Raga Identification Techniques for Classifying Indian Classical Music: A Survey

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***Abstract*—The music plays a vital role in the life of humans. People listen to music for fun, entertainment, relaxation and mental peace. The music can be applied for recovering from illness and physical fatigues. The Raga is considered as a basic unit of Indian Classical Music. The behavior of the Raga is recognized by Swara (notes) movement. The Raga may be sung as per environmental situations, events, and emotions at the particular time. In this paper, the properties of Indian Classical Music are listed which are useful for Raga identification. The various feature extraction techniques from Digital Signal Processing and Raga Identification techniques for classifying the Indian Classical Music are discussed. The paper provides several challenges for the future work.**

***Index Terms*—Indian classical raga, music, signal processing, feature extraction, data mining techniques, probabilistic model**

I. Introduction

The music expresses the feelings with the different movements of the sound. It is the most inspired and pure form of creativity by the humans. The experience of music gives the fun, entertainment, relaxation and mental peace to the humans at the different moments of life. In the modern world, the music has gained honored of healing mental illness and physical fatigue. There are many National and International organizations working on the Music Therapy. The main goal of the organizations is to make aware, educate, practice and research in the Music Therapy for the health care of common people. Few organizations have identified and listed the suitable Ragas which help to cure a particular disease [1], [2]. The availability of a huge collection of music on the web and its heavy usage in day to day life has given a birth to Music Information Retrieval (MIR) systems. The MIR systems are followed by musicologists performing artists, music scholars, and even music therapists. The researchers performed indexing, tagging on the genre, artist, an instrument of music data for efficient retrieval [3], [4]. The classification of Indian Classical Music (ICM) based on Raga will help to e-learners, composers, musicians in an efficient retrieval of data [4]. The ICM has categorized in two types Carnatic and Hindustani Music. The Carnatic music has the Melakartha Raga and Janya Raga, while the Hindustani music has Thaat and Raga. The Melakartha Ragas are called as sampoorna Raga which has all seven Swaras present. The Hindustani music has ten Thaat: Bhairavi, Asawari, Bilawal, Khamaj, Kalyan, Marva, Poorvi, Todi, Kafi, and Bhairav. Every Raga belongs to a Thaat. The ICM has twelve basic notes or Swaras. The Swaras are categorized as Shuddha (natural), Komal (flat) and Tivra (sharp) Swara. The Swaras can be considered in three different tones namely Mandra (low), Madhya (middle) and Tar (high) that generates 36 distinct notes. Every Raga has Aaroh and Avaroh which defines, as ascending and descending sequence of Swara respectively. The characteristic phrases or set of Swaras which uniquely identifies the Raga called as Pakad. The Identification of Raga based on Aaroh-Avaroh or the pakad is not the just string matching. The two Ragas may have same Swaras, but the way of expressing it may be different, which provides distinct feelings. The way of expression is called as ornamentation [5]. To develop a general automated system for classifying Music based on Raga is a challenging task. The general Raga Identification system block diagram is shown in Fig. 1.

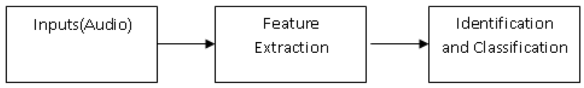

Figure 1. Raga identification of Indian classical music.

Feature extraction is the first required step for Raga Identification. The various feature extraction techniques based on timbre, pitch, and tempo are available. The well known Timbre features are Linear Prediction Coefficients (LPC), Mel Frequency Cepstral Coefficient (MFCC) and so on. The features are obtained by applying various signal processing techniques like Fourier Transform, Short Term Fourier Transform (STFT) and Wavelet Transform (WT). The pitch determines the most fundamental frequency of the sound. The Pitch Class Profile (PCP) and Harmonic Pitch Class Profile (HPCP) are widely used in tasks like melody extraction and note transcription [6]-[9].

LPC is the feature extraction technique in a time domain, which provides Autocorrelation based features. It helps in formant estimation for identifying the pitch of the signal. LPC is easy to implement, fast in computation and encodes with the low bit rate. It is mainly used in singer identification in music [6]. MFCC represents the signal in compact amplitude spectrum without losing

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original information and with less complex computations. The Mel frequency scale is linear below 1000Hz and a logarithmic above 1000Hz which is very much similar to a human hearing system. MFCC features are implemented for instrument identification, genre classification in music [8], [10]. Chroma-based features are also known as PCP. A chroma features visually represent the energies in the 12 semitones of the western musical octave. It distributes the energy in the twelve pitch classes. The pitch features are used for song similarity, Chord Recognition, note transcription [7], [9]-[11]. The tonic information is required for note transcription, chord recognition, singer or speaker recognition. The features such as zero crossing rate, autocorrelation, spectral flux, Root Mean Square energy are used to identify tonic [3], [4].

The techniques used for Raga Identification are mainly based on statistical modeling and Data Mining algorithms. Clustering is the unsupervised learning method. It finds the set of classes of interest, by applying the built-in assessment with the similarity measures. The widely used clustering algorithm is K-means. It is simple and fast in implementation but a limitation is the selection of the initial value of K centroid in advance. The final result is sensitive to the K value. It is susceptible to outliers. The time complexity of K-means is O (nkl) where n is the number of data points, k is the number of clusters and l is the number of iterations. K-means algorithm is used for Raga identification in [11], [12].The Classification is a technique which uses training data for learning. An important part of the assessment in the classification is extrinsic, and the groups must reflect some reference set of classes. K-Nearest Neighbor (KNN) algorithm is simple and fast but the computation cost is high. The limitation is the selection of the initial value of centroids, as the final results are sensitive to the centroid values. It gives effective result if training data is large. In ICM for genre classification, singer identification the KNN algorithm is implemented [11], [13]. The Decision Tree method uses a greedy approach for building the tree. It forms a tree on the basis of constrained specified for each feature. It uses properties such as entropy, information gain to determine which attributes are important. It proposes a set of rules that allows it to predict the class of a query item. It is suitable for the small set of data. It works only on discrete value attributes but not on continuous. The decision tree algorithms are used for Raga classification [11]. Support Vector Machine (SVM) classifier efficiently works for linear, nonlinear data classification. It constructs hyper-plane or set of hyper-planes which can be used for classification. The limitation of SVM is high speed and more memory required for both training and testing. It classifies even non-linearly separable data accurately by selecting the best kernel. The kernel is the function which converts higher dimensional input space in the lower dimension. In ICM, SVM is used successfully in Raga Identification of Carnatic music [11], [14], [15].

Hidden Markov Model (HMM) is a generative probabilistic model. It is a collection of different states and transitions among it. The Raga has very few Swaras so HMM effectively represents the Raga. The basic problems for defining the HMM are the probability of observation sequence, choosing optimal meaningful sequence, and how to maximize the probability of HMM by adjusting model parameters. The HMM is successfully used for Raga Identification and note transcription [16]-[18].

In this paper, Section II elaborates the earlier literature of ICM Raga identification and classification. Section III summarizes Challenges in future work. Concluding remarks are mentioned in Section IV.

II. Literature Survey

The section covers, review of various papers on Raga identification techniques for classifying ICM.

'Tansen' is the first Raga identification system. The researchers have used pitch features for the note transcription and derived the two note transcription methods, Hill Peak Heuristic, and Note duration Heuristic. In Hill Peak Heuristic the notes are identified on the basis of hills and peaks occurring in the pitch graph. The Note Duration Heuristic method is based on the assumption that in a music composition a note continues for at least a certain constant span of time, which depends on the type of music considered. The techniques δ occurrences with a bounded gap and n-gram matching are incorporated with HMM to strengthen pakad matching. The researchers exploited the similarity in the word recognition problem in speech processing and concluded that HMM can be used for representing and identifying the Raga. The HMM, which called as λ is defined as $\lambda = \{N, A, \lambda, B\}$ Where, N is set of state of symbols. Each note in each octave represents one state. The total number of states N=12, notes per octave $*$ 3 octaves=36 notes. The transition probability set, $A = \{A_{ij}\}$ represents the probability of note j appearing after note i in a note sequence of the Raga represented by λ. The initial state probability $\{\pi_i\}$ represents the probability of note i being the first note in a note sequence of the Raga represented by λ. $\{B_{ij}\}$ is the outcome probability [16].

The Chroma features are robust to noise and independent of timbre, loudness. A chromagram or PCP visually represents the energies in the 12 semitones of the western musical octave. It is a set of features implemented by Fujishima in 1999 for Chord Recognition. The musical pitch has two dimensions height and chroma. The height of pitch moves vertically in octaves telling which octave it belongs and the chroma tells where it stands in relation to others within an octave. PCP is based on constant Q transform which is a filter bank with geometrically spaced center frequencies. $f_k = f_0^{2k/b}$ where b is the number of filters per octave and f_k is the frequency of k^{th} filter bank. The bandwidth of the k^{th} filter could be defined as (1)

$$B_k = f_{k+1} - f_k = f_k * (2^{1/b}-1) \quad (1)$$

The 'Q', constant ratio of frequency to the resolution is given, in (2)

$$Q_k = f_k/b_k = (2^{1/b}-1)^{-1} \quad (2)$$

The constant Q transform is well suited for the music because it mirrors the human hearing system, which has better resolution at low frequencies and temporal resolution improves at higher frequencies. The constant Q transform of signal x (n) is calculated, as per (3)

$$X_Q[k] = 1/N[k]\sum_{n=1}^{N[k]} W_{Nk}[n]x[n]e^{-2\pi jQn/N[k]} \quad (3)$$

where, N[k] is window length of each frequency bin. W_{Nk} is the window of size N[k]. After getting constant Q transform, pitch class mapping to the histogram is performed, with (4)

$$n = 12 * \log_2(f/f_{est}) + 69 \quad (4)$$

where n is the histogram bin, f is the frequency in Hz, f_{est} is the pitch offset with respect to which we want to estimate the pitch. The PCP can be further compact into chromagram. A chromagram visually represents the energies in the 12 semitones of the western musical octave [19].

The researchers have developed a system using Pitch Class Distribution (PCD) and Pitch Class Dyad Distribution (PCDD) based on PCP features. The motivation of using PCD was to check the concept of tone in western music is applicable to ICM or not. The HPS pitch detection algorithm is applied to identify the pitch of the every frame of size 40ms [20]. The PCD was calculated by taking a histogram of pitch tracks. In future the consideration of a larger database with loud and complex accompaniment and robust methods for analyzing melodies with gliding tone to be focused [11].

A Raga recognition system for the Carnatic music is developed in 2009. The vocal signal is separated from the audio signal. The segmentation was based on Talam (Rhythm) and then sub-segments of the Talam. The frequency components are identified for every sub-segment of the Talam. The mapping of the frequency component and the Swara is performed with respect to the tonic and ratios of other Swaras to Sa. The name of the singer and tonic is stored in a database for every sample. To get the tonic, the singer for the given input is first identified and then tonic from the database is retrieved. After getting the singer name and tonic frequency, the highest energy Swaras are identified and mapped to other Swaras. The Swaras are compared with the Aaroh, Avaroh in the Raga database by using string matching algorithm to identify the Raga. To improve the performance and make generic system researchers are intend to extend the work using HMM and automatic tonic detection [3].

In reference [17] the transition probability based representation and identification of Raga, is implemented. The objective of the paper was to create the cognitive reasonable representation of Raga. The note transcription is performed manually. The Transition Probability Matrix (TPM) is 12 × 12 dimensions as 12 notes are considered in ICM. The TPM stores Swara transition values in the performances. The value of TPM(i, j) is calculated by counting how many times j is coming after i. Ten TPM were generated for ten different Ragas. To validate the TPM, the aaroh and Avaroh sequences are generated from TPM and cross checked with the Hindustani classical music literature. To create Aaroh sequence, starting from S the highest probability transition is selected and continued till S from next octave reached. The Avaroh sequence is created with similar way only from higher octave to lower octave. The testing of TPM representation is done with 100 sequences. The score is calculated for each sequence with TPM using Euclidean Distance and then allocated to the TPM having the highest score. All the sequences were correctly classified, which shows the successful representation of Raga using TPM. The similarity between two Ragas was calculated using Euclidean Distance between the TPMs of the two Ragas. The results proved that the TPM is a very good template to represent and classify the Raga. The wastage of memory is occurring, if the Raga has less number of Swaras. The system failed to capture any temporal aspect associated with melodic progression. The TPM represents on single step transition Markov Model, by increasing steps efficiency of classification may increase. In future TPM could be used for comparing Ragas of Carnatic and Hindustani music represented by using it.

The researchers have developed a Raga mining system for Carnatic music, using neural network concept. To identify the fundamental frequency the autocorrelation method is implemented on every frame of 50ms. The Note transcription is done by considering Shruti ratios with respect to the fundamental frequency. The Shruti Ratios gives the Swaras of every song. The features extracted from every song are Swara combination sequence, the number of Swara used, vakra pairs in Aaroh and Avaroh. The Swara sequence is represented by bits and then decimal value is calculated for the same. The Artificial Neural Network (ANN) is constructed with 6 input variable and 1 output variable. The six input variables are the number of distinguished Swaras, Swara combination sequences, Aaroh vakra pairs in two variables, Avaroh vakra pairs in two variables. The system could be enhanced for polyphonic audio signal input by generating a complete Swara script containing notes and rhythm information [21].

A Raga identification method is developed using statistical classification based on the intonation of Swaras in 2009. The polyphonic signal is converted into the mono channel with sampling rate 22050Hz, 16 bits per sample. The tonic is detected manually and stored in the database. The system extracted the pitch features and calculated the folded pitch distribution. The Peak, Mean, Standard Deviation i.e. Sigma and overall probability of each Swara is extracted for each segment. A Peak value gives frequency information of mostly used Swara. The Standard deviation gives information of how much variation occurred while performing. If the Swara is not used but only glided through then peak and mean come same otherwise they have lot difference. The probability of Swara was computed by adding the probability of occurrence of each bin in the partition corresponding to that swara. The Nearest Neighbor Classifier is used for classification of Raga. To calculate the similarity between PCD the Kullback-Leibler (KL) distance measure is used. The swara features are represented as 48 (12 Swaras × 4 features) dimensional vector. The combination of Euclidean Distance and KL distance is used to measure the similarity between the Swara [22].

In reference [23], a survey of Raga Recognition techniques is done and some improvements to smooth out the minor fluctuation within the steady notes are suggested. The pitch extraction is performed for every frame of size 10ms. The local slope of the pitch contour is used to differentiate stable note regions from connecting glides and ornaments. The pitch value is compared with its two neighbors to find the local slope. The pitch values are quantized to the nearest available note in the 220Hz equi-tempered scale. This step smoothen the minor fluctuations within intended steady notes. The 12-bin histogram is taken for steady notes identified above. The note values are weighted by two ways first weighting by a number of instances (P1) and second weighing by total duration over all instances (P2). The KL distance measure is used to find the similarity in two PCD while classification. The 12-bin histogram of P2, yielded the highest accuracy. The experiments of classification are conducted with different k values. The accuracy is improved with increasing k value. The output of Gamak processing was not as expected, because of fewer efforts in designing intonation of notes within micro-intervals. The researchers wanted to extend the work identify a Gamak in the Raga.

In reference [14], to identify the Ragas of Carnatic Music the researchers proposed a method based on two different features PCP and n-gram distribution of notes. A Kernel is defined for PCP that defines the similarity of Raga based on pitch class distribution. To find the similarity between the two pieces of music the KL divergence for comparing histogram is used. The other Kernel is defined for n-gram distribution of notes. Once the notes are identified the n-gram histograms is constructed. The two different and relevant histograms are incorporated in SVM framework by defining a combined kernel over them. A Non-linear SVM is used for the classification of the Raga. The researchers have compared their work with the system developed in [23] and observed improvement in result.

The above papers were referred static tonic frequency. In the reference [10], the researchers have proposed the scale independent way to identify the Raga. The Swaras plays very important role in Raga, so its value needs to be identified accurately. The maximum frequency semitones in each frame are extracted from chromagram. As the approach is independent of scale so the mapping of absolute frequency scale to the relative scale of music piece is done based on the most frequently occurring semitone i.e. Vaadi Swara and then rest of the semitones mapped to other Swara sequence. The researchers observed that, if the Ragas have same Vaadi and Samvadi Swar then some misclassification is occurred.

The two Ragas can have the same number of Swaras or even same sequence of Swaras but the pronunciation may be different. To understand the relevance of motifs in distinguishing the Raga, the researchers have developed a system by considering five ragas from Carnatic Music with the specific fundamental frequency. Initially, the most frequent motifs are marked manually. The pitch contour is extracted for the manually marked motifs. HMM structure is defined, based on the notes in a motif phrases. The experiments were performed on fifty motifs from above Raga. The authors observed that the motifs are identified correctly if the phrases are long enough. The authors observed that, the significant understanding of meter and acoustic is necessary for identifying motifs in input sample [24].

The melodic motif is the characteristics phrase of a Raga. The motif ultimately defines the signatures of the Raga which is useful in Raga identification. So in reference [18], [25] researchers worked on identification of melodic motifs of the input signal.

In reference [25] the signal is divided into segments based on Tala to get melodic motifs. The repeating patterns are identified from the segments. To find the similarity in the segments, Dynamic Time Warping distance measure is used. The researchers want to extend the work by using unsupervised clustering of phrases for large dataset of concerts.

In reference [26] based on the results, the authors found that the melodic patterns similarity is particularly sensitive to distance measures and normalization techniques. They have proposed similarity measures to exploit melodic features of the input signal. To find the similarity in the segments Dynamic Time Warping distance measure issued. They observed that the Dynamic Time Warping distance measures performed better than Euclidean Distance measure. In the future work authors mentioned to make use of other aspects of melody like loudness and timbre while calculating similarity.

The repeating patterns are not always interesting and relevant, so in reference [27] authors have generated similar patterns across one-liners of a Raga. The one liner is defined as lines from Pallavi, Anupallavi and Charanam sections in Carnatic Music. The typical motifs are filtered from these patterns, by using compositions of various Ragas. The Motifs are considered typical if they are distinctly present in a particular one Raga and not in other. The authors want to extend the work by automatic detection of one-liners.

TABLE I. DATASET AND TECHNIQUES USED

Sr. No	Ref. No	No. of Ragas in Dataset	Techniques used	Results in (%)
1	[3]	03	Pitch values and string\\ matching algorithm	60
2	[10]	08	Pitch values and Random Forest	94.28
3	[11]	31	PCD,PCDD and SVM,KNN, Decision Tree	82
4	[14]	10	PCP and Non linear SVM	83.39
5	[16]	02	Pitch values and HMM	87
6	[17]	10	Manually detected Pitch values and HMM	100
7	[21]	20	Pitch values and ANN	95
8	[22]	04	Pitch values and KNN	80
9	[23]	10	PCD with weighted KNN	76.5

In reference [28], [29] authors tried to mimic the listener. They developed Raga verification framework. In [28] authors identified correct Shadja and based on that other Swaras which further used for Raga verification. In reference [29] Longest Common Segment Set is identified using Dynamic programming approach. Authors noted that the framework is scalable and will work for any number of Ragas.

The Table I give the information about the dataset and techniques used in the surveyed papers with their identification results as mentioned in references.

III. Summary

On the basis of literature survey, the challenges found are as follows:

1) The systems are developed with very restrictive input and most of the authors have prepared their own dataset. The standard datasets are not available like western music.
2) The fundamental frequency or tonic or signer is assumed to be static.
3) The results of the existing systems are claimed fairly good but are they satisfactory when the dataset is huge or linearly non-separable?
4) The Melody is a very important factor in the Raga and it comes by characteristic phrases and Gamak. Very few systems are developed by considering motifs but in that dataset considered is limited to two-three Raga.
5) The collective use of Melody, Harmony, Rhythm and Texture in Raga Identification.
6) The researchers have mentioned the future scope as to develop a more generalized system by considering all the Ragas from ICM, but no literature is available, why it is not yet implemented? The reason may be the lack of storage space and processing speed required for implementation.
7) In recent years, the researchers have to concentrate on improving the accuracy with the efficiency.

IV. Conclusion

The rationale of this paper is to present a review of work done related to classify the Raga in ICM and identify the future research directions. A paper gives a brief introduction about ICM, characteristics of Raga, classification techniques, and feature extraction techniques for ICM. The emphasis is given for finding limitations in the existing work to get directions to the researchers for the future work.

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