of the work done is scale-invariant, and that no effort has been taken to include scale-invariance or even giving scale reference manually as an additional parameter to the models/methods. Several methods which classify Hindustani Classical Music Raagaas use MFCC as the audio features instead of the actual swaras. But using MFCC does not make sense in the context of Hindustani Classical Music as the actual features Raagaas are based on are not correctly captured in it. Paper [9] supports this claim with experimental evidence too.

There is no standard dataset for Hindustani Classical Music Raagaas in terms of the actual swaras in it or even the swara frequencies. So, nearly each paper uses different self-created datasets. This makes comparison and analysis of the results of different papers extremely difficult. There is a need for a standard dataset of Hindustani Classical Music Raagaas recordings in terms of the actual swaras included in them.

LSTM-based approaches are one of the most common ones in recent papers as it is beneficial to consider Raagaas as a language of swaras, and also that subsequently the same LSTM architectures can be used for Raagaa generation too. But LSTM-based neural networks behave like black boxes, and it is very difficult (if not impossible) to ascertain the reasoning behind a specific Raagaa being classified into a specific Raagaa. This is why a few papers like [4] approach this problem by using models which can be studied after they have been trained – like HMMs.

We also observe that most of the classification work is based around only two Raagaas – the Yaman and the Bhairavi.

Non-Hindustani Classical Music based papers also make use of some interesting approaches – like using VAEs and LSTMs. Nearly all of the papers here use MFCC for audio features as western classical music and melodies are better suited for MFCC-type methods.

III. METHODOLOGY

For conducting a comprehensive survey, we divided all of the papers into several components. The components are presented in the Fig. 1. We pooled approximately 55 papers related to the Classification and Generation of Hindustani Classical Music Raagaas, as depicted in Fig. 1. Some papers about other types of music like western music were also included to understand what other techniques are being used.

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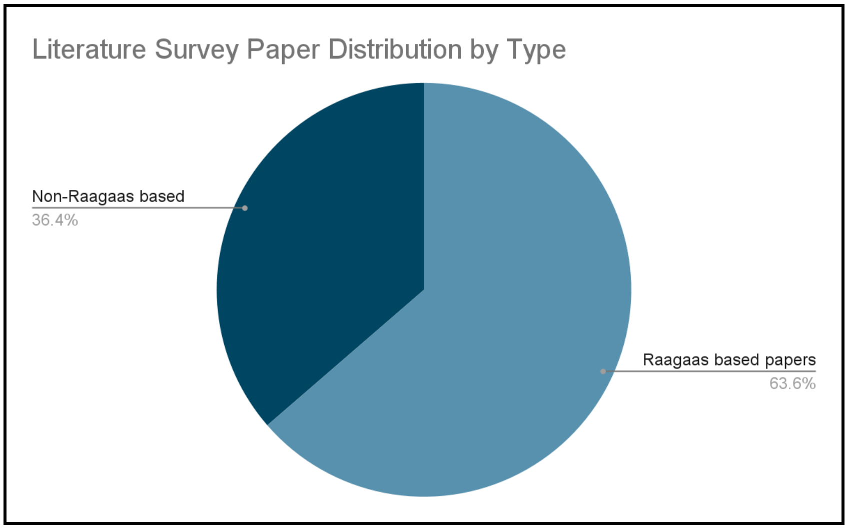

Fig. 1 Raagaas based papers and Non-Raagaas based papers

After that, we shortlisted papers based on the quality and relevance to the field of interest. The overall range of papers after shortlisting was from the years 2005 (oldest paper) to 2025 (latest paper). After aggregating the shortlisted papers, we did the thorough study of the papers for each of the paper and compared them in detail.

IV. CHALLENGES AND FUTURE DIRECTIONS

In this section, we present some of the potential future directions for Raagaa Classification problems. Particularly, we highlight the problems that were either not addressed by the existing papers, or were only partially addressed.

A. Scale Independence

A major challenge that one encounters while working with Hindustani Classical Music, over Western Music, is the problem of Scale Independence. In the Western Music, each note and scale is defined using a fixed constant frequency. A change in frequency would result in a change in the note. But, this is not the case for Hindustani Classical Music. Here, the artists have the freedom to choose the tonic frequency and every note is adjusted accordingly using a relative scale. This is a significant issue, and none of the papers within the scope of this literature survey tackles this problem. Therefore, we propose a new direction of research in the Raagaa Classification problem where the proposed models and methodologies would accurately classify the Raagaa independent of the tonic frequency and the Scale used by the artist.

V. CONCLUSION

In this paper, we summarize the techniques proposed and applied by several papers for the problem of Classification of Raagaas in Hindustani Classical Music. Using our methodology for the survey, we were able to select and filter high-quality papers with diverse proposals. Some of the categories of papers included in our survey are as follows: <TODO>. For each of the selected papers, we highlight the problems identified by the authors, the proposed solutions and methodologies, and the performance of the solution when compared with other papers of the same category. We also present some unique problems related to the classification task that were not addressed/partially addressed by the authors of these papers. After presenting the literature review and the key findings, we conclude this paper by proposing potential future directions for the problem of Raagaa classification in Hindustani Classification Music.

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