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A SURVEY ON TECHNIQUES OF EXTRACTING CHARACTERISTICS, COMPONENTS OF A RAGA AND AUTOMATIC RAGA IDENTIFICATION SYSTEM

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Abstract: This paper gives a brief survey of several techniques and approaches, which are applied for Raga Identification of Indian classical music. In particular to the problem of analyzing an existing music signal using signal processing techniques, machine learning techniques to extract and classify a wide variety of information like tonic frequency, arohana and avaroha patterns, vaadi and samvaadi, pakad and chalan of a raga etc., Raga identification system that may be important for different kinds of application such as, automatic annotation of swaras in the raga, correctness detection system, raga training system to mention a few. In this paper we presented various properties of raga and the way how a trained person identifies the raga and the past raga identification techniques.

Keywords : Indian classical music; raga; signal processing; machine learning.

1. INTRODUCTION

The Music can be a social activity, but it can also be a very spiritual experience. Ancient Indians were deeply impressed by the spiritual power of music, and it is out of this that Indian classical music was born. So, for those who take it seriously, classical music involves single-minded devotion and lifelong commitment. But the thing about music is that you can take it as seriously or as casually as you like. It is a rewarding experience, no matter how deep or shallow your involvement. Indian classical music (both Carnatic music and Hindustani music) is known for its technical soundness and its well defined structure which is defined by two basic elements Raga, and a specific rhythm (Taal). The Sanskrit word raga which means colour or passion. Therefore raga may be thought of as an acoustic method of colouring the mind of the listener with an emotion. Raga is popularly defined as a specified combination, decorated with accompaniments and graceful consonances of notes within a mode which has the power of evoking a unique feeling distinct from all other joys and sorrows and which possesses something of a transcendental element.

A given raga will use between five to twelve tones. From this, one can derive thousands of scale types. An expert in Indian classical music can identify a Raga just by noticing the unique properties of Raga such as tonic frequency, swaras, arohana, avarohana, vaadi, samvaadi, pakad, chalan, etc, in the performance, developing a system for the same has been a challenging task for researchers. The freedom that Indian classical music provides to an artist to give his/her own personal flavor to a raga makes it harder for a novice to identify two different performances of the same raga. There has been a tremendous

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progress in Music content analysis [1], musical genre detection [2] and instrument, singer identification [3] etc., in Western Classical Music where it is based on an "equal temperament" meaning the 12 notes of an octave are equally spaced. Coming to Indian classical music, the same has been a challenging task for researchers, because the equal temperament does not work much. The Indian music system has great significance for the intervening notes between the 12 notes. Certain ragas use certain notes that are sharp or flat than the western counterparts.

In this paper, we discuss various components of raga by keeping in the mind about Hindustani music in particular and the applications of Automatic raga identification system. Further, we present a brief survey of various signal processing methods and machine learning techniques used by researchers for identifying various components of raga and/or to identifying raga.

2. COMPONENTS OF RAGA AND DEFINITION OF TAAL

A Swara is a distinct tone that is reproducible and pleasing to the ear. There are 7 main Swaras (Sa, Re, Ga, Ma, Pa, Dha and Ni) and 5 variants (Komal Re, Komal Ga, Tivra Ma, Komal Dha and Komal Ni).

There are a few broad rules that are specified for each raga. For instance, the presence and absence of certain swaras, which notes can be used when climbing up, and which can be used when climbing down, down to the level of microtones.

Ragas have prescribed home notes (griha swara), dominant (vaadi), subdominant (samvaadi) and dissonant (vivaadi) notes, landing and resting notes (nyaasa) and so on. This section deals with the raga related components.

(a) ***Scale – Tonic Frequency:*** Unlike the case in Western music, the musical notes used in Indian music are not at standardized frequencies. One may choose any frequency of convenience as the reference, and this frequency would then act as the tonic or base of references for the raga to be presented.

(b) ***Arohana – Avarohana:*** Raga consists of collection of swaras or notes. Depending on collection of notes or swara combination and arohana and avrohana, raga forms its unique identity.

Arohana is subset of collection of raga notes that are arranged in ascending sequence. Avrohana is subset of collection of raga notes that are arranged in descending sequence.

(c) ***Vaadi – Samvaadi – Anuvadi – Vivadi:*** Vaadi is the most prominent note of the raga which gets emphasized in the raga and used very often. Samvaadi is the second most important note of the raga, it is used lesser than Vaadi but more than the other notes of the raga. The notes other than vaadi, samvaadi are called anuvadi notes. Vivadi is the note which is not present in the raga. But still a vivadi swar is used in raga by able singers in such a way that it enhances the beauty of the raga. This is done very rarely.

(d) ***Jaati:*** Jati gives the number of notes in Arohana as well as the Avrohana of the raga. Raga are classified based on the number of swaras in the arohana and avrohana. Sampoorna is all 7 swaras, Shadhav is 6 swaras, Audhav is 5 swaras and Surtar is 4 swaras.

(e) ***Pakad – Chalan:*** A small group of notes, which describe the unique features of the raga. In Hindustani music, a pakad is a generally accepted musical phrase (or set of phrases) thought to encapsulate the essence of a particular raga. The pakad contains the melodic theme of the raga, on listening to the pakad a person who knows the raga is usually able to identify it.

The chalan can be thought of as an expansion of the pakad. Chalan literally means movement. There may be Ragas without a pakad for which there are chalans. The chalan demonstrates the melodic outline of a Raga. A Raga's chalan shows one the characteristic ways of using clusters of notes or clusters of phrases in the development of a Raga. A Raga may have the same or similar notes, arranged in the same way in the arohana and avarohana, however the chalan can show how different clusters of notes are deployed in each Raga differently.

(f) ***Gamaka:*** Gamakas refers to ornamentation used in the performance of Indian music. Unlike Western music, Indian music do not have a fixed frequency for a swara (note) and can have various variations (movements) around a note. These variations are called as Gamakas. The variations can occur in multiple forms. For instance, it could be a rapid oscillation around a note or a slow transition from one note to another. For every raga, only a certain type of Gamakas (variations) is allowed around a swara giving an important clue for identification.

(g) ***Thaat:*** Thaat system was invented by Vishnu Narayan Bhatkhande. It is the system of classification for the ragas in different groups. Each one of the several traditional ragas is based on, or is a variation of, ten basic thaats, or frameworks. The ten thaats are Bilawal, Kalyan, Khamaj, Bhairav, Poorvi, Marwa, Kafi, Asavari, Bhairavi and Todi. If one were to pick a raga at random, it should be possible to find that it is based on one or the other of these thaats. For instance, the ragas Shree and Puriya Dhanashri are based on the Poorvi thaat, Malkauns on the Bhairavi, and Darbari Kanada on the Asavari thaat.

(h) ***Taal:*** Taal refers to a fixed time cycle, set for a particular composition, which is built from groupings of beats. Talas have cycles of a defined number of beats and rarely change within a song. They have specific components, which in combinations can give rise to the variety to exist, allowing different compositions to have different rhythms.

2. APPLICATIONS

- Automatic Song Composition: A raga Identification System can be extended / modified to automatic song composition system for light music like film songs, bhakti sangeet, etc.,
- Music Emotion Recognition system: Many issues for music emotion recognition have been addressed by different disciplines such as physiology, psychology, cognitive science and musicology. Focus on recognizing music emotions based on subjective human emotions and acoustic music signal features and present an intelligent music emotion recognition system.
- Automatic Tagging / Annotation: Automatic content tagging of unorganized digital music is important to generate metadata for available data and thus facilitate creation of easily accessible databases.
- Music Recommendation System: In the Indian system Ragas are associated with emotions, time of the day, and seasons of the year. For queries based on such criteria, a proper recommendation system can make appropriate choices using Raga identification as a base.
- Music Tutoring / Correctness Detection System: A Raga identification system can be modified to a tutoring or correctness detection system as well. While achieving this for a complex professional musical performance might be difficult, yet using it for cleaner and simpler instrumental versions of a Raga may give positive results. Mistakes like skipping some swaras or a particular rule not being followed can be identified by such a tutoring system.
- Raga Generation: Within some broad rules, Indian classical music allows a performer to modify the components of Ragas according to his creativity to create his own personalized performance of that Raga. Generative models induced from human Raga performances can be used to synthesize new Raga performances that can be made unique or personalized by injecting controlled randomness or variations.

- A Facility of Artist / Instrument change: The notations of the same raga performed by one artist (instrument) can be converted to another artist (instrument).

3. METHODOLOGIES OF RAGA IDENTIFICATION SYSTEM

An expert in the Indian classical music looks for characteristic phrases like tonic frequency, Arohana-Avroha, Pakad-Chalan etc. to arrive at a conclusion about the raga. This well defined manner of raga identification using the above properties has motivated researches to conceptualize computational models for them. In this section, we present a survey of previous systems which dealt with raga identification using the above properties. We discuss the different approaches, implementations and results.

(a) ***Tonic Identification:*** One of the fundamental components in Indian classical music is the tonic frequency (base pitch). The tonic is chosen by the performer which serves as the foundation for the melodic tonal relationships throughout the performance. Consequently, all accompanying instruments are tuned with relation to the tonic chosen by the lead performer. When considering the Automatic raga identification system of Indian classical music, it becomes evident that identifying the tonic is a crucial first step.

Justin Salamon, Sankalp Gulati and Xavier Serra [4] proposed a method for tonic identification in Indian classical music based on a multi-pitch analysis of the music signal. In the first step of the method, sinusoidal components (spectral peaks) from the music signal are extracted. In the second step extracted spectral peaks are used to compute a salience function which is a multi-pitch time-frequency representation of pitch salience over time. The peaks of the salience function represent the pitches of the voice and other predominant instruments present in the recording at every point in time. In the third step by computing a histogram of the pitch values for the entire extract, most often repeated pitches are obtained throughout the excerpt. The selected pitches are used to construct a pitch histogram. Finally top 10 peaks of the pitch histogram (one of which represents the pitch of the tonic) are taken and using Weka tool decision tree is constructed to identify tonic frequency. 364 excerpts of Indian classical music including both Hindustani (38%) and Carnatic (62%) music are taken. The excerpts were extracted from 231 unique performances by 36 different artists, including both male (80%) and female (20%) singers. Every excerpt is 3 minutes long, and extracted from either the beginning, middle or end of the full recording. Performance of 98% is achieved for Hindustani music (98%), and for Carnatic music 90% is achieved.

Group delay functions have been widely studied in the context of speech processing, for both formant and pitch estimation. Ashwin Bellur and Hema A Murthy [5] have shown a novel application of the group delay function for identification of tonic frequency in Carnatic music. In their work, group delay functions are employed to process pitch histograms to assist in accurate tonic identification. In order to do so, the pitch histograms are first characterized as the squared magnitude response of a system. Some interesting properties of the group delay function of this magnitude response has then been illustrated and exploited to identify the tonic pitch. The proposed method tested by on a large database of 344 Carnatic music excerpts. Excerpts are of 3 minute duration and pitch was extracted using Yin with a hop size of 0.01s. The pitch histogram was then computed. . Two methods were attempted to identify the tonic using histograms and GD histograms. Table 1 shows the comparison Results of performance of Histograms and GD histograms on employing tallest peak and template matching methods to identify tonic pitch value.

Table 1.
Histogram & GD histogram Comparison

Method	*Histogram*	*GD Histogram*
Tallest Peak	72.67%	83.85%
Template Matching	84.01%	90.70%

Gulati, S., J. Salamon, and X. Serra [6] have proposed method which divides the task of tonic pitch identification into two stages; tonic pitch-class identification and tonic octave estimation. For the instrumental performances only tonic pitch-class identification stage is used, where as for the vocal performances both tonic pitch-class identification and tonic octave estimation stages are applied. A multi-pitch representation of the audio signal is used to compute the pitch histograms, using which the tonic pitch-class is identified. Octave in which the tonic of the lead performer lies is also estimated. As the concept of the tonic octave is clearly defined for the vocal artists, this stage is only for the vocal music performances. The process of estimating the tonic octave is divided into three steps namely, predominant melody extraction, melody histogram computation and finally octave estimation using the constructed histogram. The core database used in this work is comprised of 352 full length audio songs, containing both vocal (237) and instrumental (115) musical pieces. The performance of the proposed method in which an accuracy of 92.96% for tonic pitch-class identification is achieved, and with the classification based approach the accuracy of (96.62%) is obtained for tonic octave identification.

A.de Cheveigné and H. Kawahara [7] proposed a method for fundamental frequency estimator for speech and music based on autocorrelation algorithm. It has been only informally evaluated on music, but there are reasons to expect that it is appropriate for that task. In their proposed work, the classic autocorrelation algorithm is presented first, its error mechanisms are analyzed, and then a series of improvements are introduced to reduce error rates.

(b) ***Note Transcription – Arohana - Avroha Pattern Matching:*** Note Transcription of music is defined to be the act of listening to a piece of music and of writing down the musical notations for the sounds that constitute the piece. Many attempts are made towards the Note Transcription of music.

S.Shetty and K.Achary [8] proposed a system in which as a first step Note transcription is applied on a given audio file to generate the sequence of notes used to play the song. Fundamental frequency of each segment is calculated using the Auto correlation Method. In the second step features related to Arohana-Avarohana are extracted. And finally Arohana and Avarohana features are given to Artificial Neural Network (ANN). The feature extraction is done for 90 songs of 50 ragas. Output of which the features of 60 songs are used to train the network. The features of remaining 30 songs are used for testing purpose. 95% of results are achieved.

Rajeswari Sridhar and T.V. Geetha [9] have proposed a system for Raga Identification of Carnatic Music. In which polyphonic music signal is analyzed by applying signal separation algorithm to separate instrument and vocal, then vocal signal is segmented using proposed segmentation algorithm which contains determination of onset and offset followed by a two level segmentation process. Taking the segment, using proposed singer identification algorithm fundamental frequency is identified of the singer. Finally other frequency components are identified into swara sequence (arohana-avarohana) based on this sequence raga is identified by applying string matching algorithm to compare the identified swara pattern with the raga database.

Anssi Kalpuri [10] proposed a system for the automatic transcription of Western music. Here, Signal processing techniques are introduced that solve different facets of the overall predicament. Main emphasis is laid on finding the multiple pitches of concurrent musical sounds.

Krishnaswamy A [11], has described a method on how Pitch Tracking is useful for Note Transcription of South Indian (Carnatic) Classical Music. He presented the results of applying pitch trackers to samples of South Indian classical (Carnatic) music. He investigated the various musical notes used and their intonation and tried different pitch tracking methods and observed their performance in Carnatic music analysis.

(c) ***Statistical Models:*** Automatic chord detection is one of the important issues in music analysis with many possible applications such as music information retrieval, music identification and automatic music transcription. Attempts are made for chord recognition [12] which is a HMM-based method for detecting the chord sequence from musical acoustic signals using percussion-suppressed, Fourier-transformed chroma and delta-chroma features.

Work done by Sahasrabuddhe et al. [13] and [14]. In their work, Ragas have been modeled as finite automata which were constructed using information codified in standard texts on classical music. This approach was used to generate new samples of the Raga, which were technically correct and were indistinguishable from compositions made by humans.

"Tansen" by Pandey [15] extended the idea of swara sequence where they worked with Hidden Markov Model on swara sequence. These swara sequences were extracted using two methods – hill peak heuristic and note duration heuristic. They also employed two separate pakad matching algorithms that improved the HMM based results. The first algorithm used substring matching for pakad identification and the second algorithm was based on counting occurrences on n-grams of frequencies in the pakad. Tansen was able to perform with an accuracy of 87% on a dataset of two ragas.

M.S. Sinith, K. Rajeev [16] proposed a scheme for the recognition predefined musical patterns in a monophonic environment in the context of south Indian classical music. Flute instrument is used for the whole experiment. The recognition scheme consists of three stages. In the first stage, tempo-tracking stage, the onset of each pitch is detected and its duration calculated. The musical piece to be analyzed is segmented with the duration taken as the window width. In the second stage fundamental frequency is generated from unknown musical pattern. Each extracted fundamental frequency is quantized using the pitch values of South Indian music. In the third stage the output from the second stage is given to a pre-trained Hidden Markov Models (one for each musical pattern). For raga identification system From a large number of types of transistor musical pattern encountered in practice in different instrumental style, six cases are selected. Several musical clips from these six patterns are tested for recognition and a recognition rate of 100% has been obtained.

HMM model is also used by P.V.G.D.Prasad Reddy et al [17] to generate automatic raga identification system. 92% accuracy is achieved for recognized ragas of trained set where as an accuracy of around 70% is achieved for other ragas from outside sets.

(d) ***Pitch-class Profiles and Machine Learning:*** P.Chordia and A.Rae [18] derived Pitch-class distributions were calculated by simply taking histograms of the pitch tracks. And to determine the Pitch-class Dyad (PCDDs) (two individual units) the note onsets were used to segment the pitch-tracks into notes. Each note was then assigned a pitch-class label distribution from Harminic Pitch – Class Profiles and used these distributions for classification using SVMs. They achieved with accuracies of 78% for PCDs and 97% for PCDDs. The dataset they had used consisted of 17 ragas played by single artist.

Parag Chordia [19] classified one hundred thirty segments of 60 seconds each, from 13 ragas. The feature vector was the Harmonic pitch class profile for each segment. Perfect results were obtained using a K-NN classifier. The algorithm proceeded in two steps, the generation of the tone profiles, and classification using a simple k-nearest neighbor algorithm.

Vijay Kumar, Harith Pandya, C V Jawahar [20] have used the procedure to identify raga in Indian Carnatic music by incorporating two kernels in a multi-class SVM framework, Each of these kernels captures the similarities of a raga based on Pitch-class profiles and n-gram histogram of notes. To evaluate the method, a dataset comprising of 4 ragas namely Kalyanavasantham, Nattakurinji, Ranjani, and Bilhari is created. All audio files are of type instrumental of type flute and are of approximately 20 minute duration from CD recordings. These full length recordings are divided into 1 minute audio clips. Each clip is 44.1 KHz sampled, stereo-channel and m4a encoded. An accuracy of 97.3% is achieved.

(e) ***Thaat Identification:*** Each raag belongs to its parent class, called thaat. Thaats always have 7 pitches which are basis for the organizing and classifying ragas of Hindustani Classical Music. If one were to pick a raga at random, it should be possible to find that it is based on one or the other of these thaats.

M. Bhattacharyya and Debashis De [21] have proposed an algorithm to identify thaat. In their proposed algorithm the song which is taken under experiment is monophony since if instruments are accompanied with the song then the note extraction will be a difficult task. In the algorithm an array is used called test_note[] in which all the notes that are used in sample raag is stored. Another array check_ndex[] is used to indicate the position of all the ten thaats. The accuracy of the algorithm depends upon three factors, firstly on the correct note extraction of the sample song, secondly the singer who has sung the song and thirdly the number of notes used in the raga.

4. CONCLUSIONS

In this paper we briefly reviewed the various raga related properties and applications. Various techniques and approaches which are applied for extracting characteristics / Components of Raga and Raga Identification System of Indian classical music were discussed. This review would be helpful to researchers to focus on the various issues of automatic raga identification system. In future course, we will review the various other techniques and algorithms which are applied in Western music.

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