A SYSTEM FOR THE ANALYSIS AND REPRESENTATION OF BANDISHES AND GATS USING HUMDRUM SYNTAX

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Abstract
A rich symbolic body of data exists for Hindustani music in the form of collections of notated vocal and instrumental compositions (*bandishes* and *gats* respectively). These compositions, however, have not been systematically encoded in a machine readable format. We propose a representation system based on Humdrum syntax, a symbolic representation system developed by Huron (Huron 95) to encode music. Additionally, a linear text-based representation for efficient data entry is described. Advantages of Humdrum-based syntax over MIDI are discussed. Humdrum was chosen in part because of the rich suite of analysis tools that have been developed for it; we discuss some of these tools along with example analyses. It is argued that this representation system in combination with the Humdrum toolkit will be a powerful platform for empirical research on bandishes and gats.

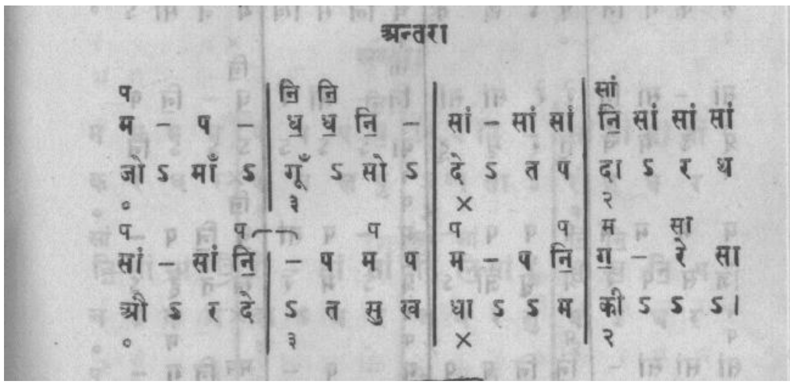
Introduction
Hindustani music, with its emphasis on improvisation, is primarily an oral tradition and until the 20th century notation was infrequently used. In the 20th century there have been two primary motivations for the notation of this music: the preservation of compositions and use as a pedagogical tool. In the first case, scholar-musicians such as V.N. Bhatkhande hoped to preserve and systematize the compositions of different stylistic schools that they felt were threatened by changes in the training and patronage of Hindustani musicians (Bhatkhande 56). Using notation as a pedagogical tool, they wished to encourage mass-education; notation's importance increased as the number of literate students increased and the continuous exposure typical of traditional teacher-student interaction (*guru-shishya parampara*) became less common.

The popularization and development of most elements of current notation systems were largely due to Vishnu Digambar Paluskar, Vishnu Narayan Bhatkande and Moula Baksh (Bhatkande 1937). In the case of V.N. Bhatkhande, his massive project to document the distinctive repertoire of different stylistic schools (*gharanas*) culminated in the six volume *Kramik Pustak Malika* (Bhatkhande 54).

It should be noted that notation in Hindustani music arose in a musical culture which was and continues to be primarily an oral tradition. In all musical traditions, notation can only be satisfactorily interpreted by musicians who have knowledge of the musical culture, and this is particularly the case in Hindustani music. No representation is complete, and the traditional representation system omits as much as it captures. This system of notation has often been criticized for omitting essential elements or greatly simplifying performances. Without entering into the debate, it is useful to remember that notation is an abstraction that can be useful even when it does not provide a recipe for the exact reconstruction of a performance. If fact, its abstraction can be an asset for the researcher, focusing attention on certain categories and simplifying or eliminating other aspects. Traditionally, over a thousand years before notation, the concept of notes and discrete pitch levels for notes was a firmly established part of Hindustani music. For the researcher, modern symbolic notation, even with its limitations, is a rich source of information about pitch and durational information in Hindustani music.

Introduction to Bhatkhande's Notation System

Figure 1: Example Bhatkhande Notation in Raag Darbari Kanada (Vol 4, pp 680)



Because most modern notation systems are based on Bhatkhande, we discuss his notation system in some detail. Figure 1 gives an example of a bandish in *raag Darbari Kanada*. Bhatkhande's notation system consists of symbols for notes indicating their pitch, and symbols for ornaments such as glissandi (*meend*) and turns (*khatka*). Note names, written in *Devnagari* script, are abbreviations of the traditional names given to different pitch-classes. The pitch height is given by a dot that is either present above or below the note, or absent. When absent this is taken to mean the middle octave, whereas the dot above indicates the octave above, and the dot below the octave below. Rests are indicated by the use of a dash ('—').

Note names are indicated by the Hindi character for the traditional names of the scale tones. In the Western alphabet, these are *Sa*, *Re*, *Ga*, *Ma*, *Pa*, *Dha*, and *Ni*. These are sometimes abbreviated to simply the first letter (e.g. S). The second, third, sixth, and seventh scale degrees have "minor" or "flat" forms, much analogous to the Western diatonic scale, which are represented by lowercase letters (e.g. re).

Grace notes (*kan swars*) are indicated by slightly smaller notes placed immediately above another note — for example *Ni* above *Dha* on the first line. Slurs above notes indicate a *meend*, gliding from the note where the slur begins to that above which it ends. *Khatkas*, which start on the upper neighbor, proceed quickly to the main note and past to the lower neighbor before returning to the main note (a "turn" in Western music), are indicated by the placement of parentheses around the note. For example (S) would indicate the movement RSNS taken rapidly. The exact neighboring notes taken are dependent on the *raag* in question. For example, if only the minor seventh scale degree was present, then (S) would indicate SRnS.

The placement of the symbols on the page gives information about the duration and sequence of notes, as well as their relationship to the metric scheme. Time proceeds from left to right, skipping to the next line when one is completed, as in standard text. In Bhatkhande's system, beats are separated by spaces. Notes that occur in the span of the same beat are written next to each other without gap, with a slur underneath to indicate they all occur in the same beat. Durations are inferred by assuming that all symbols separated by a space take the space of one beat, and that all symbols within a beat are of equal duration. In most cases this is unambiguous, such as when there are four adjacent symbols representing four notes, each taking a quarter beat. The most common rhythmic ambiguity occurs when there are three notes in the span of one beat. Contextual information must be used to decide whether they are all equal (triplets), or, more commonly, whether one note takes half the beat and the others a quarter beat each. *Kan swars* have no explicit duration.

Before each composition the rhythmic cycle (*taal*), tempo (slow, medium, fast), and part of the bandish (*sthayee*, *antara*) are noted.

Encoding Protocol

Table 1: Comparison of Symbols Used in Representations

Bhatkhande	**Intermediate**	****bhat**
scale degrees -- note names written in Devnagari script (line below for flat)	SrRgGMmPdDnNS	c c- d e- e f g a- a b- b
kan swars indicated as note above main notes	>note (e.g. >P)	noteq (e.g. gq)
meend indicated by slur above note	[note1 note2] (e.g. [n P])	beginning of glide noteH (e.g. gH)
khatka indicated by parentheses around note: (P) (=DPMP)	%note (e.g. %P)	noteS (e..g gS)
octave indicated by dot above or below note (or absent)	P' apostrophe indicates higher octave	double the letter (e.g. gg)
	P, comma indicates lower octave (indicated by dot below note in Bhatkhande)	upper case (e.g. G)
rest indicated by -	- rest (same as in Bhatkhande)	r
rhythm and other encoding points (see examples at end as well)		
spaces used to demarcate notes on different beats	one or more spaces between beats	
durations not explicitly encoded	Place one cycle per line (e.g. 16 beats on a line for tintal)	durations explicitly calculated (see text)
tala markings given below the notes for major cycle divisions.	Start each line with //	==
divisions of rhythmic cycle given by vertical lines	/ placed between beats to indicate groups of beats	
	e.g. tintial: (x x x x / x x x x / etc) jhaptal (x x / x x x / x x / x x x)	notated using reverse proportional notation (e.g. 4= 1 beat, 8= .5 beat etc.)
	if a line (say at end) has less than the number of beats in the cycle,then add silent rests which are indicated by =	
	e.g. S r g M / = = = =/ = = = =/ = = = = /	

Table 1 summarizes the major symbols used in the Bhatkhande system, their meaning, the corresponding ASCII symbol used in the intermediate notation, and the corresponding **bhat notation (discussed below). Figure 1 shows and an encoding of the *bandish* shown above. First, the comment records are included, with each bandish section receiving a unique control id.

Figure 1: Intermediate Representation of Bandish

```
id: bhatk4663a
antara: Chhin bhangur sab
vol: 4
page: 663
raag: darbari kanada
taal: teentaal
tempo: madhyalaya

// >PM – P - / >nd >nd n – / S' – S' S' / >S'n S' S' S'/

// >PS' – S' >P[n / – P] >PM P / >PM – P >Pn / >Mn - >SR S /
```

Each line begins with '//' and contains the number of beats that are in the rhythmic cycle. For example, in this case, there are 16 beats, corresponding to *tintal*. Every beat is separated by one or more spaces. When the bandish ends before the end of the cycle or begins somewhere besides the first beat, silent rests are used ('=') to fill those beats. The silent rest is used in order to distinguish between rests within the phrase structure and those which fall outside of it. Divisions within the rhythmic cycle, as indicated by vertical lines in Bhatkhande, are indicated with the '/' marker, making the line easier to read and error check. It can be seen that traditional notation does not fully account for all possible rhythmic figures. If subdivisions of the beat are not equal, then this notation becomes unwieldy. However, both because of the musical context and becuse of the intention of encoding traditional notation, this does not pose a serious problem.

Pitches are converted to a single symbol (S for *Sa*, r for *komal* (flat) *re*, R for *shuddh* (natural) *Re* etc). If the pitch height is in the upper octave an apostrophe is added after the note; for the lower octave a comma is used. Higher and lower registers are rarely necessary but may be indicated by the addition of extra apostrophes and commas. The other symbols are mapped directly as shown in the Table 1.

Introduction to Humdrum Syntax

Humdrum syntax, developed by David Huron, provides a framework within which more generalized forms of notation, known as representation schemes, can be defined. Each scheme consists of a mapping between concepts we wish to represent (signifieds) and how we want to represent them (signifiers). Hudrum syntax imposes two basic constraints: 1) signifiers must be composed of ASCII characters, 2) concurrent events occur at the same horizontal level on the page while sequential events proceed vertically from top to bottom. In practice most Humdrum representations consist of parallel vertical columns. Each column represents sequences moving through time. Records from different columns which are aligned horizontally are interpreted as simultaneous. Different columns can represent attributes of a single note or event, or depending on the representation system could represent different notes.

A given representation scheme is composed of three elements: data records, comment records and interpretation records. Comment records are used to annotate encodings and consist of free form text preceded by '!!'. Humdrum specifies a series of standardized comment records such as author, performer, date, etc. Interpretation records allow us to give information necessary to decode data tokens in a given column. They are of two types: exclusive and tandem interpretations. An exclusive interpretation tells us what scheme is being used and is specified by a double asterisk ('**'). For example, **kern is a representation that used to encode Western music. Within that scheme, `A' refers to a pitch. In another scheme, the symbol could be defined to have an entirely different meaning. A tandem interpretation, denoted with a single asterisk ('*'), provides additional information that might be used when processing the data. We might, for example, note that the pitches in a given spine are from an equal-tempered scale by writing '*equal-tempered' before the start of the data. Tandem interpretations differ from comments in that they are used by other programs to help process the data. If we specify '*equal-tempered' as a tandem interpretation, we might use it if we wish to convert pitch names to frequencies.

Table 2: Hypothetical Humdrum Representation for Sarod

**Note	**Pitch	**Duration	**String
	*equal-tempered		
1st note	Sa	1 matra	1
2nd note	Re	½ matra	1
3rd note	Ga	¼ matra	1
4th note	Ma	½ matra	1
5th note	Pa	1 matra	2
6th note	Dha	½ matra	2
7th note	Ni	1 matra	2
8th note	Sa	1/4 matra	3
*-	*-	*-	*-

These ideas are illustrated in Table 2. In this hypothetical notation, information which pertains to concurrent events is placed in the same row. For example, the first note is *Sa*, has a duration of one *matra* and is played on the first string of instrument. If we wanted to convert notes to frequency values, the '*equal-tempered' tandem interpretation would give us the necessary information. Notes which follow in time are given below; time proceeds from top to bottom. Data in each column is interpreted according to the exclusive interpretation, which precedes every column and is denoted with the '**' notation; thus, for example, we know that the number '1' in the fourth column refers to a string number. What is given here is just an example. Humdrum syntax is very general, and numbers, letters, or other symbols are all potentially valid table entries (for a full discussion of Humdrum, see Huron 1999).

The **bhat representation

Figure 2 shows the first twelve beats of a composition in *ektaal* in **bhat notation. The structure of the file is: 1) record information, 2) exclusive interpretation (type of data), 3) a comment line giving the input data, 4) the notes with their pitches and durations, 5) meter markers: symbols '==1' and '='. The former refers to the fact that this is the first rhythmic cycle, while the latter gives the metric subdivisions within the cycle.

A C++ program was created to convert from the intermediate representation to **bhat. This entailed two fundamental steps: segmenting each line into individual notes and ornaments, and assigning rhythmic values to each of those notes. The first task was relatively straightforward, as notes are represented by their pitch-class symbol and ornament symbols always apply to the immediately following note.

The most commonly used Humdrum-based system is **kern which was developed to encode Western music (Huron 97). Because many of the analysis tools have been developed specifically for **kern encoded data, it was decided that the ** bhat representation would closely follow it. This had two main consequences. Firstly, rather than using traditional scale degree names (S, R, G etc) it was decided to convert these to Western pitch names (c, d, e, etc), where S was arbitrarily set to be middle C. For pitches in the middle C octave, lower case letters are used. For pitches in the octave above, the letter is doubled (e.g. cc). For pitches in octave below, upper case letters are used (e.g. C). Flat (*komal*) notes are indicated with a minus sign (e.g. g-) and sharp notes with a sharp sign (e.g. f#). Durations, as with **kern, are given in reverse proportional form immediately to the left of the note name. In reverse proportional notation the duration is first expressed as a fraction of the beat, with one in the numerator. The denominator multiplied by some scaling factor is then used as the value. We describe this in more detail below.

Figure 2: **bhat Encoding of Bandish

```
!!id: bhatk3262s
!!sthayee: Paiya parusisani
!!vol: 3
!!page: 262
!!raag: des
!!taal: ektaal
!!tempo: madhyalaya

**bhat
!!data: // >MR M/ P D/ >DS'S' nD/ N -/ nD P/ D M/
==1
fq
4d
4f
=
4g
4a
=
aq
8cc
8cc
8b-
8a
=
2b
=
8b-
8a
4g
=
4a
4f
```

The more difficult task was determining the rhythmic values. We previously described how the input notation encodes rhythms: divisions between beats are marked with spaces, and all the remaining notes and rests (excluding *kan swars*) falling in one beat are treated as being of equal duration. Durations are encoded as the inverse of the fraction of the beat that the note takes, multiplied by a scaling factor[1]. Here the scaling factor is set to 4 by default. For example if we wish to indicate a duration equal to half the beat, we write 8. Triple notations are handled the same way. If we have, for example, three notes in the space of half a beat then the duration of each note is 1/6th of a beat and is therefore notated as 24. For example, in Figure 2, the first four beats (`// >MR M/ P D/`) are notated as having durations 4 4 4 4. In the first beat the >M is removed because it is *kan swar*, leaving R as the only note on the beat. It takes the entire beat so we give it the number 1, which we multiply by a scaling factor of 4. In Bhatkhande's system, note offsets are not notated, making it difficult to automatically determine how long a note is sustained. The conversion program assumes that the length of the note includes any rests that follow it and precede the next note or the end of the beat (whichever comes first). This allows us to notate fine

[1] The scaling factor is simply used to maintain the correspondence with Western music notation where a quarter note, rather than a whole note, is considered to occupy one beat. This may be omitted in the future.

rhythmic subdivisions without truncating sustained notes, but makes it impossible to represent notes that are sustained across beats.

Examples

At present a project is underway to encode all of Bhatkhande's bandish notations. At present 250 *sthayee* and *antara* sections from *Raags Yaman, Desh, Khamaj* and *Bihag* have been encoded, consisting of a total of approximately 16,000 notes. These can be found at http://paragcchordia.com/bhat/.

Discussion

Compared with MIDI, a great advantage of the syntax is its flexibility. In sitar and sarod *gats* it is often useful to notate whether an up or down stroke is being used. This can be done here by simply adding another column indicating the stroke type. If we desired we could go further and indicate the string that the note was to be played on and the finger used to stop the string. Consider the following fragment of a gat:

```
**bhat
**note          **stroke        **finger        **string
4g              da              1               4
4r              ra              1               4
4g              da              1               4
4a              ra              2               4
```

Likewise, lyrics (*sahitya*) can easily be incorporated into the representation as an additional spine. In this way the representation can be easily customized to suit the needs of the researcher. This cannot be done with standard MIDI files.

The **bhat representation is intended to facilitate the encoding and analysis of compositions. It is not primarily intended as a display format that can easily be read, but rather is designed to make it easy to automatically search an analyze files. This means that it is structured in a way that minimizes the need to understand the visual layout and use contextual information. The goal was to make the information explicit. For example, durations are explicitly notated and *kan swars* are indicated by a symbol rather than their placement on the page.

Humdrum toolkit

As mentioned earlier, Humdrum contains a toolkit of commands that allow the data to be processed. Humdrum makes it easy to search files for specific information. We could for example easily extract all compositions in a certain *taal* by looking at the record information. Many of the Humdrum commands are based on UNIX tools such as `grep` and `sed`, which are very useful pattern matching tools. Humdrum is particularly adept at searching for and tabulating various patterns. For example, suppose we wanted to test whether the *vadi* and *samvadi* notes (traditionally considered the "most important" notes in a *raag*) were always the most commonly used notes in a raag in Bhatkhande's notations. This could be done by assembling all the *bandishes* in a *raag*, removing all information except for pitch-class and then tabulating. At the command prompt we might type:

```
humsed 's/[^a-gA-G#-]//g' bihag/* | rid -GLId | sort  | uniq -c
```

Assuming that all our compositions in the *raag Bihag* reside in a folder named bihag, this command will count the number of instances of each note. `Humsed`, which is based on the Unix command `sed`, removes all information which is not pitch related. The `rid` command then removes any comment and interpretive records. This produces a stream of pitches which we then sort and count using the Unix command `uniq`. The returned data is given on the left side of Table 3. To illustrate a possible application of this, the pitch-class distributions for bandishes in three different raags are given in Table 3.

Table 3: Relative use of scale degrees in three *raags*

```
 62 a
  4 A
234 b
 75 B
168 c
286 cc
 55 d
 42 dd
242 e
 23 ee
201 f
 44 f#
  4 ff
360 g
 24 G
```

	Bihag	Khamaj	Yaman
S	0.27	0.25	0.18
R	0.04	0.04	0.15
G	0.14	0.17	0.25
M	0.10	0.12	0.00
m	0.02	0.00	0.06
P	0.23	0.11	0.18
D	0.03	0.12	0.08
n	0.00	0.07	0.00
N	0.17	0.12	0.10

It’s easy to see that we can begin to pose and answer a wide variety of questions. What are the most common melodic intervals used? Are 90% of duration values either ½ matra or 1 matra? After a melodic leap, does the melody tend to change direction? Is the note sequence ‘Pa Dha Ma’ more common in *raag Tilak Kamod* or *raag Jaijaiwante*? Is the average pitch-height greater in *raag* Hamir than in *raag* Kedar?

Conclusion

To date, there have been almost no empirical analyses of Hindustani music that use large sample sets to get statistically verified results. It is hoped that this project will create a common standard for encoding gats and bandishes and that these databases will be used by researchers to begin to investigate musical questions in a rigorous, quantitative fashion. Future papers will begin to answer some of the hypothetical questions posed in this paper.

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