

AN OVERVIEW OF HINDUSTANI MUSIC IN THE CONTEXT OF COMPUTATIONAL MUSICOLOGY

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ABSTRACT

With its origin in the *Samveda*, composed between 1500 - 900 BC, the art music of India has evolved through ages and come to be regarded as one of the oldest surviving music systems in the world today. This paper aims to provide an overview of the fundamentals governing Hindustani music (also known as North Indian music) as practiced today. The deliberation will mainly focus on the melodic aspect of music making and will attempt to provide a musicological base for the main features associated with the melody: intonation and improvisation; thus covering the soundscape on the micro as well as macro level. The larger objective of this endeavor is to identify relevant directions for the application of computational approaches to Hindustani music.

1. INTRODUCTION

The term 'Indian music' refers to the music system of the Indian subcontinent including seven nations - India, Pakistan, Bangladesh, Afghanistan, Tibet, Nepal and Bhutan. The extraordinary variety of musical types available in this region is probably unparalleled in any other part of the world. Music has a vital role in the religious, social and artistic lives of the people. A great deal of it could be termed functional, as it is an indispensable part of the activities of everyday life ranging from work and agrarian songs, festivities, to the music which accompanies life cycle events such as birth, initiation, marriage and death [1]. There is also a strong sense of spirituality attached to Indian music, the realization of which is essential for its study and practice. The immediate goal of music is sensory pleasure but its ultimate goal is regarded as the spiritual release.

Indian music, like the other great traditions of the South Asian classical music, is regarded as pre-eminently vocal; instrumental music of whatever degree of virtuosity is looked upon as tangential, whether regarded as accompaniment to the voice, or as an imitation / extension of the voice, or as a secondary tradition parallel to the vocal tradition. Indian music is based on melody and rhythm; harmony and polyphony, as known in the West, have no part in the music. Much of the music is modal in character and is often accompanied by a drone, which establishes a fixed frame of reference and pre-

cludes any key changes, which are so characteristic of Western music. Indian film music is of course an exception to this norm as it freely uses Western instruments and techniques including harmonization, chords etc.

Art music (sometimes inappropriately described as classical music) is one of the six categories of music that have flourished side by side: primitive, folk, religious, art, popular and confluence. The patently aesthetic intention of the art music sets it apart from other categories. It is governed by two main elements: *raga* and *tala*. It is primarily a tradition of solo performance, affording scope to innovate and interpret, and hence methods and techniques are developed to this end. Consequently, this leads to emergence of various musical ideologies and family traditions (*gharana / bani*).

There is an abundance of musical genres and forms with specific structures based on patterning of musical elements (notes, rhythms, tempi etc.). Certain forms are regarded more prestigious because of the demands they make on performers in terms of the skill and techniques required.

In India, there are two recognized streams of art music. Hindustani (or north Indian) music represents the tradition for the region where Indo-Aryan languages are spoken, that is, the Indo-Gangetic plain with the north-west quadrant of the peninsula. In the Dravidian-speaking areas (that is most of peninsular India) the tradition is represented by Carnatic (or south Indian) art music. Hindustani and Carnatic music are the same in essential abstract features but different in detail. The basic structure of typical ensembles is common to both: in addition to a drone¹ there are three separate and independent musical roles. The primary melody is carried by a singer (in vocal music performance) or an instrumentalist (in an instrumental music performance), the secondary melody is carried by the accompanying melodic instruments (either bowed or reed) and the drums provide the rhythm. However, the basic characteristics of these three roles differ, and even vocal production is strikingly dissimilar in two styles. Adherence to *raga* and *tala* and their basic principles is common to both the systems, and many *raga* and

¹ Provided usually by a *tanpura / tambura*, an open-stringed instrument, the special bridge curvature of which gives rise to an envelope that is rich in overtones and harmonics.

tala names are identical, although the actual pitch content of the *raga* and the measure of the *tala* are usually different. There is also considerable difference in the preferred expository techniques, ornamental styles and use of tempo.

Scientific enquiry into the organization of music in pitch and time, in the context of scales and meter, has been a part of ancient Indian texts and more recently revisited by prominent musicologists such as Bhatkande [29] and Jairazbhoy [7]. On the other hand, computational approaches to music have lagged far behind those in Western music. This may be partly attributed to the fact that Indian music remains a predominantly oral tradition. With growing research on digital audio processing tools, the potential of computational approaches in Indian music may now be realized. In this paper, we review the musicological bases of Hindustani music leading up to contemporary performance practice. A review of recent research initiatives in music computation is presented together with a discussion of promising new directions.

2. HINDUSTANI MUSIC PERFORMANCE

Hindustani music is essentially structured around the soloist. The ensemble includes one main artist, either vocalist or instrumentalist and the accompanists (their number varies depending on the type of concert- vocal / instrumental). For vocal music, there are either one or two tanpura (drone) players, a sarangi player (nowadays often replaced by a harmonium) to provide melodic accompaniment and a percussionist (either tabla or pakhavaj). In instrumental solo, the instrumentalist receives support from the percussionist and a tanpura player (nowadays many instrumentalists even prefer to replace this by an electronic tanpura). The soloist occupies the central position on the stage as depicted in the photo in Fig. 1, and has the main responsibility of music-making. Tanpura players provide the tonic. They occupy the position behind the main artist on either side and often, they may be disciples of the soloist. The percussionist and the sarangi (or harmonium) player sit on either sides of the soloist (usually, the percussionist on the right and the melody instrumentalist on the left). Some vocalists themselves play one of the tanpura or even prefer to strum *svaramandal* (for occasional reinforcement). The sarangi (or harmonium) follows the vocalist and is only occasionally allowed to play solo phrases. The percussionist is expected to keep the rhythmic (*tala*) cycle going in specified tempo (*laya*). Occasionally, the soloist might let him improvise while he himself or the melody instrument keeps the time. In appropriate measure, such interludes can be aesthetically satisfying. In case of a solo percussion recital, the melody instrument assumes the role of time-keeping while the percussionist becomes the principal artist.

The ideal setting for a recital is a select and small gathering of appreciative listeners who sit like the artist on the floor. Besides providing acoustic intimacy, the close proximity helps to establish communication with the audience. There is a two-way communication between the artist and the audience involving verbal in-

terjections and / or non-verbal expressions such as facial or hand gestures. A knowledgeable audience knows how and when to appreciate while the performer is expected to have the sensitivity to respond to the audience-reaction.

A performer of classical music (*shastriya sangit*, i.e. music based on scientifically and systematically formulated norms) presents one or more *raga*-s (depending on the availability of time). The three main vocal genres of Hindustani music are: *dhrupad*, *khayal* and *thumri*. These terms designate both, the composition as such and the genre as a whole. Whilst *dhrupad* is considered to be the oldest and the most disciplined (in terms of the purity of *raga* and rigidity of the composition structure) of the Hindustani genres heard today, *thumri* is the lightest and the most ornamented genre. *Khayal* stands in between these two extremes.



Fig. 1. A Hindustani vocal concert setting. The singer is flanked by two tanpura players. The tabla player is seen on the right above, and a sarangi player on the left.

3. TONAL SYSTEM

3.1 Tonal Material

Indian music uses seven notes or scale degrees (*svara*), which are known as Sa, Re, Ga, Ma, Pa, Dha and Ni. Together they are referred to as SARGAM. Each symbol used to represent these notes is an abbreviated form of the real note names, which are Shadj, Rishabh, Gandhar, Madhyam, Pancham, Dhaivat and Nishad.

The natural form of notes corresponding to the Western major scale is called *shuddh* (natural, lit. pure). In notation, they are represented as S R G m P D N. Further, Re, Ga, Dha and Ni can be flattened by a semitone and are then called *komal* (flat, lit. soft). They are notated as r, g, d & n. Ma can be sharpened by a semitone and is then called *tivra* Ma (lit. sharp), notated as M. Thus the 12 tones within an octave are notated as: S r R g G m M P d D n N S. Sa and Pa are immovable (*achal*) and hence their position cannot be altered. Mainly three octaves are used: low (*mandra*), middle (*madhya*) and high (*tar*).

Unlike Western music, pitch in Indian music is not absolute. It is rather relative (in terms of intervals) to the tonic provided by the tanpura, which becomes the continuous point of reference for both the performer and listener. Vocalists have the freedom to choose a pitch of Sa that allows them to reach at least the fifth below and

an octave and a half above the tonic. For male vocalist this is usually C or D, and for female vocalists it is G or A.

3.2 Intonation

Indian musicians attain a high degree of consistency in pitch with deviations that are often under one percent. “Tunefulness” (*surilapan*) is one of the most important aesthetic requirements in Indian tradition. In fact musicians’ training (*talim*) and practice (*riyaz*) is largely aimed at refining the conception of intonation.

The exact pitch of the notes has never been standardised in frequencies or ratios. It is understood that the actual position of the semitones excluding the tonic and the fifth can vary slightly. The flat notes can be lowered by approximately 20 cents, and similarly the sharp Ma can be made sharper. These microtonal variations are often referred to as *shruti*. As far as steady pitches are concerned, empirical research indicates that intonation is fairly standard and no significant deviations can be correlated to specific *raga-s*, as has often been claimed by protagonists of the *shruti* theory [2, 3, 4, 5]. This does not apply to pitch inflections, which are known to be connected to the *raga* and context.

Empirical studies on context-related intonation suggest that two salient factors are responsible for consistent difference in intonation. The first, which was already indicated by Ratanjankar in 1940 and corroborated by Levy, is that in ascending passages notes are intoned higher, while in descending passages they become lower [3, 6]. The second is the tuning of the first string of tanpura, which can either be Ma, Pa, or Ni of the lower octave. In the Ma-tuning (m S S low S), the Ga is higher, at almost 400 cents, while the Dha is lower, a harmonic major third above the Ma (884 cents). In the Ni tuning (N S S low S) with Ni at about 1105 cents) all notes tend to be higher.

Scholars starting with Bharata (200 BC – 200 AD) have formulated concepts such as *svara* and *shruti* to describe intonation. Whereas *svara* is defined as a musical note or a scale degree, *shruti* is regarded as a more subtle division of the octave. From early times an octave was supposed to contain twenty-two *shruti-s* and the relation between *shruti* and *svara* has been a major source of confusion. It has not been uncommon to refer to *shruti-s* as quarter-tones or microtones, but evidently, twenty-two *shruti-s* divided over seven *svara-s* in an octave presents a mathematical problem.

The crux of the problem lies in the centuries old fallacy of thinking of melody in terms of fixed positions of intonation. Whereas, experimental studies conducted during the twentieth century provide evidence for flexible intonation, ruling out the notion of pitch as fixed points. [2, 3, 4, 5, 7]. Modern scholars have observed intonation as a statistical phenomenon in which the note densities occur, not as exact points but rather as limited ranges within a certain tonal region. The influence of melodic context on the pitch is also clear from these studies. In fact, *raga* specific intonations of specific individual notes do not occur in isolation, and hence, they need to be examined within the respective melodic context.

Intonation in Indian music is characterized not only by the individual pitches, but also by the way they are connected, leading to specific melodic contours or shapes. Theoretically, there exist infinite number of possibilities in which the given two notes can be melodically linked. However, in reality, melodic contours are guided by the grammar of the *raga*, the immediate context and the details of individual ornamentation. Contemporary musicians use the term *shruti* in conjunction with highly specific ornamentations of some notes in particular *raga-s*. Thus, they speak of the *shruti* of the flat third (*komal Gandhar*) in the *raga* Darbari or Todi, or the *shruti* of the flat second (*komal Rishabh*) in the *raga* Bhairav.²[8,9] Although most scholars have related the ancient concept of *shruti* to pitch positions or tuning schemes, the contemporary meaning of *shruti* seems more related to ornamentation, or to put it in the words of Nicholas Cook, “music between the notes”. [10]

The presence of microtonality in Indian music is evident to anybody who practices this music or listens to it critically. Empirical research also proves beyond any doubt that the concept is not merely an organological construct of historical relevance.³ However, the formulation as it is presently understood, needs a paradigm shift from regarding *shruti* as discrete points to defining it in terms of a melodic shape or melodic contour. To describe intonation in the contemporary *raga* performance, we need a more comprehensive model including acoustic parameters of not only pitch but also volume dynamics and timbre dynamics in relation to the temporal axis.⁴[11]

3.3 Scale types (*that-s*) and Classification

That (lit. type or group) can be defined as an arrangement of notes having potential to generate *raga-s*. *That* is a genus whereas a *raga* is a species arising out of it. Thus a *that* is a heptatonic scale using each of the seven notes.

In the context of Carnatic music, such scale type is referred as *mela*. Venkatmakhi, a well known scholar of the 17th century, arrived at a system of seventy-two scale types on the basis of permutations and combinations of the notes within the septet.

It is generally assumed that the original Indian scale had a lowered third and seventh: S R g m P D n. From this parent scale six other scales were derived by shifting the tonic to each of the seven notes. These are:

S R g m P D n - Kafi *that*
 n S r g m P d - Bhairavi *that*
 D N S R G M P – Kalyan *that*
 P D n S R G m – Khamaj *that*
 m P d n S R g – Asavari *that*
 R G m P D N S – Bilaval *that*

² For a detailed acoustical analysis of some examples of intonations in these *ragas*, refer to Rao & Meer (2004 & 2009) [8,9].

³ Given that Bharata explains this theory with the help of two *vinas* (a string instrument) with 22 strings.

⁴ For an exhaustive review on the subject of *shruti*, refer to Rao & Meer (2010) [11].

In addition to the above scales, the following chromatic scales were derived.

D N S r G M P – Marva *that*

N S r G M P d – Purvi *that*

D N S r G M P – Todi *that*

Yet other scales came to be used, of which Bhairav *that* must be specially noticed:

S r G m P d N - Bhairav *that*

The ten scales are presented in Western staff notation below with the tonic represented by middle-C.

Fig. 2 *That* system of Hindustani music.

The above mentioned ten scales form the *that* system of V. N. Bhatkhande (1860-1936), which he used as a pragmatic model for classifying his collection of thousands of compositions in over two hundred Hindustani *raga*-s. However, this system is not without limitations, e.g. this classification does not satisfactorily cover some of the scale-types like Lalit, Patdip, Ahir bhairav and pentatonic *raga*-s like Malkauns, Bhupali etc. Further, the classification becomes ambiguous as it relies totally on the scale-type as a supreme classificatory tool. These shortcomings aside, Bhatkhande's ten *that* system provided a sufficient framework for defining and classifying the most common tone material used in *raga*-s, and has since become standard.

4. MELODIC AND METRIC CONCEPTS

4.1 *Raga*

Raga is the central and predominant melodic concept in Indian music. Many scholars have suggested that the characteristic tunes of various *raga*-s have originated from folk songs as well as from the local and provincial melodies. *Raga* as understood in the contemporary musical parlance eludes a simple and concise definition. As Harold Powers puts it: "A *raga* is not a tune, nor is it a 'modal' scale, but rather a continuum with scale and tune as its extremes." [12]. Broadly speaking, it can be termed as a melodic mode or tonal matrix possessing a rigid and specific individual identity, yet bearing immense potential for infinite improvisatory possibilities. *Raga* serves as a basic framework for composition and improvisation in Indian music (which is essentially melodic and monodic in nature). Technically, *raga* is a musical entity in which the choice of notes; their order and hierarchy, the manner of intonation of individual notes, relative duration and their specific melodic approach, are clearly defined.

Being a dynamic musical entity with a unique aesthetic identity, structurally it is dictated by a set of rules forming its grammar. This includes: choice of notes forming the scale, the ascending (*aroha*) and descending (*avroha*) patterns leading to general progression (*chalan*), and hierarchy of tones (*vadi*, *samvadi*, *nyasa svara* etc).

Certain melodic phrase/phrases and /or characteristic intonations of particular notes can readily define the essence of a given *raga* (*pakad*). Although there may be *raga*-s with similar scales-similar melodic configuration, similar melodic configuration- different scales, similar scales-different melodic configuration and those exhibiting partial similarity; by virtue of the above mentioned musical characteristics, every *raga* becomes an embodiment of a specific musical idea (*ragabhava*) which is uniquely identified with it.

Due to the influence of Vedic and Tantric philosophy, many extra musical references and associations such as specific deity, colour, gender, visual contemplation (*dhyana*), time/season for performance and aesthetic emotion (*rasa*) etc. were attached to *raga*, some of these associations (especially the time of the performance and the aesthetic emotion) are valid even today. Over the centuries, many changes have occurred with respect to *raga*, such as disappearance of certain *raga*-s, emergence of new ones, transformation of *raga*-s and different interpretations of *raga*-s.

4.2 *Tala*

The concept of time in the Indian philosophy is cyclic and not linear. *Tala* is defined as a measure employed in the act of keeping time. It is a rhythmic framework governing the temporal aspect of vocal & instrumental music, and dance. Like *raga*, theoretically, infinite number of *tala*-s are possible though musicological texts have settled on 108 *tala*-s. Any *tala* can be described as having a certain number of time units or beats (*matra*-s) and more importantly sections into which these beats are

grouped and stressed (*vibhag* or *khand*). Cyclicity (*avar-tan*) is a vital aspect of any *tala*. The common North Indian *tala*-s have 6,7,8,10,12,14 or 16 beats per cycle. Tintal having 16 (4-4-4-4) beats is the most common *tala*. The first beat of the *tala* is called *sam*. The process of improvisation may or may not start from *sam* but it invariably ends on this beat, which is often accentuated and stressed. On the other hand, the beat which serves as a counterpoint to *sam* is called *khali* (lit. empty). Generally, *khali* is in the middle of the *tala* cycle.⁵

Laya in its broad sense means 'time' of music. In Indian classical music, the speed at which a composition is performed is specified in not absolute but relative terms: slow (*vilambit*), medium (*madhya*) and fast (*drut*). Generally, as the performance progresses, the speed of rendition goes on increasing; within a given composition as well as between the two compositions.

4.3 Ornamentation and Tonal Space

Although Hindustani music often uses long drawn steady notes with a great sense of accuracy of intonation, space between the notes and the manner in which the notes are linked, are also as important. About fifteen types of ornamentation are described in the musicological treatises under the generic title of '*gamak*' [12]. Most of these ornamentations are no longer extant and the contemporary musical practice shows usage of different ornamentation. In some cases a specific ornament is required within a particular *raga* and therefore defines its flavour, but often these embellishments have purely aesthetic function.

Kan is a single grace note before, after or within a main note. It is widely used as an ornament showing the way in which notes are approached in a particular *raga*. In fact, *kan* is so common that the attack of a note without a preceding grace is extremely rare.

Mind is a continuous gliding movement between two notes.

Andol (or *andolan*) is a slow and repeated intonation of a given note with a *kan* of an adjacent (upper or lower) note. The contemporary musicians often use the term *shruti* in conjunction with these ornaments, especially *andol*.

Murki is a fast and complex ornament involving two or more notes. Except in rare cases, it is a pure ornament; it does not characterise the *raga*. Rather the complexity and frequency of *murki* depends on genre and style. Lighter the genre or style, greater the use of *murki*. Thus, the frequency and complexity of *murki* is much more in *thumri* as compared to *khayal*.⁶

Though the term '*gamak*' is a generic term used in the medieval period (and even today in South Indian music)

⁵ Except in case of *Rupak* where it is the first beat itself.

⁶ The term 'light' refers to those genres in which performers can take liberty with respect to the rules of *raga*.

to collectively refer to all the ornaments; in Hindustani music it denotes a specific note-treatment. It involves intonation of several notes (in relatively fast passages), each with a *kan* of either lower or higher note, laying stress on the main note.

Sunth is yet another type of ornament which is a long *mind* with a nasal pronunciation using the vowel sound 'u'. While *sunth*, *mind* and *gamak* are used in *dhrupad*, *kan*, *murki*, *mind* and *gamak* find application in *khayal* tradition. Besides these, there are more ornaments such as *krintan*, *ghasit* etc. which are included in the instrumental music, especially on the string instruments.

5. IMPROVISATION

Improvisation is an essential aspect of music practiced in India. Though the idea of improvisation is conceptually contrasting to 'pre-composed' presentation, it also does not imply an impromptu expression or a random arrangement of notes or melodic phrases. It rather accepts creativity within the bounds of the *raga* grammar and aesthetic norms of the performance practice. Thus improvisation in Indian music is something like a golden mean between extreme order and absolute chaos! Although the techniques used for melodic improvisation can vary depending upon the tempo and the register, they are essentially based on the principle of permutation and combination of notes, use of various ornamentation, and varying emphasis (accent) which can comprise volume, duration or timbre change. In the process of improvisation, both matter and manner, or the content and technique, play crucial roles.

5.1 Phrasing

5.1.1 Content

The matter or the content constitutes the body of the performance and is comprised of distinct melodic phrases; their content and sequence being based on the principles of improvisation and the grammatical rules of the *raga* being performed. The order /sequence of the involved notes and their duration defines a given phrase. The order may be a straight sequence (*sapat*: S R G m P) or a zigzag pattern (*vakra*: S G R m G P). Some notes may be omitted (*varjit*) either from ascending or descending passages or from both; depending upon the rules of the *raga*. For example; in *raga* Jaunpuri, Ga is omitted in the ascending passages but included in the descending movement (S R m P, m g R S), whereas in *raga* Darbari it is omitted in descending passages and included in the ascending phrase (S R g m P, g M R S).

In the process of phrasing, the dominant notes (*vadi* and *samvadi*) are the most frequently used notes, often (but not necessarily) held for a long duration within a phrase. Many phrases are concluded on the *nyasa* (resting/final) note/notes of the *raga*. Besides the order and duration of the selected notes, the accent or the emphasis (*vazan*) with which different notes are intoned within a given phrase; also becomes significant. Most importantly, validity of phrasing is ultimately governed by the aesthetic considerations.

In an attempt to characterize the *raga*, phrasing follows very distinct patterns. In fact, a single phrase by a master musician is sufficient to instantaneously create an atmosphere of the *raga*. Yet the process of phrasing is so complex and elusive that no scientific model has yet been formulated to codify the rules governing phrasing in *raga*-s. In practice, the technique of phrasing is learnt through oral-aural mode of knowledge transfer, in which both direct and indirect way of learning become operational.

5.1.2 Technique

The manner in which the content is treated is as equally important as the content itself. Various techniques are used including varying emphasis, volume and timbre, and use of ornamentation. The speed of rendition of phrases is one of the important factors determining the resulting melodic shape of the phrase. Thus there is certain flexibility available to the musician in rendering the content, e.g. a chosen phrase of the *raga*, and this is where technique plays a role.

5.2 Elements of a Raga Performance

A *raga* performance consists of a number of elements such as the free form introduction (*alap*), composition (*bandish*), rhythmic improvisation (*layakari*) and fast sequences of notes (*tan*). The details of these aspects, their order in a performance, the types that are used and the emphasis placed on each of these elements depend upon genre, school (*gharana*) and the selected modality (vocal, instrumental etc.).

Alap

Alap section is meant to clearly delineate phrases to show the individuality and flavour of the *raga* (*ragabhava*). In some cases (as in *dhrupad* & instrumental music performance) it is rendered at the beginning of the exposition in a very slow and / or medium pace without the drum accompaniment. However, in case of a *khayal* performance (barring the exception of Agra *gharana*) such exposition occurs along with a melodic (*bandish*) and a rhythmic framework (*tala*). In such cases the delineation is woven with the *tala* cycle and the *mukhda* (lit. face, a brief section of the *bandish*) is used to conclude each segment of improvisation. In vocal music it is common to sing *alap* with the vowel sound 'aa'. However, when it is rendered using words of the composition (with the *tala*), it is known as *bol-alap*.

Bandish

Notwithstanding the importance accorded to the aspect of improvisation as an essential component of music practiced in India, a well-structured composition (combining melody, rhythm and lyrics, often referred as *bandish* or *cheez*) forms its core.⁷ Different *bandish*-s can be understood as viewing a *raga* through kaleidoscope -different combinations of the same set of notes bound by the same

⁷ Compositions meant for instruments may or may not include lyrics. Also, those meant for percussion instruments, san both melody and lyrics.

grammar. Further, composition gives the basic framework for improvisation. The dynamics of composition and improvisation influences the quality of a music performance.

Improvisation associated with the composition is called *badhat* or *vistar*, literally pointing to its growth or expansion [13]. Nonetheless, in some genres improvisation can also precede composition, in which case it is purely an exploration of the *raga* (*alap*) without any rhythmic /poetic framework. The process of improvisation (accompanied with or without composition) is akin to 'story telling'. Musicians have a strategy (*silsila*) comprising of a chain of musical statements, which occur in a fairly disciplined (but not rigid) order of sequence. There is a subject to be explored, storyline to be followed, grammar, logic and syntax to be adhered to, micro as well as macro structure to be kept in mind, to finally create a portrait of the *raga*. Any attempt at studying and modeling this complex process must include, besides the principles of permutation and combination, and the story-telling logic, aesthetic principles of the *raga*, genre and style (*gharana*).

Preliminary investigations of intonation and melodic movements in *raga* Yaman suggest that a *raga* performance is a 'rule based' as well as a 'model based' phenomenon⁸. Outwardly it may seem to be impromptu, but in reality, any *raga* exposition is essentially governed by certain rules comprising its grammar and also the model preconceived in the mind of a performer which results from his/her training, experience, imagination and skill and even occasion for performance. Thus the model is the strategy planned by the performer to unfold the *raga*. The similitude of the tonal configuration makes it possible to correlate it with the unique character of the *raga* (*ragabhava*) and consequently to the aesthetic emotion elicited in the mind of a sympathetic listener, often referred to as *rasa*.⁹ [14]

Layakari

Layakari (*laya* + *kari* meaning to work on tempo) is the introduction of temporal / rhythmic variations with reference to the assumed tempo. This may consist of presenting the composition at various tempi such one and half times, two times, three times the original tempo or using off beat melodic phrasing.

Tan

A rapid sequence of notes is called *tan*. In ancient and medieval theory, the term *tan* designates a melodic phrase in general, but in contemporary practice it exclusively refers to fast and often long series of notes of equal/unequal duration, usually at a tempo that is two, four, eight or sixteen times faster than that of the accompanying rhythmic cycle. The *tan* phrases are not composed arbitrarily; rather there is logic in its development, which aims at creating a meaningful melodic structure

⁸ This heptatonic *raga* has all natural notes, except the fourth, which is augmented.

⁹ The concept of *rasa* is unique to Indian poetics and dramaturgy. There is no exact equivalent in other cultures but ideas denoted in terms like *ethos*, *empathy*, *eurfulung*, *gestalt* and *duende* are somewhat similar.

within the rules of the *raga*. Two main varieties of *tan*-s as mentioned in theory are: *shuddh* (pure) and *kuta* (complex / puzzling). The contemporary performance displays a great variety in *tan*-s, both in melodic and rhythmic structure as well as in technique; although, not all 5040 *tan*-s that are enumerated by the medieval theory on the basis of mathematical rules of permutation and combination. The most common melodic varieties are *sapat* (the straight moving) *tan* and *vakra* (zigzag) *tan*. The notes in a *tan* may be grouped in different numbers, thereby creating various rhythmic patterns (*katav*). In vocal music, this is often underlined by attaching syllables of the wordings to each group of notes (*bol-tan*).

The instrumental music expose comprises *alap*, *jod*, *jhala*, & compositions such as *vilambit (masitkhani) gat* and *drut (razakhani) gat*. The features such as *layakari* and *tan* also form part of improvisational strategies in the instrumental music.

6. NOTATION

Notation is essentially a way of manipulating visual designs to communicate one's individual impressions of music to other people.

6.1 Role of Notation in India

In India, music is first and foremost an oral tradition. Many features concerning education, performance, appreciation and propagation of music are directly and deeply rooted in the oral tradition. Although systems of music notations have existed in India at least since the early centuries AD, the relationship of notation to performance in the Indian tradition is very different from that in the West. As observed by Widdess, Indian musical notations are oral in origin, and mnemonic in function; in both respects they contrast with Western staff-notation, which is graphic in origin and prescriptive in function [15].

The Indian notation system uses mnemonic syllables (*SRGM*), which basically means that sounds are given names by which they are referred, essentially to help talk about, think, discuss as well as transmit both melodic and rhythmic music. The mnemonics can include note names and strokes of stringed instruments or drums. They can be recited and remembered with specific inflections that symbolize ornamentation and/or dynamics of volume and timbre. It is to be noted that independence of Indian art music from written notation allows, or is a function of, a high degree of variation, embellishment and improvisation practiced in performance.

6.2 Notation: Advantages

For musicians, there is a direct connection between sounds and mnemonics, and hence they resort to *sargam/bol* for musical thinking- teaching and composing. The sketchy *sargam* notations are an aide-memoir especially to keep record of traditional compositions. From the late 19th century onwards, compositions were printed and published

with notation for the purpose of instruction, dissemination and preservation of traditional repertoire, which has so far come to us mainly through oral tradition.

6.3 Notation: Limitations

Although the 'oral notations' may be committed to writing in whatever syllabic script prevalent locally, both in intention and actuality, notation is expected to be skeletal. It is neither graphical in the way the Western system is, nor is intended to precede or replace oral instructions but only to reinforce it. Although there is a direct connection between sounds and mnemonics, the ways in which the mnemonics of Indian music can be interpreted are far more diverse than words in the domain of language. During the process of writing music, the 'extra' information in terms of various inflections is never written; rendering the system inadequate for the visual representation of music. Although such sketchy notations are an aide-memoire, in general, the practitioners rightly maintain that 'written' music doesn't represent the musical events as they are transmitted through oral-aural mode adopted in the traditional method of instruction.

7. COMPUTATIONAL OPPORTUNITIES

Computational approaches to Western music have been a subject of research for computer scientists over the past few decades exploring aspects such as the empirical testing of musicological concepts, musical performance research and historical musicology [16]. The ability to process huge amounts of information facilitated research in traditional areas of musicology as well as opened up new areas such as Music Information Retrieval (MIR) in response to the rapid growth of digitized music archives. Most computational work for Western music has involved written scores. The availability of vast digital audio archives has opened up prospects of research in musical performance, spreading further to other musics of the world including oral traditions such as Indian music. The relationship of the storehouse of implicit musicological knowledge, discussed in this article, to contemporary practice can now be carried out with audio analyses of the performance recordings of eminent musicians. Recent work along these lines has addressed the aspect of intonation and *raga* identity. These studies are based on the melody derived by pitch analysis of the main artiste in concert audio recordings. While *alap* sections provide the main voice relatively free from accompanying instrumentation, it is typically necessary to consider the polyphonic nature of the audio in order to extract the main melodic line from concert recordings. Predominant-F0 detection methods have been applied to the task of detecting vocal pitch in the presence of percussive and melodic accompaniment such as the *harmonium* [17,18]. The time-varying pitch so derived provides a visual representation of the melodic contour which, as envisioned by Seeger in 1958 [19], constitutes a kind of transcription that is unconstrained by the limitations of written notation.

Apart from providing for enriched listening (as demonstrated by the ATRIM project [20]), the visual representation facilitates insights into the unifying and

distinguishing aspects of melody in a specific *raga* performance. Automatically detected continuous pitch contours have provided the basis for studies on note intonation and *raga*-characteristic phrase intonation. The question of whether steady notes follow standard intonation, or instead conform with traditional *shruti* theory, where intonational differences between the same named intervals exist across *gharana*-s and *raga*-s, has been addressed through pitch interval histograms constructed from extracted melodic contours. Datta et al. [21] analysed 142 recordings of 42 eminent vocalists' *alap* sections to obtain pitch histograms computed from steady pitch segments detected based on a standard deviation threshold. Distinct peak locations were observed corresponding to different *shruti* positions in 4 different ragas for the five *gharana*-s under study. With the similar approach, fine differences in note intonation have been used to automatically distinguish, from audio recordings, *raga*-s that share the same *svara*-s [22]. A comparison of tuning patterns in modern day practice across Hindustani and Carnatic music was derived from pitch histograms [23]. However, the last word has yet to be said on intonation and the concept of *shruti* in contemporary practice. As discussed in Sec. 3.2, *shruti* has probably more to do with the perception of pitch inflections than any observable discrete note values. It is obvious that computational studies can contribute significantly to resolving this question.

Automatic identification of *raga* has been the topic of several recent studies. Apart from its possible potential in music retrieval tasks, the value of such work lies in discovering how implicit musical knowledge manifests in performance practice. That *svara*-s in a *raga* are a hierarchically organized subset of the 12 pitch classes of an octave has encouraged the use of pitch class profiles in *raga* identification ([24, 25]). Since the tonic in Indian music is not an absolute pitch but rather one chosen by the performer, the identification of the tonic is a crucial component of any melody based study. Automatic tonic detection has been a subject of recent research as well [26].

Other important musicological aspects of *raga* performance refer to events at larger time scales such as melodic motifs or characteristic phrases (*pakad*) and *raga* progression (*chalan*). As discussed in this article, both composition and improvisation in a *raga* are marked by recurring melodic phrases that are characteristic of the *raga*. A phrase is described by the sequence of *svara*, their relative duration and ornamentation. The automatic segmentation and labeling of melodic motifs from audio recordings is an interesting problem that could have important applications in MIR. Some work on exploiting note-sequential information has been based on converting the continuous pitch contour into a discrete notes (*svara*) representation and applying pattern recognition methods to the resulting discrete sequence [27, 25]. However the variability of phrase intonation, while still retaining its strong link to the underlying *raga* identity, makes the data representation and matching tasks challenging. Both

timing and pitch variations are observed to occur across instances of a *raga*-characteristic phrase even within a performance beyond what is captured in its written notation. As for the phrase segmentation problem, knowledge about the governing rhythmic structure was incorporated usefully to limit the search space for the main melodic motif (*mukhda*) in *bandish* performance audio recordings [28]. However this is not generally applicable to *raga* phrases due to the loose connection between the melodic and underlying rhythmic structure, especially in slow *khayal*. Further, the melodic shape of a characteristic phrase is observed to change with speed (*laya*) change to *dru*t (*laya*). This dependence is an interesting aspect to explore with computational methods on audio. Other musical dimensions such as loudness and timbral dynamics play a role in phrase intonation that has yet to be explored. Computational modeling of ornaments from attributes of pitch, timbral and volume dynamics can be useful in MIR to identify *gharana* and *raga*-specific styles of ornamentation.

While we have restricted our discussion to computational aspects of melody, there is equal scope for computational research in the rhythm aspects of Hindustani music including identification of *tala* and its surface manifestations including the temporal aspect of the *laya* and the technical subtleties effected by varied drumming patterns around each beat of the rhythmic cycle. Computational modeling of rhythmic structure is likely to help in audio segmentation where distinct sections of the concert such as the *alap*, *vistar* and *tan* differ prominently in rhythmic attributes.

In summary, Hindustani music offers immense potential for computational studies as evident from the broad overview presented here. There are a number of musicological theories that could be enriched by validation from performance audio analyses. Further, MIR based on automatically extracted attributes can help to greatly improve organization of, and access to, classical music archives. Machine learning methods have been applied in music information retrieval based on high-level features extracted from the audio. The challenges include modeling musicological knowledge that can potentially enhance purely data-driven approaches, and, of course, the generation of adequate ground truth information for the development of the computational methods.

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