A MOTION-BASED APPROACH TO ANALYSIS, NOTATION AND CREATION OF HINDUSTANI MUSIC

TEJASWINEE KELKAR

IIIT Hyderabad, AP
India

tejaswinee.k@research.iiit.ac.in

BIPIN INDURKHYA

IIIT Hyderabad, AP
India

bipin@iiit.ac.in

Keywords: Visualization Of Music, Hindustani Music, Motion, Gesture

Performers of Hindustani Classical Music depend heavily on complex models of motion and movement to elaborate melodic ideas through hand gestures and motion metaphors. Despite advances in computational modeling of grammars that govern the elaboration of a raga, these systems run into difficulties because of the nature of pitch systems in computer programs and in performance. We elaborate the problems with trying to obtain the ideas in a flexible-pitch scheme like HCM through the means of a fixed-pitch scheme-like notation and computer music generation. In this paper, we present some experiments to study the effectiveness of a graphical notation scheme in HCM, sound tracing study and an analysis of the terminology used for ornaments – through which to understand motion in HCM. We plan to analyze them computationally to develop a formalism that would be more suitable to the nuances of HCM than the present schemes.

1. INTRODUCTION

Hindustani Classical Music (HCM) typically features a main melodic instrument or voice, and a percussionist. The performances in HCM are centered on the idea of a *raga*, which is a form of melodic abstraction that lies between a scale and a fixed melody (Srinivasamurthy *et al.*, 2011). A *raga* is most easily explained as a collection of melodic motives, and a grammar for expanding smaller pieces into large improvised works. This happens in the framework of a *bandish* or a fixed composition that is based in a hypermetric cycle called as a *taala*. A theme based on a raga is established in a *bandish*, elaborated through the sung octave and improvisation in various forms such as theme and variation, slow and fast elaboration, syncopation and rhythmic play etc is presented in the duration of a performance. The semantic content of a *bandish* can be varied, as well as the thematic properties of different *bandishes* in the same raga, but the fundamental grammar of the raga has to be intact in classical music.

1.1. DEFINITION OF A RAGA

A raga is sometimes compared to a mode in music, although the primary difference is in the elaboration of notes. A raga is always centered on a tonic note or a key center, and one cannot modulate to another key or escape from this central tonic note. A raga typically consists of a selection of between 5 and 8 notes from the scale of 12, making it more like a mode – but the movement between these notes and the allowable phrases are what distinguishes a raga form from a mode.

Although the concept of melodic structures and fixed melodic schemes seems limiting to the concept of improvisation – which is central to HCM, a raga is expounded by performers with various elaborate techniques, thus escaping cliché.

1.2. PERFORMANCE OF A RAGA

HCM is performed with elaborate visualization and gesturing by vocalists. The idea of multimodal associations with musical objects is central to the learning and performance of HCM. Performers and singers often teach with the help of elaborate instructions regarding the mood of the raga, explaining its nature and behavior in terms of

the mood, while sometimes attributing personality types or characteristics to the raga.

Some examples of the types of hand gestures used can be seen in Fig. 1. We can see that singers sometimes trace out the phrases that they sing, sometimes display the positioning of these phrases as being located in different places around the body, and sometimes maneuver melodic objects as if they were real objects that they could pick up and use.

Fig. 1 Examples of gesturing during performance of Hindustani Music

1.3. CONCEPT OF NOTE, SEPARATING SPACE BETWEEN RAGAS

Hindustani music is based on 22 microtonal intervals, also called *shruti*. Twelve of these are abstracted to form a scale that is quite close to the just intonation system in Western music. Although ragas are based on these 12 notes and the intervals, practically it is more common for a vocalist to move between pitches freely and render the inter-tonal spaces carefully. Despite the relative flexibility of tones, there is still a definite grammar for pitches and pitch transitions. Thus, what is more important in a performance of HCM is not the intervals themselves, but the spaces between these intervals. Performers often use concepts such as the approach towards the note, the release of it, and so forth, without which a raga does not come to life even though the sung notes may all be correct.

Written notation is still frowned upon by several performers of HCM for the reason that there is no way to represent many of these motion categories in the existing notation system.

For a form that is in its entirety based on the idea of inter-tonal motion, specifying discrete notes becomes a level of abstraction. A form of notation with only discrete

pitches is a reduction of HCM. We investigate these intertonal motions with the help of performer gestures and their body movements.

2. INNATENESS OF VISUAL MODELS IN HCM

2.1. PERFORMANCE GESTURES

Gesturing almost always accompanies musical performances. Although the use of gestures is so common, these gestures are neither taught nor formally learnt, and do not get any attention in study. Performers learn these gestures simply from getting familiar with the gestures of their teachers and fellow performers. Students of HCM rely on live interaction and observation of their teacher for learning. In this discussion we are referring to physical gestures, which occur side by side with the music in a performance and are involuntary.

The shapes that are drawn by these hand gestures might have close connections with the musical shapes and patterns that the performers are modeling in their minds. This has been investigated in Rahaim (2010) and Clayton (2008). Performers describe thinking in terms of patterns or shapes rather than notes while improvising or performing. A lot of the gestural vocabulary is directly taken from the guru, and the student imbibes the gestures of the guru's body as their own so as to sing like them. However, there is variability in the amount of gestural use. Some singers represent each melodic figure with their hands, while others use their torso and head, while some others gesticulate minimally.

We investigate these melodic shapes and the characteristics of motion, through which we can arrive at simpler basic units that might explain a raga performance through other schemes than notes and note transitions. This might help us move past the problem of computer-generated HCM phrases that sound mechanical and unnatural.

3. AI MODELS AND THEIR APPLICABILITY TO HCM

3.1. HCM NOTATION

In early 20th century, Dr V. N. Bhatkhande developed his own system of notation and archived hundreds of compositions in hundreds of ragas. His notation system was influenced by western classical notation, incorpo-

rating the ideas of barlines, note names, text written underneath, slurs and so forth. Fig. 2 is an example of a composition written in this notation scheme. This is the notation style most commonly used to write compositions from HCM today. As Bhatkhande's work is the first authoritative written source for obtaining data for HCM, it is a natural source to use for creating computer models of ragas.

Fig. 2 Example of notation in Bhatkhande's system

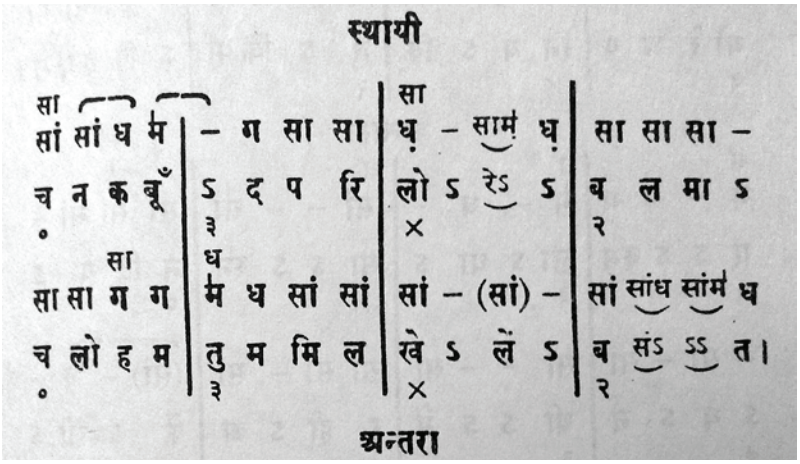
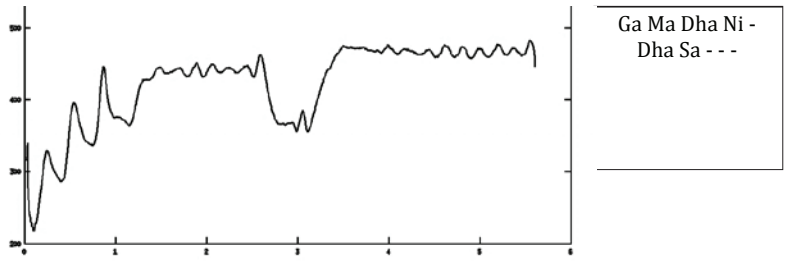


Fig. 3(a) 3(b) Visualization of pitch data. Fig 3 (a) shows a pitch tracing vs time of the phrase that is written down in notation form in Fig 3 (b).

3.2. REQUIREMENT OF FLEXIBLE PITCH BASED NOTATION



Although this notation scheme seems fairly straightforward even from the perspective of ragas and their descriptions, when musical phrases for HCM are analyzed for pitch, we get data that looks much less obvious like discrete notes than the notation style suggests. This is because flexible pitch schemes are widely used to sing and perform in HCM. It is implied that discrete notes need to be connected or tied together by using the spaces in between.

3.3. GENERATIVE MODELS OF HCM

There are several models that have tried to simulate generative grammars in HCM by training machines to recognize note patterns, or treating note groups as words and making generative-grammar-like systems for ragas in HCM.

In Srinivasmurthy *et al.* (2012), a scheme to generate valid HCM phrases via Multiple Viewpoint Markov models (MVMs) is elaborated to elicit the grammar that governs a raga. The database is taken from Bhatkhande's notated *bandishes* in various ragas. MVMs allow a computer to construct phrases that are not limited by their length, and due to this limitation, all possible phrases can never be found. Based on the data, instances of phrase that are true to the grammar of the four ragas in the purview of the study were extracted through MVMs.

Despite this, the extrapolated phrases have not been validated against listeners / performers of HCM, or for the ability of the machine to make its phrases sound natural. *Bandishes* that form the database in this study are extracted from Bhatkhande's corpus, which itself only includes the notation system described above, and excludes the inter-tonal spaces and motion content from music. Notes are abstracted into midi-type data points, and then processed. Since much of computer music is written and processed keeping in mind the basic building unit of a fixed frequency to begin with, even if the generated phrases come very close to actual phrases in music, those phrases will only sound somewhat natural.

We propose experiments to extract other forms of melodic ornaments and their associations with shape to elaborate on the idea of a computational model that goes beyond discrete pitches.

4. EXTRACTING SHAPE OF FUNDAMENTAL ORNAMENTS

4.1. TERMS INDICATING MOTION METAPHORS

There are several terms in HCM that are used directly to represent certain kinds of musical movements. Many of these represent ornaments that are sung. It is important to remember that these ornaments do not just serve the purpose of filling out space between notes, but are crucial for note transitions between ragas. In Table 1, we present a list of such words and the motion meanings they incorporate.

NAME	MEANING	STYLE OF PERFORMANCE
Khatka	Sudden force	Force on one note with pressure, and complete the ornamentation
Ghaseet	Drag	Drag the power of one note into others
Sapaat Taan	Flat speedy notes	Notes are strung one after another rather than threading through other notes
Samet	Gather	An improvised phrase is gathered and finished quickly to meet with the tala cycle
Vajan	Weight	A note that is sung with weight
Gumfit	Tied	Notes weave into each other
Andolit	Oscillating	As if the note is swinging, without a fixed intonation
Pakad	To Hold	The phrase which enables you to have a hold on the raga
Chal / Achal Swar	Walking / Steady note	Fixed notes don't have accidentals (tonic and the fifth)
Golai	Roundness	Smoothness in transitioning between notes / legato

Table 1 Words implying motion in music

The songs/*bandishes* sung in HCM often come from a collective database of *bandishes* set traditionally by older musicians, and unless the name of the musician appears in the last line of the piece, the composer is unknown. Even a known composition will have traveled multiple generations thus obscuring or enhancing the composer's intentions.

If ornaments form a part of the music separate from the notes themselves, then they could be freely applied depending on the performer's choices and their artistic voice. This however is not the case: the raga grammar and *gharana*, or the family of music that a performer comes from, determine the ornamentation and the phrases that are legal at different note points in the octave.

The term "Raga Topology" has been used to describe this kind of motional aspects of raga. (Clayton, 2008) This refers to the behavior of raga resembling a physical scheme. If we are able to extrapolate such a topology through gestural studies, then we can model raga in terms of its physical behaviors regarding note values. This means that fixed notes get fixed patterns and qualities of motion such as 'gravity', 'touch', 'strike' etc., which are elaborately described in theoretical works.

4.2. NOTATION USABILITY OF PITCH DATA – BASED GRAPHICAL NOTATION SCHEME

Meer *et al.* (2010) elaborate a scheme of notation system based on pitch movements through time. Their project emphasizes the need for a new kind of notation system that clearly represent pitch transitions. Despite the difficulties in making melograms from recorded music due to the overlapping of different instruments, lack of clarity and differences in intensity, the melogram system surely contains far more information than plain notation. This scheme comes closest to graphical notation.

This notation system is one of many modifications proposed by modern musicologists to better include ornaments specific to Indian music. Some other examples can be illustrated in Magriel (2008) and Bor, J (2002). Many musicologists also prefer to simply use Western notation where a lot more granularity can be represented than just in Bhatkhande type notation as seen in Jairazbhoy (1995).

We conducted an experiment to see the applicability of using actual pitch vs time representation in notation form to find out whether non-expert participants understand these visualizations any better than written notation which doesn't contain graphical information.

We studied this in the form of an identification and recognition task with 24 participants, of mixed genders, all of whom were musically inclined or trained. They were given a day to learn both types of notation systems. An example of the type of questions asked is illustrated in Fig. 4 (a). Fig. 4 (b) illustrates five sung renditions of a musical phrase in melograph notation. All five would be written in the same way in the Bhatkhande style.

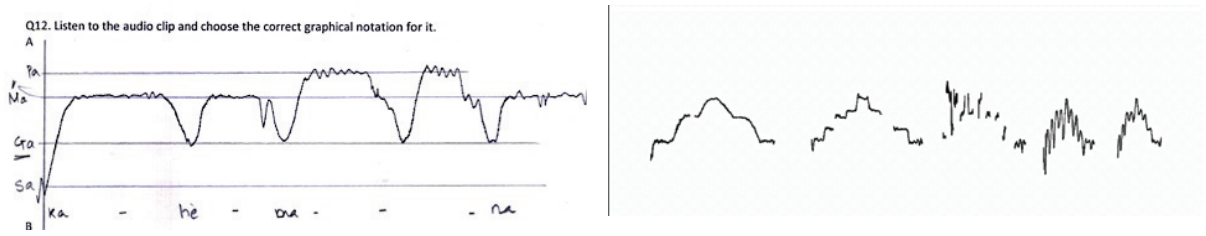


Fig. 4(a) Example question from the notation test **Fig. 4(b)** Examples of melographs analyzed for 5 different articulation types. All 5 of these would be written exactly the same way with traditional notation.

4.3. SOUND TRACING STUDIES

Sound Tracing is a method to study motion that has been applied both in Western and Indian musical systems. Tracing sounds and sound objects can also be a direct

clue to multimodal mappings as studied in both language and co-verbal gesture (Johnson, 1987; Johnson and Larso, 2003, Lakoff and Johnson, 1980). More recent studies focus on obtaining tracings of musical / sound objects from participants for specific stimuli. These experiments have been done for tracings of sound objects (Godoy *et al*, 2010; Jensenius 2010).

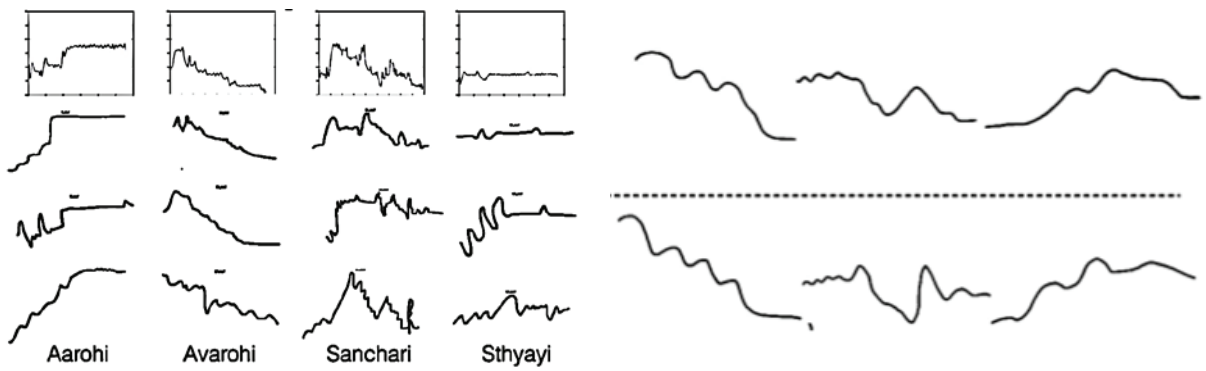
This study aims to further these findings by applying similar principles on sound tracing studies in HCM. Formal theory of melody in Indian music appears across many texts, especially in Abhinavagupta's and Bharatamuni's writings. Features for identifying musical characteristics and analyzing differences between notes have been described in various ways, starting with: a) intonation specifics, b) *jati* of a raga, specifying the characteristics of notes used, their weight and texture, and finally according to the theory of melody, which divides all possible melodic phrases into 4 categories or four *varnas*. Hereafter the rules for combinations of such phrases are described (Rowell, L., 1981)

Table 2 Four Phrase types chosen for experim

Aarohi	These are phrases that ascend from one note to another as prescribed in the raga transition
Avarohi	These are phrases that descend from one note to another as prescribed in the raga transition
Sthyayi	These are phrases that hover around a stationary point in the melodic frame
Sanchari	These are phrases that have a mixture of the three phrase styles

The tracings were recorded on a WACOM Digital Tablet. Each stimulus was played twice with a white noise mask between the two stimuli. We created 32 stimuli mixed across 4 raga groups and 4 phrase types. 2 types of articulations were used: Flat and Gamak. All stimuli were vocal renditions between 4 and 6 seconds. 8 additional stimuli were added at the end of these 32.

Fig. 5(a) Comparison of pitch with tracings of 3 participants for 4 categories **Fig. 5(b)** Repeated tracings.



5. RESULTS AND CONCLUSIONS

5.1. USABILITY OF NOTATION SYSTEM

The average score for trained and untrained participants for Graphical notation reading was found to be 14.36 (out of 20 points) (std. dev. 5.44), and the average score for Bhatkhande system was found to be 13.305 (std. dev. 4.00). This suggests that it was not significantly easier for the participants to identify pitch-time-based notation as opposed to Bhatkhande system of notation, although pitch-time notation is graphical. An explanation for this could be found in the sound tracing study, where the overall envelope of the melodic phrase depended not just on the pitch at each time interval, but also on the meta-level relationships between pitch, amplitude. Moreover, the local perception of pitch at each different point in the long phrase was found to contribute significantly to the phrase shape.

5.2. LOCAL-GROUP SCHEME, TEXTURAL REPRESENTATION IN TRACINGS

In the experiment for sound tracing, we found that what works most accurately for trained as well as untrained participants is a local idea of shape. Tracings are elaborated phrase by phrase, and the pitch distances drawn are relative to the current phrase rather than having an absolute position. This was consistent among all the participants. This might be the reason that a fixed pitch-time melograph does not correspond well with the mental representations. It was also found that texture or melodic articulation (Flat / Gamak) was drawn often in the tracings.

To classify the tracings into four phrase types, we fit a cubic spline function with 8 knots to the tracings to capture the overall contour. The tracings were normalized with respect to the maximum and the minimum stroke heights, and a randomized 10-fold cross validation was performed on the raw data. Then, a K-NN search using the city block metric as a distance measure was performed, selecting the best mode out of the top 11 results for each query.

We found an overall accuracy of 54%. The accuracies for individual phrases are shown in Table 4. Classification results for the first three categories are above random chance, suggesting that consistent mental models

are used for these phrases. The categories Aarohi and Avarohi are found to be the most easily classifiable, as they have fixed spatial properties in the form of an overall ascending / descending envelope, while Sthyayi has fixed temporal properties and Sanchari is a mix of all three.

Table 3 Confusion matrix for classification of phrases

	Aarohi	Avarohi	Sanchari	Sthyayi
Aarohi	**81**	11	24	39
Avarohi	3	**63**	21	13
Sanchari	3	23	**41**	19
Sthyayi	11	1	12	**28**

5.3. CONSISTENCY OF MENTAL MODEL

We compared the repeated phrases for all participants and found several similarities in the corresponding tracings, regardless of whether they reported that this was a repeat or not. Eight out of 32 samples were repeated for each participant, chosen randomly, to analyze whether the tracing is similar – indicating consistency in mental imagery. We report an overall median correlation of 0.68, suggesting high similarity between traces and similarity in trace duration and span. Qualitative results for three phrases and corresponding repetitions for one participant are shown in Fig. 5 (b).

5.4. ORNAMENTS AS BUILDING BLOCKS OF HCM

We have elaborated melographs and sound tracing as methods of extracting information about phrase shapes, melodic forms and ornamentation types in HCM. These ideas of shape were used as basic building blocks to describe HCM in old treatises. We can use a similar method through phrase shape integration for making generative models for ragas in a way that is visually more intuitive, and more accurate in representing HCM than a fixed pitch model. An approach to making a more efficient graphical notation and analysis system can be found through these studies.

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