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Melodic Pattern Recognition of songs based on Raga Music for Content-based Music Retrieval

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ABSTRACT

Many popular Indian Hindi film songs are based on Hindustani classical raga melodic patterns. Composers of film songs are not bound by raga rules and have liberty during the composition of the song. Automatic identification of melodic raga patterns in a song, which is used as a basis for song composition, is a challenging task. This is probably the first experimental attempt to identify raga associated with the song using machine learning. The machine learning model is trained using raga excerpts and the raga base is predicted for the song in the test phase with the song as an input. The proposed pitch-class distribution (PCD) algorithm is used for melodic feature extraction from raga rendition. PCD algorithm is evaluated using 2 methods as with or without extracting specific pitch values. Machine learning classifiers Support vector machine (SVM) and neural networks (NN) are trained and tested for accurate predictions. NN and PCD with a pitch extraction algorithm combination provided excellent results for the test data used. This contribution is useful for content-based music retrieval based on melodic features and clustering for similar songs as playlist and recommendations.

Keywords: *Raga music, Melodic Pattern Recognition, Machine Learning, Music Retrieval.*

1. INTRODUCTION

Pop music, defined as commercially popular music, has many facets in the Indian subcontinent. With influences from different genres such as jazz, Western Classical music, Indian Classical music Ragas, it is quite a wide genre. The Indian folk drama had songs as an addition to the art of acting. This has always been an influence on the movie culture in India thus the songs in movies. The Indian film industry, now known as Bollywood (Hollywood of Bombay), helped give access to the music to a large crowd and therefore had a defining role in the pop music of India. The composers of the music for movies were often trained in Indian Classical music thus influencing the music and using the elements of Classical music in popular songs [1]. The vocal melodies would be influenced by a Raga and the instruments would complement the vocals using elements of Western Classical music or Jazz. This can be seen in many songs. The song composed need not adhere to stringent raga rules of classical music.

Raga is the heart of Indian classical music and it dictates the rules to be followed during the presentation of the raga. Many ragas are available in Hindustani classical music and they can be broadly classified into 10 different thaats or scales as per Bhatkhande [2,3]. Raga is a composition of different melodic notes with some prominent notes. The prominent notes are the notes which the performer stresses the utmost during a Raga unfolding. Arising patterns and the sliding pattern of the Raga are called Aarohan and Avarohan respectively. The Arising and sliding patterns can have differing musical notes. Figure 1 shows The Arising and sliding notes patterns for raga Bhoop as a reference.

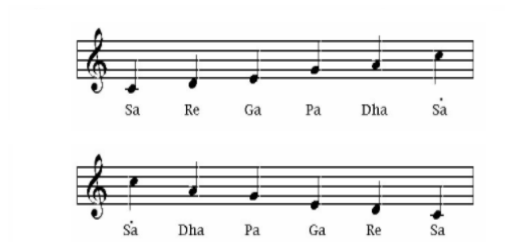

Figure 1. Raga Bhoop: Arising and sliding notes patterns

Ragas selected for the initial experimentation are Des, Bhairav, Darbari Kanada, Lalit, and Bhoop. These 5 ragas belong to different categories or thaats as Khamaj, Bhairavi, Asavari, Poorvi, and Kalyan from the 10 thaat classification proposed [2, 3]. Features are extracted using a modified pitch-class distribution algorithm. The machine learning model was trained using samples of each raga. The algorithm is tested for the film songs based on raga for melodic pattern recognition. The hypothesis is the classifiers will correctly identify the songs from training with the raga renditions and melodic features extracted using PCD. Widely used supervised machine learning algorithms SVM and NN are used for the initial experimentation considering their success in different domains.

SVM (support vector machine) is one of the popular supervised machine learning algorithms [4]. It classifies two data classes by representing them in an n-dimensional space (where n is the number of features) and separating them by a hyperplane. Figure 2 shows an example of SVMs in action. A

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two-dimensional space that contains two classes is divided by a linear classifier. This parallel hyperplane is situated such that the distance from both the classes to this hyperplane is greatest. The vectors closest to the hyperplane which help in defining it are called the support vectors, therefore the name Support Vector Machines.

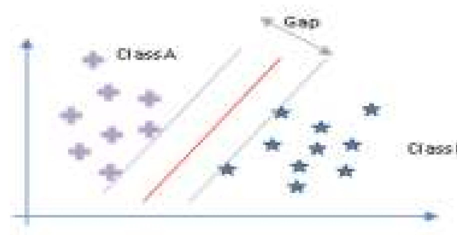

Figure 2. Support Vector Machines

The neural network approach recently gained more attention due to the success of deep learning in applications such as image or speech recognition. A Neural Network is a network of neurons or nodes as shown in Figure 3, where the nodes process the input to make meaning of the data provided [5]. The nodes form layers which have a specific weight attached to them to process the input in a certain required way. When there is no feedback from the outputs of the nodes, the network is termed as Feedforward Neural Network. Each hidden layer can be assigned a function, forming a layer of functions.

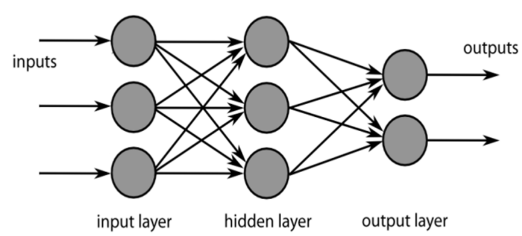

Figure 3. Feedforward Neural Network

The objective of this experimentation is,
1. To train the machine learning classifiers using classical raga compositions.
2. To predict the raga base of the pop songs.

The novelty of the experimentation performed is to recognize melodic raga patterns from the songs based on the raga. This work is useful for the content-based retrieval based on melodic patterns such as raga and grouping of possibly similar songs for different music information retrieval applications based on content-based approach.

2 RELATED WORK

Mining melodic patterns in Indian classical music has been studied and experimented by many researchers [6, 7, 8]. Various approaches have been used for raga identification and verification [9, 10]. Use of Swara intonation [11], chromogram patterns and Swara based features [12], motifs [13], Swara histogram-based analysis [14] are some of the major approaches used. Pitch class distribution approach for automatic raga identification is successfully applied by researchers for classical music [15, 16].

Different computational approaches are used for raga performance modeling [17] or transcription [18]. Raga pattern identification from classical music is one of the most studied topics in research related to Hindustani classical music. As per the literature survey conducted by us, none of the researchers have attempted for automatic identification of raga melodic pattern from the Hindi film songs.

Support vector machines (SVM) are excellent classifiers and are used extensively for various tasks related to classification. Classification of pop songs with multiple artists using SVM and KNN was compared for various distance measures using song level features [19]. Music genre classification using multi-layer SVM shown better results compared to other statistical learning methods [20]. The ensemble of SVM was used for genre classification with a combination of visual and acoustic features [21]. Neural networks are used for various applications in pattern recognition tasks [22]. Neural networks are used successfully for music classification [23]. The deep convolutional neural network is the recent approach used for music feature learning and classification [24].

Considering the literature survey and the success of SVM and NN classifiers in computational music, they are used for the prediction of melodic patterns in the experimentation done. Features are extracted using a pitch class distribution approach considering its success in Indian classical music.

3 METHODOLOGY

A musical tune is a collection of pitches organized to convey musical information. The spread of the probability of the frequency of different pitches is represented as Pitch Class Distribution (PCD). This information assists in the distinguishing of Ragas. The Ragas can have diverse pitches. Some ragas have the same pitches but their presentation is different. This resonates with the fundamental of a Raga as two Ragas with same notes have differences in the importance of the notes. PCD is an important representation of raga classification. This section attempts to determine if it is a complete differentiator in the context of songs as the occurrence of notes can hint at multiple Ragas in the domain of pop songs. Two methods were tested to obtain the Pitch Class Distribution of the audio samples which are explained in the subsections 3.1 and 3.2. The pitches were assigned a pitch band to associate frequencies to a note.

3.1 Without extracting the pitch

The absolute square of each frequency bin in the spectrum was attributed to the respective pitch band. Thus the energy density of each pitch value was obtained. The octaves were then folded to obtain the energy density of a Chroma. This gave the distribution in an octave [25]. The distribution was

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divided by the overall energy to find the Pitch Class Distribution.

The implementation included performing the FFT on the input audio sample. Figure 4 showcases an example of the audio spectrum. A parallel process involved estimating the frequency of A4 of the audio sample. The function used as a part of the Chroma Toolbox in MATLAB [26]. This enabled the algorithm to select the closest filter bank of pitch frequencies. This was extremely important as Indian Classical music uses the Just Intonation tuning system. This tuning system requires the creation of a filter bank based on the tonic. The combination of the input tonic and the estimated filter bank helped obtain the frequency of pitches in the Just Intonation tuning system for further analysis. These obtained frequencies were then used to create a filter bank with the above-mentioned procedure.

Proposed Algorithm for feature extraction using Pitch class distribution without pitch extraction is as follows.

1. *Input Audio signal and tonic frequency*
2. *Calculate the just intonation filter bank using tonic or fundamental frequency*
3. *Find the Fast Fourier transform of the input signal.*
4. *Estimate the energy density of the pitch*
5. *Perform octave folding*
6. *Represent probabilities as feature values for 12 notes*

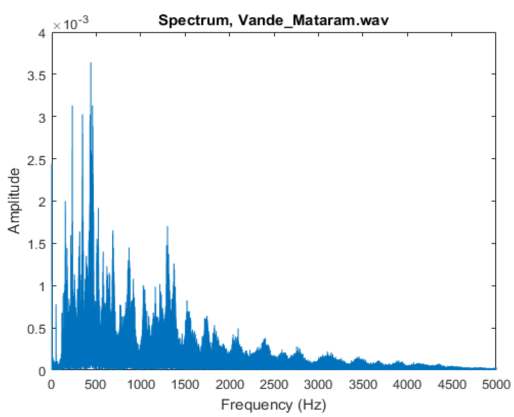

Figure 4. Amplitude Spectrum of 0 to 5000 Hz of Vande Mataram

The energy spectral density was then measured by squaring the individual samples in the absolute spectrum given by Equation (1).

$$E_{xx}(f) = |\hat{x}(f)|^2 \quad (1)$$

Where Exx (f) is the energy spectral density, f is the frequency and x(f) is the spectrum. With the help of the previously obtained pitch frequencies, boundary frequencies for each pitch band were calculated. The energy spectral density in each pitch band was summed and divided by the number of bins in that band to get the energy density of the pitch as seen in Equation (2).

$$F_{xx}(N) = \frac{1}{K_N}\sum_{f=N_l}^{N_u} E_{xx}(f) \quad (2)$$

Where N represents the pitch band with Nl as the lower and Nu as the upper frequencies and KN is the number of bins in the band N. Figure 5 showcases an example of the energy density of the pitches. The x-axis contains seven octaves starting from A#0 and ending at A7.

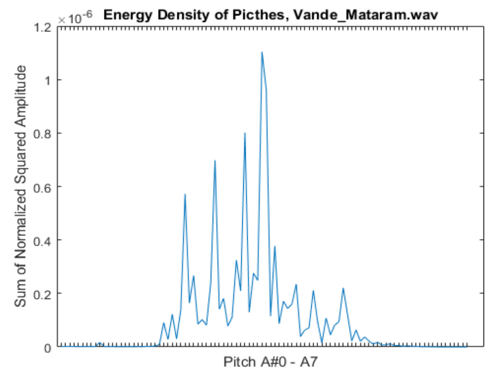

Figure 5. The energy density of pitches of Vande Mataram

In the case of PCD, tone height is not the main concern and therefore, the distribution in the Chroma dimension of the pitch was required. This was achieved by folding the octaves using equation (3)

$$\mathrm{PCD(c)} = \sum_{o=1}^{Z} \mathrm{F_{xx}(c + 12o)} \quad (3)$$

Where c (1 – 12) is the Chroma number, o (1 to Z) is the octave number. In this case, Z was equal to 7. PCD(c) represented the energy distribution in each Chroma. To attain a distribution comparable to other similar distributions, it was divided by the total energy which resulted in the Pitch Class Distribution of the audio sample. An example can be seen in Figure 6.

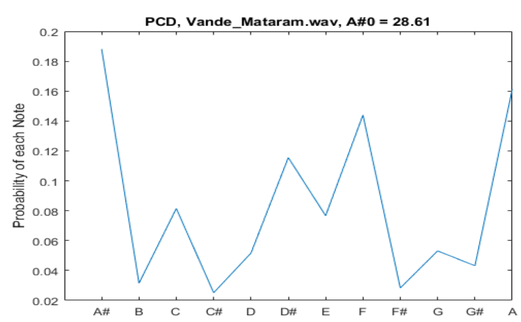

Figure 6. Pitch Class Distribution of Vande Mataram without pitch extraction

3.2 With extracting the pitch.

The pitches at every time stage were calculated and the quantities of incidents of the frequencies in a pitch band were assigned to that pitch. This quantity signified the presence of a specific pitch. The octaves were then folded to determine the occurrence of a Chroma. The distribution was divided by the entire amount of incidences to get the probability distribution of the pitches; resulted in the PCD.

Proposed Algorithm for feature extraction using Pitch class distribution with pitch extraction is as given below.

1. *Input Audio signal and tonic frequency*
2. *Calculate the just intonation filter bank using tonic or fundamental frequency*
3. *Extract pitch values from the input audio signal*
4. *Calculate the occurrences of the pitch in each band*
5. *Perform octave folding*
6. *Identify the frequency of occurrences for 12 notes*
7. *Calculate probabilities of each note occurrence*
8. *Represent probabilities as feature values for 12 notes*

For the implementation, pitch extraction as mention in the previous section was performed. The pitch contour was extracted from 'Praat' [27].

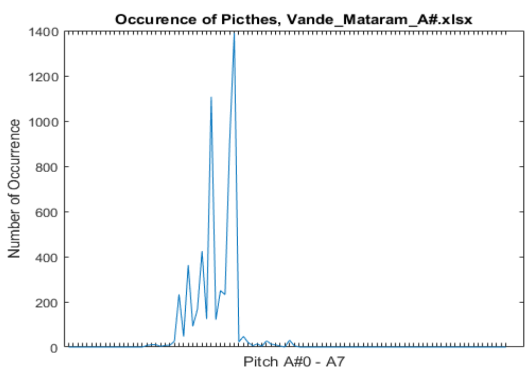

Figure 7. The occurrence of pitches in Vande Mataram

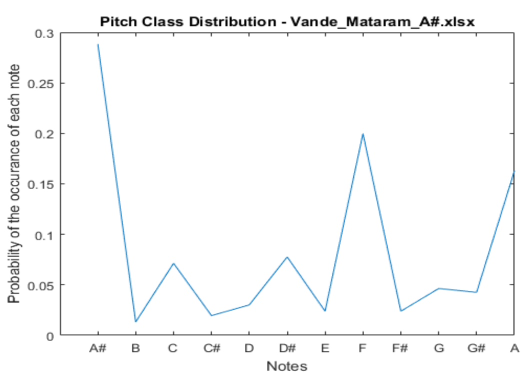

Figure 8. Pitch Class Distribution of Vande Mataram using pitch extraction

Using the identified pitch and the limits of the pitch bands, pitches situated with each pitch band were identified. Further, the number of incidences of pitches in each band was obtained. It can be observed in Figure 7. It removed any effect of the possible harmonics during the estimation of the PCD. Octaves were then folded using Equation [3] in order to find the degree of incidences in every Chroma. After the folding of octaves; the numbers of incidences in every Chroma were divided by the total quantity of incidences to give the probability of the incidence of the pitch which was PCD. The result can be observed in Figure 8. A thorough comparison is done in the next subsection.

3.3 Comments on differences

The two methods show results that are close but not alike to each other as shown in Fig. 9. The differences can be attributed to certain aspects such as formants. While using the algorithm without pitch extraction, all the formants are included in the calculation. This leaves the algorithm susceptible to the influence of stronger or different formants. It showcases accurate information about the energy in each pitch. While using autocorrelation, the probability of the existence of the pitch is precisely shown as the formants are not accounted for. Another aspect is simplicity. The algorithm using pitch extraction proves to be much simpler than that without pitch extraction. It was observed to be computationally more efficient while performing Raga identification.

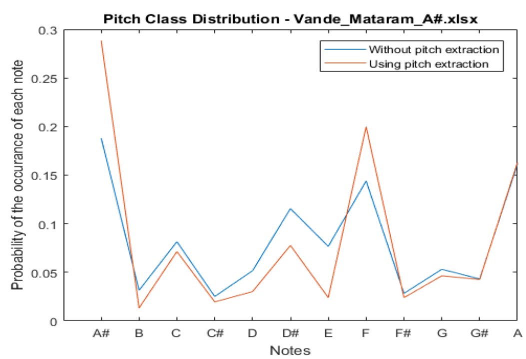

Figure 9. Comparison of the two methods for obtaining the Pitch Class Distribution

4 RESULTS

The classifiers were trained with the input as the feature values obtained using the PCD algorithms as mentioned in the previous sections (Section 3.1 and 3.2) from both the methods. Various excerpts of Ragas were used for training. SVM and NN classifiers are used for the experimentation and results are compared as training accuracies obtained and testing for the songs based on the raga. 5 vocal samples of each raga were used for training. The duration of each training sample was about a minute. The duration decided considering the results obtained for the least duration experiments for raga identification [28]. The trained model was further tested for 2 songs based on each raga.

To test the accuracy of the SVM classification, the training set was 10-fold cross-validated. Figures 10a and 10b show the confusion matrix for both the algorithms. It can be observed that the percentage accuracy in classifying PCDs with pitch extraction was 84 % which is higher when compared to

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classifying PCDs without pitch extraction which is 64 %. Thus, it was expected that the algorithm with pitch extraction would perform better.

Target class

1	**3**	0	0	1	1
2	0	**3**	1	0	1
3	1	0	**3**	1	0
4	0	1	0	**3**	1
5	1	0	1	0	**4**
	1	2	3	4	5

Output class — **64 % Accuracy**

Figure 10a. Training confusion matrix of SVM classifier; inputs are PCD of Ragas without pitch extraction

Target Class

1	**4**	0	0	0	1
2	0	**4**	1	0	0
3	0	0	**5**	0	0
4	0	1	0	**4**	0
5	0	0	1	0	**4**
	1	2	3	4	5

Output Class — **84% Accuracy**

Figure 10b. Training confusion matrix of SVM classifier; inputs are PCD of Ragas with pitch extraction

The sample performance results using the SVM classifier are shown in table 1. As observed from Table 1, the identification with pitch extraction has performed better than without pitch extraction and is obvious considering the training accuracies. It can be observed from the table that for the song Vande Mataram based on raga Des, the results predicted using without pitch extraction identification were wrong as Bhairav. Wrong predictions are marked in bold for immediate identifications. The results reflect the need for more samples for training in the case of raga Des and Darbari Kanada considering the mismatch between expected and predicted results. Another approach could be fine-tuning parameters for SVM.

A similar exercise with Neural Networks without pitch extraction yielded better identifications compared to SVM with 76 % training accuracy. While testing, out of 10 songs, one song prediction was wrong with actual raga as Darbari Kanada predicted as Des for the song “Tu Pyar Ka Sagar Hai” in case of NN without pitch extraction.

PCD with pitch extraction and Neural Networks made a robust case with 100% training and testing accuracy for the identification of Ragas in film songs.

Songs	Raga Base Expected	Without Pitch Extraction Identification	With Pitch Extraction Identification
Vande Mataram	**Des**	**Bhairav***	Des
Jaago Mohan Pyaare	Bhairav	Bhairav	Bhairav
Mruganayana Rasik Mohini	Darbari Kanada	Darbari Kanada	Darbari Kanada
In Aankho Ki Masti ke	Bhoop	Bhoop	Bhoop
Mohe Bhool Gaye Saawariya	Bhairav	Bhairav	Bhairav
Tu Pyar Ka Sagar Hai	**Darbari Kanada**	**Des***	**Des***
Pyar Hua Chupke Se	**Des**	**Bhairav***	**Bhairav***$^{}$
Jyoti Kalash Jhalke	Bhoop	Bhoop	Bhoop
Koi Pass Aya Sabere Sabere	Lalit	Lalit	Lalit
Raina Beet Jaye	Lalit	Lalit	Lalit

Table 1. Sample results using SVM classifier

5 DISCUSSIONS

The present experimental models are trained and tested for 5 ragas and song samples based on them. The preliminary results validate the methodology used. For the use case of identifying Ragas in a film song, it is observed that using Neural Networks in combination with Pitch Class Distribution is a simple yet effective method with 100% accuracy for the sample dataset tested. Considering the selection of ragas from different thaats, it was expected to get high accuracy in training and testing. It would be interesting to see the results with closely associated ragas where human experts find it difficult for the identification of ragas such as Bhoop/ Deskar/ Shudh Kalyan or Darbari Kanada/ Adana/ Jaunpuri.

Making the computer identify the melodic patterns in the popular songs is a challenging task and is like simulating the expert in the classical music domain. This initial attempt with success is encouraging for further experimentation using the robust methodology with more data such as more samples per raga for training, more ragas, and songs. Different machine learning classifiers with an ensemble approach can also be explored with further fine-tuning to achieve the best possible results

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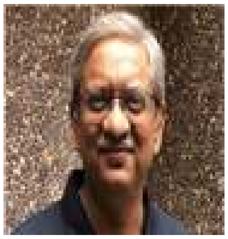
AUTHOR PROFILES



Makarand Velankar completed basic graduation in computer engineering from Walchand College of Engineering, Sangli in 1990. After working in the industry for 11 years as a development engineer, he joined MKSSS's Cummins College of Engineering, Pune in 2001 and is presently working as Assistant Professor in Information Technology Department. He completed a master's in Computer Engineering in 2003 from PICT, Pune University. He is pursuing a Ph.D. from PICT, Pune University in the domain of computational musicology. His research interests include music analysis, machine learning, artificial intelligence, Information retrieval, algorithms, soft computing, etc. He has presented papers in prestigious conferences such as Coling 2012, Acoustics 2013, etc. and delivered invited talks at ICIASP 2013, FRSM 2017, etc.

Amod Deshpande while completing his bachelor's in civil engineering learned various musical instruments. In order to find a common path between engineering and music, he pursued an MSc in Engineering Acoustics at the Technical University of Denmark. There he researched music, emotions and machine learning. After completing his MSc in Engineering Acoustics, he moved back to India to start his own company. Now he is an acoustical consultant and a researcher. He was invited as a guest lecturer for the students of architecture (pursuing both bachelor's and master's) at the D. Y. Patil School of Architecture, Lohegaon, Pune to teach Acoustics. He also volunteers as a facilitator for Techstars Startup Weekend to help accelerate entrepreneurship. As a means of creative expression, he has turned his writing and music skills into filmmaking which he now pursues alongside his business and research which has resulted in the winning of the 'Best Music Composition Award' in the TNID Festival in 2018.

Parag Arun Kulkarni is one of the world's leading authorities on Business Strategy, Knowledge Innovation, Machine Learning, Systemic Learning and Building Innovative Knowledge Corporations in the knowledge economy. He is a consultant on Innovation and Strategies for start-ups and SMEs and contributed to making many start-ups successful. He holds a Ph.D. from IIT Kharagpur, Management education from IIM Kolkata. UGSM Monarch Business School – Switzerland conferred higher doctorate - DSc on him for his contribution towards innovation and knowledge management. Recipient of Oriental foundations scholarship, he is also Fellow of IETE and The IET. Parag is Founder, Chief Scientist and CEO of the Kvinna Limited: an innovation, strategy, and business consulting and product development organization. He has been visiting professor/researcher at technical and B-schools of repute including IIM, Masaryk University – Brno, COEP Pune. Parag headed various organizations and research labs and contributed to the success of more one dozen organizations through his strategic and Business acumen and innovative product building. He is a core contributor to more than a dozen commercially successful products. He headed Research Labs at Siemens, IDeaS and many other organizations. One of the well-known Product Innovation and Business Innovation strategist, he is an advisor to many industries and academic institutes. His core work includes innovation and knowledge strategies for start-ups, knowledge strategies for organizations, building innovative products, breaking away from the competitive landscape. His work is on systemic innovation and learning is published with many reputed journals.