Signal Processing and Machine Learning Approaches and Evaluation for Indian Classical Music

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Abstract. In the field of signal processing, a considerable amount of work has been done in the analysis and implementation of various techniques related to speech signal processing. When it comes to the Music signal processing, the techniques that are originally developed for speech signal processing have been applied to music signal with good results. In comparison with Indian classical music, lot of research work done in Western classical music on music audio analysis like information retrieval, singer/instrument identification, genre detection, etc.,. This paper provides an overview of some signal processing, and machine learning techniques that specifically applied to the Indian classical music for analyzing and identifying features such as tonic identification, genre classification, raga recognition, music transcription, rhythm, and timbre. We will look at how particular features of Indian Classical music signals impact and how these features are extracted.

1. Introduction

Traditionally rich in Indian classical music, its roots date back to Vedic scriptures more than 6,000 years ago, when tunes formed a system of musical notes and rhythmic cycles[1][2]. Indian classical music is truly linked to nature; numerous ragas were produced based on the seasons and time of the day, influenced by nature. Within the structure of notes, compositions of different ragas are set but can be improvised. This gives spontaneous freedom to music performers, where every performance is guaranteed to be unique. Indian classical music, characterised by two fundamental components, Raga and Tala. In Sanskrit, the word raga represents colour. Thus, raga can also be considered a way of colouring the minds of the listeners with an emotion. Usually, Raga is described as a special mixture, ornamented with notes in a manner that has the power to invoke a distinctive feeling distinct from all other joys and sorrows.

Any raga can have between five to twelve notes. From these tones, one can obtain thousands of scale types. Simply by observing the unique properties like arohana-avarohana, vadi-samvadi, pakad/chalan, etc., a raga in the performance can be identified by an expert in Indian classical music. However, it has been a difficult task for researchers to build a framework for the same purpose. It is more difficult for beginners to identify two separate presentations of the same raga because of the freedom provided to an artist give a raga its personal flavour. Western music is based on the same temperament, i.e. the equal spacing of the 12 octave notes. For researchers, equal temperament is a difficult task in the case of Indian classical music, since it does not work much.

The role of computers is deeply involved in various aspects related to the music signal, which varies from note transcription, singer identification, genre classification, rhythm, and timbre. In this article, we address different melodic characteristics and ornaments of raga concerning for Hindustani classical music in particular, and the application of signal processing and machine learning techniques to music signals to extract information that may be necessary for various types of applications such as tonic frequency, note transcription, automatic Raga recognition, Singer, Gharana, Thaat and Mood identification.

2. Melodic features and Ornaments in Hindustani Classical Music:

In Hindustani music there are 7 main swaras and 5 variant swaras. Indian swaras and equivalent Western notes (in C major) are listed in Table 1. Each symbol in Western music notation, represents an absolute note. However, Indian music swaras are made of relative notes where the note *Sa* can be *C, D, E, F, G, A, B* or, *C#* or, *Ab*. When we play western music notations, we are expected to play exactly as it is written. However, when we play Indian music swaras, since only relative notes are shown, it is up to the player to choose which scale he/she wants to play in. This section we discuss with the melodic features and ornaments of Hindustani ragas.

Table 1 Notes of Hindustani music and equivalent Western music notes

Full Name	Symbol	Western Symbol
Shadaj	Sa	C
Koma Rishabh	re	C# or Db
Shudh Rishabh	Re	D
Komal Gandar	ga	D# or Eb
Shudh Gandar	Ga	E
Shudh Madhyam	ma	F
Teevra Madhyam	Ma	F# or Gb
Panchama	Pa	G
Komal Dhaiwat	dha	G# or Ab
Shudh Dhaiwat	Dha	A
Komal Nishadh	ni	A# or Bb
Shudh Nishadh	Ni	B

- **Tonic Frequency:** In Indian music, the notes are not at standardized frequencies, unlike western music. Any swara note of convenience may be chosen by artists as the reference note, and this swara note will then serve as the base reference note for the raga to be presented.
- **Arohana – Avarohana:** Collection of notes (swaras) arranged in ascending and descending sequence are called Arohana and Avarohana respectively. For example, the arohana and avarohana sequence of raag Bhupali are Sa-Re-Ga-Pa-Dha-Sa' and Sa'-Dha-Pa-Ga-Re-Sa respectively.
- **Jaati:** The number of notes the Raga has in ascending and descending sequence is called Jaati. The possible Jaatis for example, Sampoorna Jati raga contains 7 notes in ascending and 7 in descenting sequence, Shadava jati ragas contain 6 notes in ascending and 6 in descending, and Odava Jati contains 5 notes in ascending and 5 notes in descending.
- **Vaadi – Samvaadi:** Vaadi is the swara that is the raga's most prominent note that is highlighted and used very much in raga. Samvaadi is the raga's second most important note; it is less used than Vaadi but more than the raga's other notes. Other than Vaadi, Samvaadi notes are referred to as Anuvadi notes. A note that is not present in the raga is called Vivadi, but a Vivadi swar is seldom used in raga to enhance the beauty of the raga.
- **Pakad and Chalan:** Pakad is a small subset of notes, which define the raga's distinctive characteristics. Usually, a pakad is a musical phrase thought to encapsulate a specific raga's soul. An expert in Hindustani music can easily recognise the raga by listening to the pakad. Chalan, which is pakad's elaboration, means movement. The Chalan shows the melodic outline of a raga.

- **Samaya:** Each Raga has a particular time of the day assigned to it when it should be performed. For instance, the raga like Bhairav is performed early morning between 6 AM to 8 AM, similarly Malkauns raga is at midnight between 12 AM to 2 AM**.**
- **Thaat:** In Hindustani classical music, a thaat is a mode. There are always seven different swaras in Thaats and they form the basis for organizing and classifying ragas in classical Hindustani music[3][4]. Vishnu Narayan Bhatkhande, one of the most influential musicologists in the field of North Indian Classical Music, developed the method in the early decades of the twentieth century. The ten thaats are Marwa, Bhairav, Bhairavi, Purvi, Bilawal, Kafi, Todi, Asavari, Kalyan, and Khamaj.

2.1. Ornaments

Ornaments are called Alankara in Hindustani music. The meaning of alankara in Sanskrit is decoration, which is important for the beauty of Indian ragas. Alankaras' classification relates to the structure and artistic component of Ragas. Alankaras provides Hindustani Music with elegance and also characterises and differentiates Ragas[3][4]. Kan swar, Meend swar, Andolan, and Gamak are the four important ornaments in Hindustani music.

3. Signal Processing & Machine Learning Techniques

The techniques that are used in speech signal processing having been applied to Western music signals with good results. Very little work has been done in Indian classical music. One explanation for the virginity of Indian classical music is non-equal temperament. For scholars, the same has been a difficult job in Indian classical music, since the equal temperament does not work much. Another explanation for perfectly recognizing raga is that several raga-related details have to be extracted, such as tonic frequency, arohana-avarohana, pakad, etc. We try to explain the different signal processing and machine learning techniques used in the identification and classification of ragas in the following section.

3.1. Tonic Frequency

In Hindustani classical music, the tonic frequency called base pitch is one of the fundamental and essential components. The tonic frequency is selected by the performer, in the performance which serves as the basis for the melodic tonal relationships. As a consequence, the tonic selected by the lead performer is tuned to all accompanying instruments. It becomes apparent that recognising the tonic is a critical first step when considering the automatic raga recognition method of Indian classical music. The spectrogram of C# note as a tonic note of a tanpura instrument in the following figure.

Figure 1. Spectrogram of C# note (Sa-Pa) as tonic using Tanpura instrument
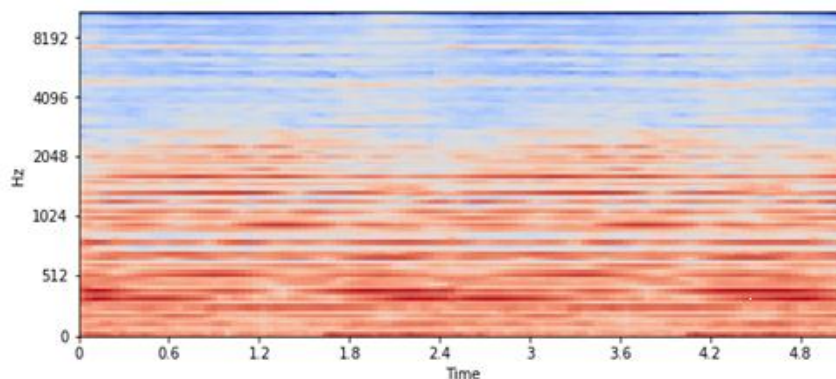
Justin Salamon, S.Gulati, and Xavier Serra [5] proposed a method on polyphonic audio for tonic identification using multi-pitch approach. A multi-pitch analysis is the job of analyzing the polyphonic audio signal's pitch material. The calculation of the frequency and number of pitches in each time frame is included. Spectral peaks used in the method to measure a salience function, which is a

representation of pitch salience over time by multi-pitch time-frequency. A histogram of the pitch values for the complete extract is then computed. To define tonic frequency, the top 10 peaks containing the tonic pitch are taken and the decision tree is created. From 231 unique performances, 36 separate musicians, including male and female singers, extracted 3 minute-long excerpts. For Hindustani music, 98 percent precision is achieved, and for Carnatic music, 90 percent is achieved.

Group delay functions in the context of speech processing are generally studied for pitch estimation. Ashwin Bellur and Hema A Murthy [6] showed a creative application of the group delay function for the identification of tonic frequency in Carnatic music. To process pitch histograms, group delay functions are used to help distinguish tonic frequency reliably. The proposed method tested was extracted with a hop size of 0.01s using Yin on 344 Carnatic music extracts of 3 minutes long and pitch. A histogram of the pitch was then computed.

3.2. Note Transcription

Transcription of music from a note is defined as the transformation of an acoustic signal into a symbolic representation consisting of musical events and their parameters. Arohana in a raga is the sequence of notes that are used as the pitch goes up in the ascending passages. The series of notes to be used in descending is Avarohana. For example, notes related to arohana (Sa-Re-Ga-Pa-Dha-Sa') of raga Bhupali shown in the following figure.

Figure 2. Arohana notes of Raga Bhupali
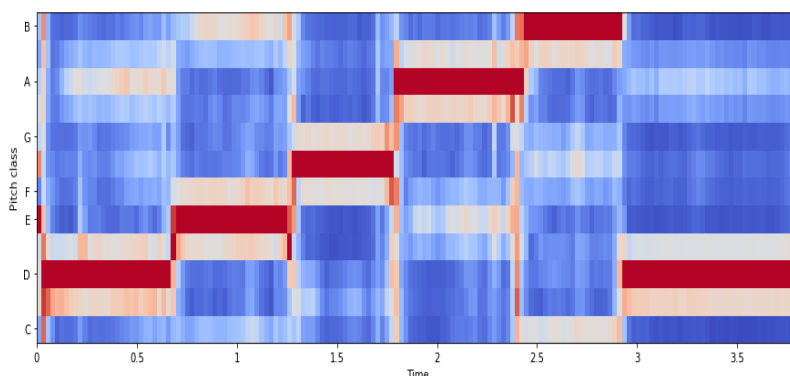
S. R. Kharvatkar, D. G. Khairnar, M. Sharma, I.C.Naik [7] proposed an automated note transcription system based on Hilbert-Huang transform (HHT). As an input to the system, a stereo music signal from a harmonium (Music instrument), with an unknown frequency, is given. Music signal in .wav form is used for applying HHT. The technique of empirical mode decomposition decomposes the music signal in the first step. Hilbert spectral analysis is applied to the outcome of the first step, called the intrinsic mode function, in order to measure the instantaneous frequency as the derivative of the phase function to obtain both the amplitude and frequency of the music signal as a function of time. This is finally used to plot a 3-D image offering spatial time, signal frequency-energy.

S.Shetty, K.K Achary [8] suggested a raga recognition method. The implementation of the scheme is performed in two steps using Matlab. Note transcription is applied to produce the sequence of notes in the process as a first step. The features related to arohana-avarohana are extracted in the next step. For training and checking he device, these arohana-avarohana associated features are fed to ANN.

A Raga Identification System proposed by Rajeswari Sridhar and T.V. Geetha [9] for Carnatic Music. Initially, the signal separation algorithm is implemented to distinguish instrument and vocal on a polyphonic music signal, then the vocal signal portion is segmented using the proposed segmentation algorithm containing a two-level segmentation mechanism followed by the determination of onset and offset.

3.3. Raga Identification

A classification method SVM for raga Identification was suggested by Vijay.K, H.Pande, C.V Jawahar [10]. Significant pitch values are extracted from a piece of music and converted to the scale of cents, then mapped to a single octave and the stable note area defined. The notes are used to establish the pitch-class profile of pitch values and the distribution of n-grams. Raga recognition is rendered by integrating the details from the pitch-class profiles and n-gram distribution that are integrated into an SVM.

C. Mishra, Pandey, and P. Ipe [11], illustrates the application of the Secret Markov Model to the Ta nsen classification of music. Two heuristic techniques called hill peak heuristic and note length heurist ic were used to extract Swara sequences and expanded the concept with the Hidden Markov Model on the swara series. To separate pakad-matching algorithms were used to maximise the results of the HMM model. For pakad recognition, the substring-matching algorithm is used and the frequencies of pakad occurrences are counted on n-grams. Tansen was able to work on a dataset of two ragas with the precision of 87 percent.

In the sense of automated musical genre classification, a pitch histogram representation is used.
The use of the histogram is defined in[12], a method proposed by R. Pradeep, P. Dhara, K.S.Rao, P.Da sgupta. The method used to eliminate irrelevant portions from the music signal by taking the polyphon ic music signal as an input to the preprocessing block. The pitch sequence is supplied as an input to the note transformation block, to get a sequence of notes. The notes-based characteristics are extracted and those characteristics are provided to classify the raga as the suggested KNN classifier input. The 82.34 percent efficiency is observed.

3.4. Gharana, and Thaat Identification

We find the term known as Gharana (schools) in Hindustani music, which has a rich heritage. Gharana music indicates the styles of singing. The concept of a Guru-Shishya leads to the development of Gharanas. Every Gharana has different characteristics. Gwalior, Agra, Kirana, Jaipur, Banaras, and Mewati are a few famous Gharanas in Hindustani music. K.Mahto, Abhilash.H, Sandeep.S, Chakraborty [13] made an attempt to classify Gharana from Raga Results. The model is implemented by feature extraction process. Timbral Texture features extracted using MFCC and Rhythmic features.

Each raga, known as thaat, belongs to its parent class. An algorithm for the identification of thaat was proposed by Bhattacharyya.M and Debashis De[14]. In the proposed algorithm, monophony is the song that is taken during the experiment. An array called test _note[] is used in the algorithm, in which all the used in sample raga are stored. To show the location of all the 10 thaats, another array is used. Three factors depend on the accuracy of the algorithm: accurate note extraction of the sample song, the performer, and the number of notes used in the raga.

4. Conclusions

In this paper, we briefly explained various Melodic features and Ornaments in Hindustani Classical Music. Extracting melodic characteristics such as tonic recognition, note transcription, Thaat, and singer identification of raga and raga Identification methods were also discussed. This analysis will be useful for researchers to concentrate on the different problems of the method of automatic recognition of raga. In the future course, we will review the various other signal processing and machine learning techniques and algorithms which are applied in Western music in comparison with Indian Classical music.

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