MOTIVIC ANALYSIS AND ITS RELEVANCE TO *RĀGA* IDENTIFICATION IN CARNATIC MUSIC

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ABSTRACT

A *rāga* is a collective melodic expression consisting of motifs. A *rāga* can be identified using motifs which are unique to it. Motifs can be thought of as *signature prosodic phrases*. Different *rāga*s may be composed of the same set of notes, or even phrases, but the prosody may be completely different. In this paper, an attempt is made to determine the characteristic motifs that enable identification of a *rāga* and distinguish between them. To determine this, motifs are first manually marked for a set of five popular *rāga* by a professional musician. The motifs are then normalised with respect to the tonic. HMMs are trained for each motif using 80% of the data and about 20% are used for testing. The results do indicate that about 80% of the motifs are identified as belonging to a specific *rāga* accurately.

1. INTRODUCTION

The word *rāga*, is derived from language Sanskrit. The meaning of a *rāga* in Sanskrit is *colour or passion*. In the context of *Carnatic* Music, one could think of the *rāga* as a mechanism to colour the notes in a given melody using prosody. Prosodic modifications include increasing/decreasing the duration of notes, using an appropriate intonation pattern, by employing *gamakas*, and modulating the energy. A seamless prosodic movement through a sequence of notes is yet another characteristic of a *rāga*. We define motifs as a particular "prosodic phrasing of a sequence of notes," that are unique to a given *rāga*. The motifs are aesthetically concatenated using prosody, thus defining a *rāga*. Ālāpanā is a segment of a piece, where a musician elaborates and improvises using the motifs of the *rāga*. The ālāpana has an inherent pulse or *kālapramāṇa*. The *kālapramāṇa* for a particular piece depends on the *rāga*, the artist and the particular presentation. Although the above characterisation is abstract, nevertheless, there is a consensus amongst musicians, musicologists and listeners on the identity of a *rāga* in terms of the the motifs.

There is hardly any literature on motivic analysis of *rāgas* for Indian Music [1–4]. In [1], *rāgas* are identified by the histogram of the notes. The permissible arrangement (or phonotactics) and prosody of musical notes in a *rāga* is not exploited [1]. Clearly, this approach works well only for *rāga*s that are *sampūrṇa* [2]. In [2], the sam of the tāla (emphasised by the bol of the tablā) is used to segment a piece. The repeating motif in a bandish is identified for Hindustani Khyāl based music. [4] has extensively studied the motifs in the *rāga Tōdi*. In [5], the audio is transcribed to a sequence of notes and string matching techniques are used to perform *rāga* identification. In [6] pitch-class and pitch-dyads distributions are used for identifying *rāga*. Bi-grams on pitch are obtained using a twelve semitone scale. In [7], the authors assume that an automatic note transcriber is available. The transcribed notes are then subjected to HMM based *rāga* analysis. In [8, 9], a template based on the *Ārōhaṇa* and *Avarōhaṇa* are used to determine the identity of the *rāga*s. [3]

It is well-known that in *Carnatic* Music, the meandering around the notes is a continuum and can seldom be quantified into bins. The quantification of notes leads to loss of information.

We conjecture that, to determine the identity of a *rāga*, neither is a knowledge of the *Ārōhaṇa* and *Avarōhaṇa* required, nor is the transcription of the prosodic phrase. Such quantisation can lead to errroneous identity owing to the loss of information through the process of annotation. In *Carnatic* Music, notes are seldom steady. Only the tonic (*Ṣaḍja*) and its fifth (paṇchama) are relatively steady. Therefore transcribing to a discrete set of notes from the audio is nontrivial, since a note which is *Ri* in a given context can be a *Ga* in another context. Further, as suggested by [4], [10], the improvisations in extempore presentations can vary from musician to musician. From a signal processing perspective, a motif can be defined as a prosodic phrase. The prosodic phrase is characterised by the phonotactics of swaras, and their corresponding duration, energy and pitch. In addition, the trajectory of the pitch contour, and the energy contour also play an important role. Figure 1 shows the phrase *Sa Ri Ga Ri* of *Śaṅkarābharaṇa* and *Kalyāṇī*. The notes are identical. While the swaras, especially *Ga* is sustained in *Śaṅkarābharaṇa*, it meanders in *Kalyāṇī*. Further, the pitch of *Ga* in *Śaṅkarābharaṇa*

[1] For want of better terminology, we refer to this as phonotactics of notes – phonotactics is used in the context of speech sounds

[2] A *Sampūrṇa rāga* (in the context that is used here) have all the seven notes, and have the same set of notes in ascent and descent

[3] *Ārōhaṇa* and *Avarōhaṇa* correspond to a sequence of notes in the ascent and descent of *rāga*, respectively.

is seen to be higher than that it *Kalyāṇī*. But, the *Ga* in *Kalyāṇī* is perceived to be higher because of the gamaka expression on it. The gamaka or meandering begins at a frequency, little lower than the actual frequency *Ga*, moves to *Ma* and back. An annotation would have led to different swaras for both motifs. The objective of this paper is to

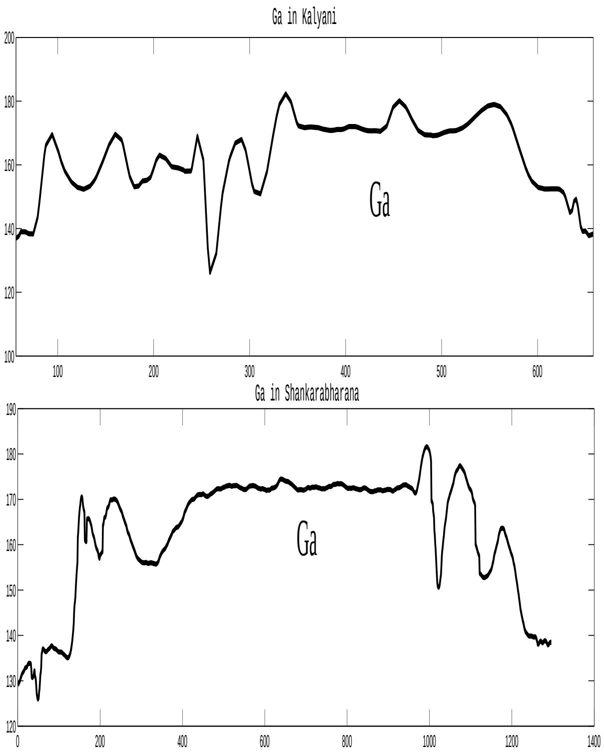

Figure 1. Illustration of motifs of *Kalyāṇī* and *Śaṅkarābharaṇa* with same swaras

distinguish between the manualy identified motifs and then classify them into their respective *rāga*s. We have chosen a set of five *rāga*s for this, namely, *Kāmbōjī*, *Kalyāṇī*, *Śaṅkarābharaṇa*, *Bhairavī*, *Varāḷī*. Of these, *Kalyāṇī* and *Śaṅkarābharaṇa* are sampūrṇa *rāga*s. *Varāḷī* and *Kalyāṇī* correspond to *prati-madhayama rāgas*, while the others belong to *śuddha madhyama rāgas*[4]. A set of prosodic phrases that are unique to that *rāga* and that are often repeated in concerts are manually marked. The dataset is then divided into a training set and a testing set. HMMs are trained using the training set of the motifs. The HMMs are tested on the test set. The prosodic phrases are defined relative to the tonic. The motifs are normalised with respect to the tonic using the approach discussed in [11]. Figures 2 and 3 show Bhairavī and Kāmbōjī motifs in terms of the pitch contour for a number of different musicians, respectively.

Visually the motifs of the same *rāga* are similar, while those of different *rāga*s are different. A simple string matching approach will not suffice, because the duration of a motif can vary based on the artist. Also the same motif is sung with different variations by the same musician. Thus a mo-

[4] *prati madhayama* corresponds to Ma2 and *uddha madhyama* corresponds to Ma1.

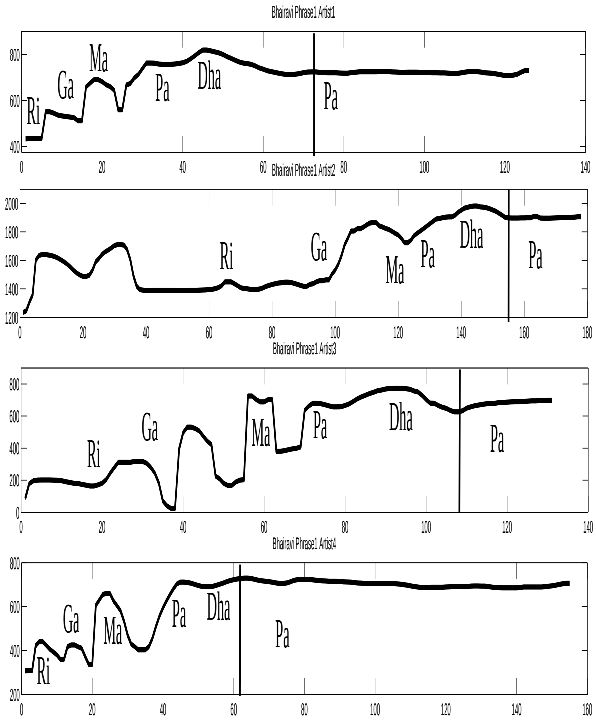

Figure 2. Similar motifs for Bhairavī from different musicians.

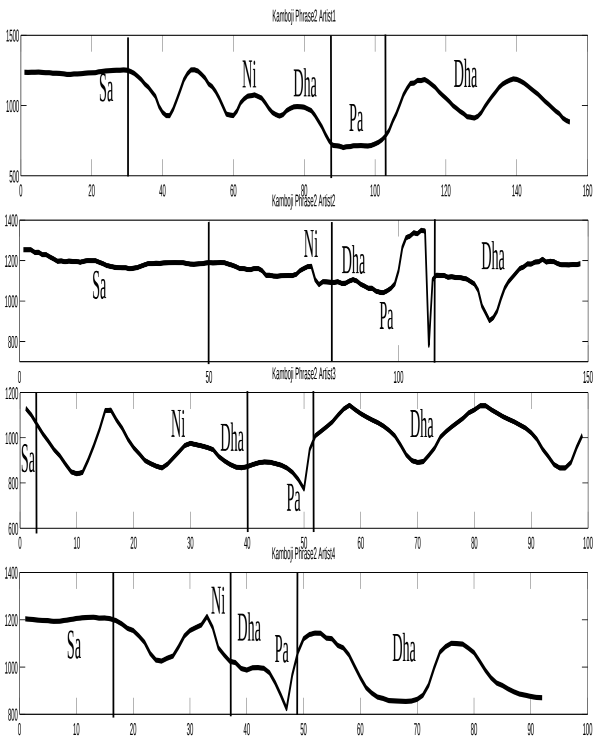

Figure 3. Similar motifs for Kāmbōjī from different musicians.

tif will not always be repeated in the same manner. This is because the gamakas expressed in the phrase are similar but not identical. From the figure, it is rather difficult to identify where a given note ends and the next note starts. To accommodate the issues highlighted above, it was felt that Hidden Markov Models may be appropriate for the given task. Each motif is modelled using continuous density HMMs. The HMM structures are appropriately designed based on the motif that is to be identified.

In Section 2, we describe the database used for this analysis. In particular, we discuss the motivation for choosing the set of *rāga*s. Next, we also discuss the methodology that was used to extract motifs from the various pieces. It was decided to label motifs that were unique and popular in a *rāga*, since covering all motifs characteristic to a *rāga* is not possible. Next in Section 3, we discuss the need for using HMMs for identifying motifs. The experimental results are also presented. The results vindicate the claim that a motif identifies a *rāga* uniquely. Finally, the conclusions are presented in Section 4.

2. DATABASE DEVELOPMENT FOR THE STUDY OF MOTIFS

As mentioned earlier, the purpose of this paper is to explore the possibility of using machine learning to perform motivic analysis of a *rāga*. Machine learning warrants a large database of phrases. A statistical analysis was therefore first performed on a personal collection of the authors, to determine *rāga*s that are popular. The list is obtained from concert collections of about 20 artists (male, female and instrumental) and 103 concerts. Table 1 shows a partial list of the *rāga*s that are rendered frequently in Carnatic Music.

The *rāga*s Kāmbōjī, Kalyāṇī, Śaṅkarābharaṇa, Bhairavī, *Toḍi* are considered to be popular *rāga*s. These are chosen for elaborate exposition in concerts. The statistics obtained in Table 1 seconds this hypothesis. Although the list given in Table 1 is not exhaustive, there exists a large repository of compositions in the aforementioned six *rāga*s. This results in a large repository of motifs for development and improvisation.

In this paper, an attempt is made to study the *rāgas Kāmbōjī, Kalyāṇī, Śaṅkarābharaṇa, Bhairavī, Varāḷī.* Although *Toḍi* is performed extensively (according to the table), it was not included in this database, since it is in itself viable for independent analysis [4]. Ālāpanās of various performances were taken and the motifs were labelled by a professional musician in the five *rāga*s chosen for the study.

Initially, a number of different motifs for each *rāga* were identified and marked. For example, for the *rāga*s, Kāmbōjī thirty different motifs were identified. But it was observed that many of the motifs did not occur frequently. The most popular set of motifs were therefore marked first to meet the requirements. A set of 10 phrases were chosen from the Ālāpanā section of a piece in the database and labelled. Out of these 10 phrases, typically one or two phrases generated a large number of examples. Table 2 gives a statistic of the number of phrases marked along with the total number of instances across all phrases.

Some of these phrases are used as refrain phrases after improvisation to highlight the identity of the *rāga*. These may not be complete phrases but are typical of that particular *rāga* alone. A combination of vocal (male and female) and violin were chosen for labelling phrases. Depending on the availability of examples for HMM modelling and uniqueness of the phrase to a *rāga*, table 2 was further pruned. The pruned set is given in Table 3.

Rāga	Number of songs
Tōdi	1797
Kalyānī	1712
Kharaharapriyā	516
Śaṅkarābharaṇa	1206
Bhairavī	1384
Kāmbōjī	1622
S=avēri	561
Dhanyāsi	300
Gowḷa	390
Varāḷī	483
Kānadā	60
Bilaharī	452
Mōhana	575
Śriranjini	69
Śivaranjini	35
Janaranjini	128
Surati	108
Madhyamāvatī	540
Manōharī	223
Nāṭa	205
Abōgī	354
Sahānā	220
Devagāndhārī	188
Hemavatī	72
Vācaspatī	134
Mukārī	374
Husēnī	107
Darbār	55
Nāyakī	170
Ṣanmukhapriyā	481
Simhēndramadhyama	102
Harikāmbōjī	404
Māyāmalavagowla	265
Hindōḷam	385
Hamsadhwanī	649

Table 1. Database

Rāga Name	Phrases labelled	Instances
Bhairavī	10	205
Kāmbōjī	30	343
Śaṅkarābharaṇa	10	366
Kalyāṇī	9	138
Varāḷī	5	144

Table 2. Total no. of phrases

rāga	**Phrases**	**Instances**
Bhairavī	Phrase 1	70
	Phrase 2	52
Śaṅkarābharaṇa	Phrase 1	101
Kāmbōjī	Phrase 1	104
Kalyāṇī	Phrase 1	52
Varāḷī	Phrase 1	52

Table 3. Phrases for modelling

3. CONTINUOUS DENSITY HMMS FOR MODELING MOTIFS

Given that the motifs are quite typical of each *rāga*, initially an attempt was made to find the location of these motifs in a continuous piece. This is akin to keyword spotting in continuous speech. Given that the pitch and energy contours are rather noisy, the results were very poor. To accommodate the variations in the prosody of the motif, it was felt that HMMs may be appropriate. The HMM structure is approximately dependent on the number of notes that make up a phrase. A left-right HMM was used.

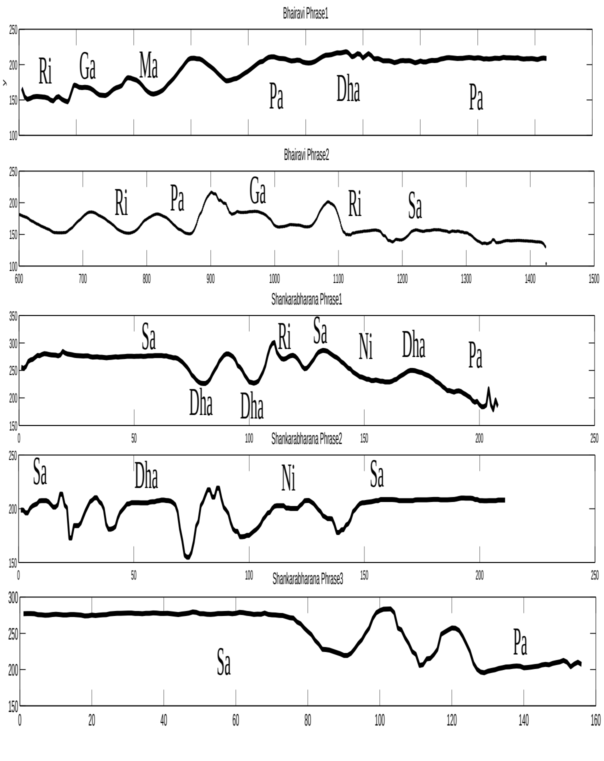

Figure 4. Motifs of Bhairavī and Śaṅkarābharaṇā

Figure 4 and Figure 5 show typical pitch contours for the motifs. The figures give the approximate length of the sequence in terms of number svaras, and the corresponding HMM structures required for each of the motifs. The number of states in the HMM structure was based on the changes that we observed in the pitch contour. The state in an HMM is supposed to correspond to an invariant event. We therefore chose the number of states based on the number of invariant events in the motif. Two mixtures were

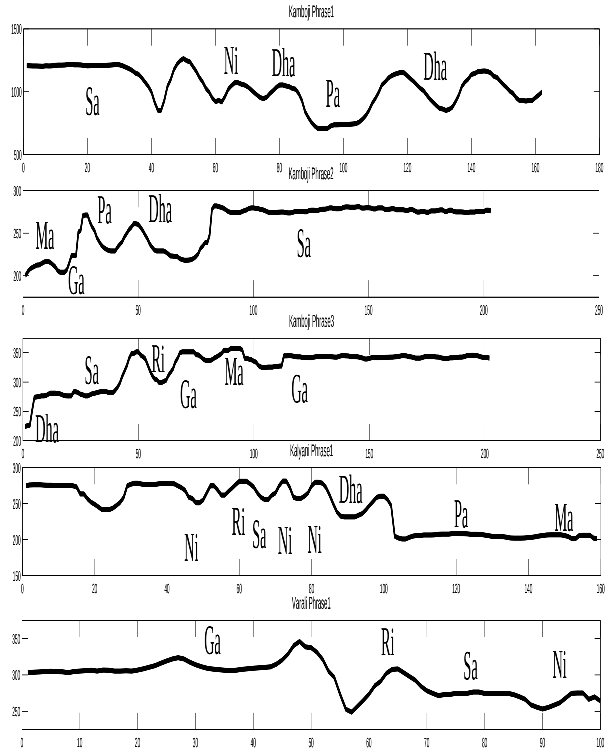

Figure 5. Motifs of Kāmbōjī, Kalyāṇī and Varāḷī

used for every state, since some phrases are rendered in two octaves.

A total of 10 motifs were experimented with – two *Bhairavī* motifs, three *Kāmbōjī* motifs, three *Śaṅkarābharaṇā* motifs, one *Kalyāṇī* motif and one *Varāḷī* motif. The choice was based on the number of available examples. Table 4 gives the confusion matrix for motif recognition. In the table, the *rāga* names are replaced by appropriate acronyms. The integer suffix refers to a specific motif. The following observations can be made from the table:

- Similar motifs of the same *rāga*s are identified correctly.
- Different motifs of the same *rāga*s are distinguished quite accurately.
- Motifs of different *rāga*s are also distinguished quite accurately, except for sk3 (diagonal elements in the Table).
- Motif $sk3$ is confused with $ky1$ and $kb1$. This is because the phrase is rather short and at the macro level consists of only two svaras.
- The HMM output must be postprocessed using duration information of every state.

4. CONCLUSIONS

The relevance of motivic analysis for understanding *rāga*s is studied in this paper. In particular, the use of machine

Rāga	bh1	bh2	ky1	kb1	kb2	kb3	sk1	sk2	sk3	va1
bh1	**40**	2	1	0	0	6	0	0	0	3
bh2	0	**61**	4	1	4	1	1	0	0	0
ky1	0	1	**23**	10	0	0	11	2	5	0
kb1	0	0	3	**91**	0	0	6	3	1	0
kb2	0	0	1	2	**44**	0	0	0	1	0
kb3	0	0	2	1	0	**41**	0	0	0	0
sk1	0	2	18	13	3	0	**28**	7	9	0
sk2	0	0	7	0	1	0	4	**34**	2	4
sk3	0	1	23	25	1	0	29	5	**10**	2
va1	3	0	1	0	0	0	0	0	0	**48**

Table 4. Confusion matrix for motif recognition using HMMs(bh – Bhairavī, ky – Kalyāṇī, kb – Kāmbōjī, sk – Śaṅkarābharaṇā, va – Varāḷī)

recognition of motifs is attempted. Interesting observations include the fact that there indeed exist distinctive prosodic motifs for each *rāga*. It is also shown with examples that motifs should not be transcribed into svaras, since annotation could lead to significant loss of information. Ideally, one would like to spot motifs in a recital. But this requires that one be able to first identify the intonation units or breath groups of the performance. As a motif is likely to be confined to a breath group, the search space can be considerably reduced. This requires significant understanding of metre and the acoustic cues that enable their identification.

5. ACKNOWLEDGEMENTS

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