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Raga Identification Techniques of Indian Classical Music: An Overview

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ABSTRACT*: Raga plays an important role in Indian classical music. Raga consists of different characteristics which make each raga unique in it. Raga is sequential collection of swaras and it is divided into two systems Hindustani (North Indian) music, Carnatic (South Indian) music. In this paper, we discussed basic introduction about raga identification. We surveyed the different raga identification techniques such as scale matching, arohana avarohana pattern, statistical approach and Pakad matching, Pitch class distribution (PCD) and pitch class dyad distribution (PCDD), An unsupervised statistical approach: LDA model, swara intonation. We reviewed these techniques with their system structure and results obtained by them. We have identified the challenges associated with raga identification and related future work.*

Keywords : *Indian classical music, Pitch, Raga identification, Swara,*

I. INTRODUCTION

Indian classical music is different from western music. Raga plays an important role in an Indian classical music. Raga consists of different characteristics that are not easy to extract or mine by applying the approach that is used for the identification of western music. By this some properties of raga may be lost. Hence there is a need for the different data mining techniques for raga identification. Raga is a collection of different notes that are having some special properties (e.g.arohana-avarohana, Pakad, Taal, etc.). Raga is divided into two system Hindustani (North Indian) music, Carnatic (South Indian) music. Both of these systems differ in their characteristics and performance. Raga is having special characteristics of their timing, that depend on their nature they can be played in different timeslots of the day. Notes of a raga arranged in an ascending order forms arohana of that raga and notes of a raga arranged in a descending order forms avarohana of that raga. Different notes are called swaras in Indian classical music.

Raga identification consists of techniques that identify different notes from a piece of music and accordingly classify it into the appropriate raga. Raga Identification is a process of listening to a piece of music, synthesizing it into sequence of notes and analyzing the sequence of notes for identifying the raga it follows. Ragas are sometimes defined as melody types. The raga system is a method of organizing tunes based on certain natural principles. Tunes in the same raga use the same (nominal) swaras in various combinations and with practice, the listener can pick up the resemblance. Indian classical music is defined by two basic elements-it must follow a Raga (classical mode), and a specific rhythm, the Taal. In any Indian classical composition, the music is based on a drone, i.e. a continual pitch that sounds throughout the concert, which is a tonic. Each raga has a swaroopam (a musical form or image) that is defined by the swaras used, the gamakas given to these swaras, the progression in which the swaras occur etc. Arohanam is the sequence of swaras used in a raga in the ascending passages i.e. as the pitch goes up. Avarohana is the sequence of swaras to be used in descent. The arohana and avarohana (or the scale) of a raga provide only emaciated outline upon which the rest of the raga is formed.

II. THEORETICAL BACKGROUND

Indian classical music is mainly based on the raga and its different characteristics. Raga is equivalent to the melody but it seems more complex than melody in western music. Raga is a collection of different notes that are having some special properties (e.g. arohana, avarohana, Pakad, Taal etc.).

A. Swaras or shrutis or notes:

Raga is a sequential arrangement of swaras or notes. Different notes are called *swaras* in Indian classical music. The basic seven notes in classical music are S (Sa),R (Re or Ri), G (Ga), M(Ma), P (Pa), D (Dha), N(Ni) which can be considered as analogous to the C, D , E, F, G, B, A. In another way we have 12 swaras or shrutis in Carnatic music, S, r, R, g, G, rn, M, p, d, D, n and N.

Note can be identified in Carnatic Music from Frequency Spectrum. Prashanth T R, Radhika Venugopala proposed system for note identification with the help of frequency spectrum characteristics of the given sample.
A raga is classified into melakarta (parent) raga, janya (child) raga depending on the collection of notes. A melakarta Raga will have all the seven swaras and a janya raga will have at least 5 of seven swaras.

B. Arohana and Avarohana:

Ragas consist of collection of swaras or notes. Depending on collection of notes or swara combination and arohana and avarohana, raga forms its unique identity. Arohana is subset of collection of raga notes that are arranged in ascending sequence. Avarohana is subset of collection of raga notes that are arranged in descending sequence.

C. Gamakas

A note has a specific and fixed frequency value. Notes in a raga are arranged in a way that there is continuous oscillatory movement about the note, such arrangement of notes is called as gamakas. Gamakas can be of 10 types, arohana, avarohana, ahatha, pratyahata, sphurita, tripucha, dhalu, andolitha, kampitha, and murchchanai gamakas.

D. Pakad

A Pakad is a characteristic phrase or set of swara which uniquely identify a raga. For each raga there is a unique and different Pakad from other raga.

III. TECHNIQUES FOR RAGA IDENTIFICATION

There are different data mining techniques which automatically identify the raga for given music sample. In this section, we have presented a survey of previous system which was dealing with the raga identification. We discuss the different approaches, implementations and results. In the next section we present issues regarding these systems. Previous computer based approaches for raga identification have based themselves on the properties of raga such as, scale used, arohana- avarohana pattern, pitch class and pitch class dyad distribution ,and pitch captured by n-grams or HMM, swara intonation. The needed input is collected by note transcription, labeling swaras, etc.

3.1. Scale Matching

Sridhar and Geetha [1] used an approach to identify raga based on scale used in the sample and it is compared with the scale stored in the database. The raga that is matched with the raga stored in the database is the resulting raga and output of the system. Their test data consists of 30 samples in 3 melakarta ragas sung by 4 musicians, 175 Talam, raga database having raga name, arohanaavarohana in swara component form. It consists of following steps:

- In this input music signal is separated into voice and music (**signal separation**).
- Then **onset detection** (onset is beginning of music, in which amplitude rises from zero to an initial peak) is made on the music through taking input as copy of signal ,convert it in spectral energy, map these individual points into time domain signal and finally mark that as onset.
- Then in similar way **offset detection** is made and then signal between points of onset and offset is taken.
- Then **first level segmentation** is done by matching output of onset and offset detection as segmented signal with Talam stored in database.
- **Second level segmentation:** The segment is divided into one, two or four individual Talam segment (i.e. swaras) depending on tempo in which song is sung.

Feature extraction: HPS algorithm is used to determine frequency component for each swaras. Fundamental frequency which normally corresponds to S swara is determined from the singer identification.
Frequency mapping and Raga identification: Swara correspond to every frequency is identified by ratio available, used these swaras and compared with swaras correspond a particular Raga in the raga database.

3.2. Arohana –Avarohana Pattern

Shetty, Achary [4] have used an approach for identification of raga based on arohana- avarohana pattern. In this system, test data consists of 4 song of each 20 raga, input as 6 features x1- number of distinguished swaras, x2-swara combination,
x3, x4- arohana vakra pair's values, and x4, x5- avarohana vakra pairs values. It consists of following steps:

Note transcription: It is the conversion of input song into sequence of notes i.e. swara script. In this frequency extraction is done through finding fundamental frequency of each segment and converting it into swaras.
Feature extraction: From input files, swara combination, number of swaras used in raga, vakra pair in arohana and avarohana. We find out the vakra pairs and assigned a value according to which 6 features x1- x6 are generated for non-linear raga. For linear raga, no vakra pairs, feature value will be zero.
Training and testing: A neural network is used for the training purpose. Features x1-x6 of two or three song is selected at random and given as input to training system. System generates weight according to input given. This is tested which gives output indicating raga identification.

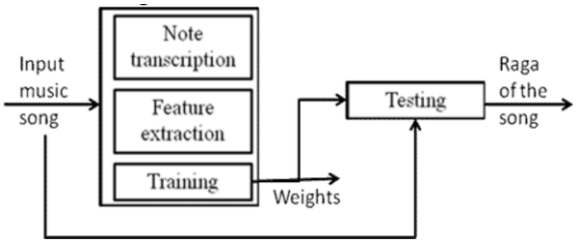

Fig.1.System structure for arohana avarohana pattern.[4]

R.Sudha, A. Kathirvel, RMD.Sundaram [3] used similar type of system of Tool for Identifying Ragas using MIDI. In their work they used same system structure discussed above for note transcription. Further work they performed based on technique used for scale matching with the help of frequency mapping, raga annotation, pitch detection (onset ,offset segmentation), use of swara features. They used 70 songs for train work and performed feature extraction on 90 songs of 50 ragas. Prashanth T R, Radhika Venugopala [14] proposed a system for Note Identification in Carnatic Music from Frequency Spectrum. Instead of using note transcription one can also identify only notes in the input song. Their system takes '.wav' files as an input, frequency spectrum characteristics are analyzed and depending on that they mapped notes. Their test data consist of 15 raga alap with 3-8 min clip of various artists. They have achieved up to 90% of accuracy.

3.3. Statistical Modeling and Pakad Matching

Pandey, Mishra, Paul [9] proposed the system'Tansen' which is based on Hidden Markov Model and string, Pakad matching. Their test data consists of result on only 2 ragas Yaman kalian and Bhupali. They used HMM model because notes are small in number and the sequence for raga is very well defined. Baum Welch learning algorithm is used for identification of transition and initial state probability in HMM algorithm. Again for improving performance over HMM, Pakad matching approach is used by incorporating knowledge into the system. There are two ways for matching Pakad with input string of note to enhance our result.

- *δ-Occurrence with α-Bounded Gaps:* Dynamic approach in which individual note from piece(t) is matched with notes in sample(p) with condition that

1) There should be maximum difference of δ between current note of p and next note in t.
2) Position of occurrence of note t in p is displaced at most α.

Based on above score calculation is done, which is used as input for final determination of raga.

- *N-gram matching:* n-gram matching approach count frequency of successive n-gram of the Pakad. Successive n-gram of a string is its substring that starts with first character or note in string and go on till end of string met. For example successive 3-gram of string ***abcdef*** are ***abc, bcd, cde, def.*** Based on above another score calculation is done, which is used as input for final determination of raga. Final determination of underlying raga is based on three step procedure that are,

- Store values in increasing order of probability of likelihood $prob_r$
- Values γ_r score of δ-Occurrence with α-Bounded gap approach is stored in increasing order,
- Otherwise final determination of raga is based on a specific formula.

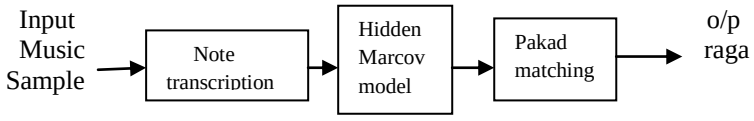

Fig.2. System structure statistical modeling and Pakad matching.

Note transcription is done through two heuristics which convert input audio sample into sequence of notes. The two heuristics are as follows:

- The Hill Peak Heuristic: This heuristic identifies notes from input audio sample based on hill and peak value in its pitch graph.
- The Note Duration Heuristic: First of all the assumption is made that a composition of music continues for at least some constant amount of time or duration. Based on value of constant duration of a note, notes in a sample are found. HMM approach is also used for automatic raga recognition for Carnatic music which is proposed method given in [7, 8]. Here in this raga recognition is made on the melakarta ragas. The HMM model is defined first and then used for raga recognition. Tansen is build to identify two ragas Yaman Kalyan, Bhupali.

3.4. Pitch Class Distribution (PCD) and Pitch Class Dyad Distribution (PCDD)

Chordia, Rae [5] used pitch class distribution and pitch class dyad distribution for the identification of raga. Their test data consists of 20 hours of recorded performance in 31 different ragas by 19 different performers. Individual recording were segmented into 30 sec and 60 sec chunks. Classification of raga is made by using Support Vector Machine (SVM), Maximum A Posteriori (MAP) rule using Multivariate likelihood model (MVM) and Random Forests. Initially annotation is done trough labeling each raga sample with frequency value. Then pitch detection is done on sample segment using Harmonic Product Spectrum (HPS) algorithm. Thresholding complex Detection Function (DF) on each segment, note onsets are determined.

Pitch class distribution (PCD): It is calculated by taking histogram of the pitch tracks. For each notes of chromatic scale the bins associated segment is found out and bins are centered about the tonic for segment. The five octaves then folded into one and their values are normalized to create a pitch class distribution.

Pitch class dyad distribution (PCDD): The note onset is used to segment pitch tracks into notes instead that of histogram for pitch tracks. Each note is labeled with a pitch class label. The octaves for notes were folded into one. The pitch classes then arranged in group of two (bi-grams), or in musical term it is called as dyads, which creates pitch class dyad distribution.

3.5. An Unsupervised Statistical Approach: LDA Model

Sridhar, Subramanian [2] proposed a method for raga identification based on Latent Dirichlet Allocation (LDA) model. The assumption is made that notes of a given music piece can be mapped to words in a topic and topic in a document can be mapped to a raga. The first step in LDA model process is to identify notes of a given signal. They used raga lakshana characteristics. Dirichlets distribution is used for distribution of words in a given topic. Then they used 4 length patterns to derive parameters α as K dimensional parameter and θ as topic weight vector. For each raga LDA parameters α and θ are constructed by initially assuming a constant value for each raga. The value of θ which is unique for each raga is computed by using sequence of notes. The value of parameters α and θ are then matched with constructed LDA model for identification of raga. Characteristic phrase determination is done by swara identification. Swara identification is done by identifying fundamental frequency, frequency component. Frequency component are identified by using Fast Fourier Transform on each segment. LDA construction is done by using 4 length pattern combination and computing parameters α and θ. Sridhar, Subramanian used pseudo code algorithm for construction of LDA which is as follows:

Algorithm: LDA Construct ()
{
Determine 4 length pattern combinations and assign equal probability.
For every Raga
{
Compute *α*: Choose songs belonging to all Ragas by assigning a little weight if 4-length pattern found in given song.
Compute θ: Choose song belonging to one Raga weight if 4-length pattern found in given song add a little weight by choosing from α.
Re compute α using computed θ vector.
}
}

3.6. Swara Intonation

Belle, Joshi, Rao [6] proposed a method pertaining to swara intonation on Hindustani classical music. Their test data consist of 4 ragas Desh, Tilak Kamod, Bihag, Kedar, Desh and Tilak Kamod use same scale. Bihag and

Kedar use same scale. All performances for different raga are converted into mono channel. There are 4 important steps in their experimental methodology as follows.

Pitch Extraction:

Raw audio waveforms of selected segments were passed to polyphonic melody extractor for detecting pitch of singing voice. Pitches extracted every 20 ms to found out pitch contour and to correct any vocal detection or pitch tracking errors. Further steady note sequences are extracted.

1.*Folded Pitch Distribution:* Pitch distribution was folded into one octave to compute an FPD. Then FPD was normalized by dividing value in every bin by sum of all bins. This gives peak value and bin containing peak is considered as tonic bin. The FPD then rotated so that **tonic bin** becomes first bin.

2.*Pitch Class Distribution:* PCDs are distribution with 12 bins of which each represents probability of occurrence of 12 swaras over one octave. Each bin centered about their corresponding swara center and boundaries of bins are founded. PCDs were constructed from tonic aligned FPDs.

Swara Features:

FPDs divided into 12 partitions of 100 cents each. Four features for each swara peak, mean, sigma and prob are extracted from FPD of each performance segment. Peak, Mean, sigma, prob corresponds to most likely position, mean position, standard deviation, overall probability of a swara (in cents). Peak, Mean, sigma, prob are swara feature from various segments. For classification they used Nearest Neighborhood Classifier with leave one out cross validation. To compute distance between various instances they used Kullback Libeler (KL). Distance between swara features were computed by using combination of Euclidean distance and KL distance. The automatic tonic detection can also be done through using special algorithm used in ninad [9]. This tonic detection is especially made for the Hindustani classical music. The technique is based on the preprocessing of the input data or song.

IV. CHALLENGES

For automatic raga recognition there are many limitations involve with respect to different aspects of dataset/ database, algorithm used, raga characteristics, etc. Raga recognition is not a simple technique. It involves analysis of large amount of database with sufficient knowledge about raga and also requires training for raga recognition. For different steps involve in raga recognition by different approaches there are many challenges associated with them. Different challenges with raga identification are discussed below:

- Limited database containing limited number of raga.
- Incorrect pitch extraction.
- Manual tonic detection.
- Assumption made for different parameters of algorithm.
- Different constraints on inputs, such as limitation to singers, number of swaras, time length, monophonic type.

V. CONCLUSION

A brief introduction about raga is discussed. The characteristics of raga that make them sufficient to be identifiable from each other are introduced. Past raga identification techniques are surveyed with introduction to their basic system structure. Apart from this we have also discussed about the test data used by the techniques. The different techniques are better than other technique depending on the input parameters and on constraint on the input and on method. The scale matching, arohana- avarohana pattern, statistical approach and Pakad matching, Pitch class distribution (PCD) and pitch class dyad distribution (PCDD), An unsupervised statistical approach: LDA model, swara intonation techniques are based respectively on scale stored in database given at the training time, arohana- avarohana and vakra pairs in given sample HMM model built, pitch distribution in given music, raga identification parameters α and θ, and finally on swara features peak, Mean, sigma, prob. The improvement over raga identification can be made by improving previous technique with removal of challenges associated with it or by introducing new technique having steps which are challenge free. There is lots of limitation associated with the techniques discussed above for raga identification. In future the improvement over the technique can be done by removal of limitations on that technique. Lot of work is done for western music but less for Indian classical music. The other technique can be build for raga identification with other or similar type of technique used above, with no assumptions and that will have good result for raga identification.

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