SWARALIPI: A FRAMEWORK FOR TRANSCRIBING AND RENDERING INDIC MUSIC SHEET

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ABSTRACT

Creating music in computer system through its music notations requires two primary components. The first one is the mechanisms to encode music notations of respective music genres and the other one is a framework to provide the look and feel of the music written like a published or handwritten music sheet. Popular music scorewriters like Finale, Sibelius, MuseScore can edit, render and playback music transcribed in Staff notation. Being vastly different from the Indic music system in grammar, notation symbols, tonic system and encoding style, the architecture used in the music software for western music cannot cater to the Indic music system. For this reason there is a dearth of such scorewriters for Indic music system which is rich with a variety of musical genres, each different from the others in their unique notation system and language for depicting their lyric. In this paper, we propose a new framework for transcribing and rendering Indic music sheets for different genres of Indic music in computer. This framework is designed to support all major Indic notation systems and Indic language scripts and is explained using three major notation systems and language scripts throughout the paper as a case study.

1. INTRODUCTION

Music notation or musical notation is defined as a system for representing music in written glyphs or characters by encoding its pitch, duration, rhythm, lyric and ornaments. Notation systems have helped in the preservation of musical compositions through the ages and also in spreading them accurately among cultural systems and traditions.

Music and its perception have evolved in a variety of ways over the years in different regions of the world. Hence with change in tradition and culture, the music notations vary, from one country to another. Among others Staff notation is the most popular modern music notation system which was originated in the European classical Music.

Another musical genre of importance in the eastern part of the world is — the music of India. The tradition of the classical genre of *Indic music* has existed for almost a millennium. Its origin can be traced back to Samaveda, the sacred Hindu Mythology [1]. Indic music comprises of myriad varieties of music. Carnatic (South Indian Classical Music) and Hindustani (North Indian Classical Music) Sangeet are two richest varieties, besides the other varieties of *folk*, *Baul*, *Bhajan*, *Rabindrasangeet*, *Thumri*, *Ghazal*, popular or Filmi and pop. However, it is remarkable to note that despite global acceptance of Staff notation, in India, teaching, learning and composing Indic music (particularly classical) are carried out in Indic notation systems even today.

Indic music notation systems have received their present forms from the contribution of three stalwarts - Pt. Vishnu Narayan Bhatkhande, Pt. Vishnu Digambar Paluskar and Rabindranath Tagore. While, notation systems for Hindustani music were introduced by Bhatkhande and Paluskar, Rabindranath Tagore introduced a new musical genre called Rabindrasangeet. Jyotirindranath Tagore, elder brother of Rabindranath Tagore, created *Akarmatrik* notation system for encoding Rabindrasangeet in the year 1905 [2].

Various systems have been developed for displaying and rendering Staff notation in computers. Finale from MakeMusic [3], Sibelius from Avid Technology [4], and MuseScore are some of the leading music notation software. These are used to arrange, notate, display and print engraver-quality sheet music in Staff notation. On the other hand, we know of only one such software, Swar Shala by Swar Systems [5] , for Indic music. However, it lacked in the features required to arrange Indic notation symbols to create music. This absence of a proper system for encoding, composing and preserving Indic music has deprived Indic music lovers and composers from participating in computerized music creation in an environment entirely unique to Indic music. One of the main difficulties of creating such software is the diversity of grammatical structure present in various Indic notation systems. Moreover, the architecture for Staff notation cannot be employed for transcribing Indic music notation systems due to the differences in their notation arrangements. For example, it does not have any bar line; notations are entirely different and depends on Indic language scripts. Hence, there lies a need to develop

a robust framework or architecture for arranging and presenting musical components in computer similar to published music sheet, for Indic music notation system.

2. PROPOSED ARCHITECTURE

The proposed architecture helps to encode, arrange, display and render Indic music symbols in computer and in order to do that, we have examined the structure of different music sheets written in popular Indic music notation systems. To demonstrate the test cases we have considered three of the main notation systems presently active in India - *Bhatkhande*, *Paluskar* and Akarmatrik notation system.

Figure 1, 1 and 2 show instances of music sheet written in Bhatkhande, Paluskar and Akarmatrik notation system respectively taken from [6, 7].

Figure 1. (a) Music sheet written in Bhatkhande system taken from [6] and (b) Paluskar system taken from [7]

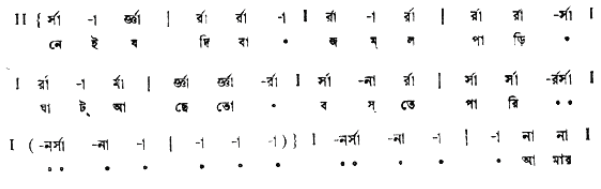

Figure 2. Part of Rabindrasangeet piece "Amar Naiba Holo Paare Jawa" in Akarmatrik Notation System taken from [8]

Minute observations on these music sheets have revealed that each one of them possesses a rectangular structure having a number of rows and columns and some notation symbol/s at each of the intersection of the rows and columns. Based on this similarity a matrix model has been proposed for representing the structure of the music sheet. The detail architecture has been described next.

2.1 The Matrix Model

In order to build the framework, each music piece is converted into a collection of strings of 2-D matrices as shown in Fig. 3. As each line consists of several rows, each line represents a single 2-D matrix and the number of 2-D matrices is equal to the number of lines in the music piece. Due to the fact that each line of a music piece is not necessarily of the same length, the size of all the 2-D matrices are not equal. Each cell thus produced can store either Unicode character(s) or character(s)/glyph(s) of true type or other format necessary to define the notation systems in computer software. The inputs for this model are Taala, Avartana, number of lines of the music piece and position of the notation symbols.

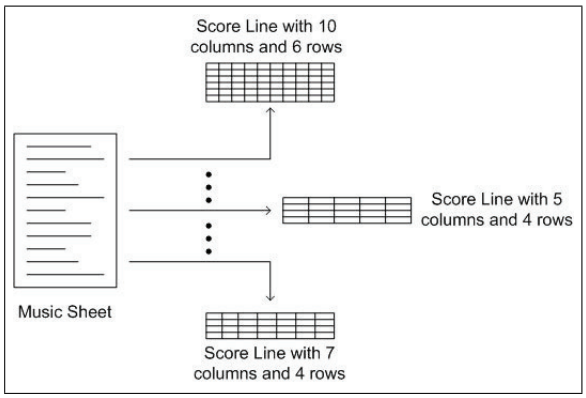

Figure 3. The Visualization of the Matrix Model

For simplicity the entire matrix model has been divided into two sub-models — the row model and the column model. Row model defines the number of rows of the model, the number of rows in each 2-D matrix and the alignment between them. Likewise, column model defines the number of columns for each 2-D matrix. It means that each line of the music piece forms a 2-D matrix and consequently the whole music piece presents a three dimensional rendering. In any 2-D matrix, the number of rows can be selected by the user to encode all necessary features of the music (main notes, lyrics, repetition notes, beat markings, *Meend* etc.). Likewise, the number of columns can be selected depending on the Taala, Avartana and need of initial or terminal phrasings. Each cell contains none, one or more musical glyphs and/or characters.

Figure 4 shows some of the typical lines of an Indic music sheet, specifically Rabindrasangeet. It is scored in the Akarmatrik system capable of depicting Swaras or notes, Sparsha Swaras or grace notes, Maatras or beats, Taalanka or beat markings, equal or unequal Taala Bibhagas or measures, Meend or glide between two notes, Shrutis or microtones, repetition phrase, melody changes in repetition, lyric etc. Some but not all of the musical components mentioned above can be described in Staff notation system. The components which cannot be realized in Staff system are — unequal measures in a Taala, the cyclic nature of

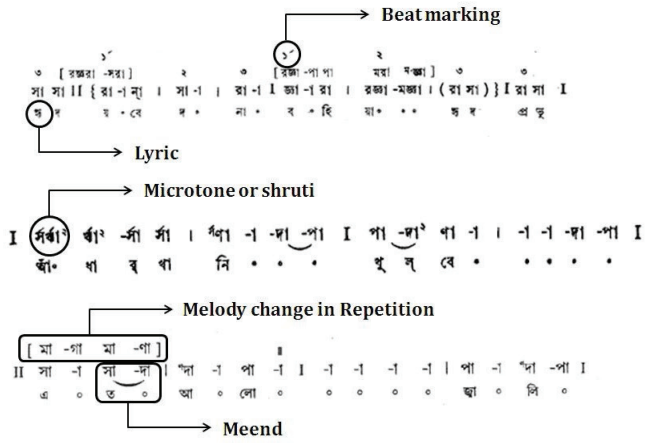

Figure 4. Major Components in Akarmatrik Notation System

Taalas, milestones on the Taala cycle and Shrutis. An appropriate Indic music notation system can describe all the components contained in Indic classical or regional music. To edit and render this kind of music electronically, a new architecture was needed and this is where the present work comes in. We shall present the model with respect to the Rabindrasangeet music sheet as Akarmatrik notation was found to be the most robust and well-content notation system for presenting different components present in Indic music. Then we shall present justifications on other notation systems and music genres as well.

2.1.1 The Row Model

2.1.1.1 The Number of Rows Per Line

It is named row model as it determines the number of 2-D matrices and the number of rows in each line present in the model of a particular music sheet. In the simplest case, a line of a music piece written in any Indic music notation system can have two rows —one for notes and the other for the lyric. But almost always, four rows are required —the lyric row (Fig. 4), the Meend row or the row for accommodating the Meend symbol shown in Fig. 4, the note row or the row for placing notes (Fig. 4) and the Taalanka or beat marking row (Fig. 4), as schematized in the bottom half of Fig. 5. However, if a segment needs to be repeated with a variation, it needs to be shown above the primary melody segment, as shown in the first four rows of Fig. 5. These lines can accommodate other symbols, such as the end of piece symbol as shown in Fig. 4. So altogether each music piece will need at most eight rows —four bottom rows for primary melody lines and four top rows for notes with melody variations.

2.1.1.2 The Meend Symbol

Meend (shown in Fig. 8) is one of the musical ornaments present in Indic music which is an Indic counterpart of Portamento or Glissando [9]. In Meend, one note slides to another note of different pitch over a specified number of beats. It is obvious that the Meend symbol cannot be entered entirely into one cell of the 2-D matrix because two

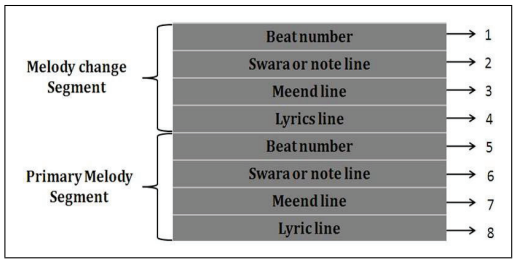

Figure 5. A 2D matrix depicting one line of an Indic music piece, its components and associated row number. The accordance of the components changes when notation system changes

notes between which the Meend slides will be in two different cells of the 2-D matrix. So, the entire symbol is divided into three symbols 1, 2 and 3 as shown in Fig. 6 and can now be entered into the framework. For Meend, we have a dedicated row both for primary and changed melody line of the music piece.

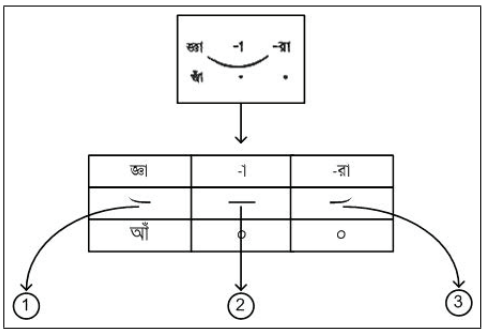

Figure 6. Implementation of Meend symbol in the present architecture

For example, in Fig. 6, Meend starts from 1 (Komal Gandhara), slides through 2 (same as previous note) and ends at 3 (Suddha Rishabha). First part of the Meend symbol will be placed above or below the cell from which the Meend slides. Likewise, the last part of the symbol will be placed above or below the cell to which the Meend slides. If there are multiple notes in between start and end note then the second symbol will be placed above or below every cell of those notes. In Akarmatrik system the Meend curve is drawn below the notes while it is drawn above the notes in Bhatkhande and Paluskar system.

2.1.2 The Column Model

The number of columns of the 2D matrix depends upon the following factors:

1. Taala, i.e., the cyclic beat pattern which specifies the number of Bibhagas (i.e., measures) per cycle, the name of each measure, number of beats in each measure (not necessarily equal, as shown in Table 1)

2. Avartana i.e. the number of cycles per line.

Table 1 shows some of the common Taalas used in Indian classical music and Rabindrasangeet.

Table 1. Some common Taalas used in Indic music system along with their total number of beats and beat pattern

Taala Name	Maatra or Total Number of Beats	Taala Bibhaga or Measures
Dadra	6	3+3
Shashthi	6	2+4 or 4+2
Rupak	7	3+2+2
Kaharba	8	4+4
Jhaanp	10	2+3+2+3
Ektaala	16	3+3+3+3 or 4+4+4
Tritaala	16	4+4+4+4

According to Table 1 Tritaala has one cycle of four measures of four beats each. Not all Taalas have equal number of beats per measure. Each repeated cycle of a Taala is called an Avartana. These two features form the building block of the column model of the architecture.

Figure 7 shows a matrix of a typical line of a music piece of Akarmatrik notation system having Shashthi Taala with two unequal measures having 2 beats in the first measures and 4 beats in the last, 2 Avartanas and the lyric line is written in Bengali script, have been transformed into the architecture having 2 rows and 17 columns.

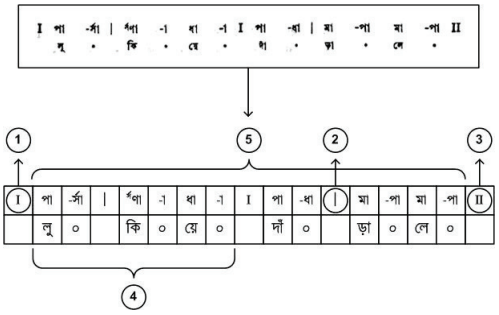

Figure 7. Determination of column number of a line of Rabindrasangeet score in the present architecture

After the empty matrix is constructed, it is populated by music symbols. Each matrix contains cells. The number of cells in each 2-D matrix is the product of the number of rows and columns. A cell may contain no symbol, one symbol, or more than one symbol. Symbol 1 (I) in Fig. 7 signifies the beginning of the Taala and thus occupies a cell before the first beat of the Taala. It is repeated once every cycle of the Taala. Symbol 3 (II) in Fig. 7 signifies the end of a musical phrase after which the first phrase (Aasthayee) must be sung; it also occupies a cell by itself. Symbol 2 (|) in Fig. 7 is the Taala Bibhaga symbol which comes between adjacent measures of the Taala and occupies a cell by itself. Figure 7 shows the Shashthi Taala which has two unequal measures of 2 and 4 beats (part 4 of the Fig. 7) respectively. The shown musical line starts with Symbol 1, shows two repetitions (Avartanas — part 5 of the Fig. 7) of the Taala (separated by symbol 1), and ends with Symbol 3. Because there are only two measures per cycle of this Taala, symbol 2 is used only once per cycle in Fig. 7. In general, the number of columns required to store symbol 2 can be found by the following equation:

$$n = (a \times m) \tag{1}$$

$$t = (b \times a) + (a - 1) + n + 2 \tag{2}$$

where n is number of columns for symbol 2, a is number of Avartana, m is the number of measures of the Taala, t is the total number of column of the matrix and m is the Maatra or total number of beats in the Taala.

For Fig. 7 the number of columns is therefore (6 x 2) +1+ (2 x 1) +2 = 17.

2.2 The Notation Font

While creating the fonts to be used for the implementation of the architecture, we have considered two components — the notation system and the language used for transcription. The task for designing fonts are merely drawing each glyph/character with the help of font creating software and mapping them to a key. But the real challenge is to explore the available notation systems in India and listing down each of their characters, mining intra and inter notational similarities and the language script they use. Our exploration brought into light one useful information — the connection between language script and notation system. We have used this interrelation to design the set of fonts for Indic music. To visualize the inter-relation, first we will give a brief introduction on different notation systems of Indic music. The main objective of this section is not to demonstrate the symbols of various notation systems, but to focus on extracting their common behaviour and gather this knowledge to conclude a common system. This common knowledge has been used to facilitate the guidelines for designing of notation fonts.

2.2.1 Main music annotating styles of Indic Music

As mentioned previously, three major notation systems used in India are Bhatkhande, Paluskar and Akarmatrik. Music sheets written in one of these notation systems may use different Indic language scripts to write the lyric and which in turn describe certain musical symbols of that particular notation system. In this paper we use the term *language base*, elaborated later, to define these language scripts. For a particular language base, we have found some inter and intra notation similarities among these three notation systems.

Figure 8 shows the notation symbols when the language base is Bengali. The properties are written in the leftmost column and their English counter name is given for better understanding.

2.2.2 Intra and Inter notational system similarities

The second, third and fourth column of Fig. 8 describe the symbols of the main properties of Akarmatrik, Bhatkhande and Paluskar system. We have found some similarities between them. They are

1. Pure notes
2. Akarmatrik lower octave and Paluskar flat notes.

Notation Properties	Akarmatrik System	Bhatkhande System	Paluskar System
Pure Notes	স,র,গ,ম,প,ধ,ন	সা,রে,গ,ম,প,ধ,নি	সা,রে,গ,ম,প,ধ,নি
Flat Notes	ঋ,জ্ঞ,দ,ণ	(_)রে্,গ্,ধ্,নি্	(ˌ) স্,র্,গ্,ম্,প্,ধ্,ন্
Sharp Notes	ক্ষ	(ˈ)র্ম	ম্র
Middle Octave	স,র,গ,ম,প,ধ,ন	সা,রে,গ,ম,প,ধ,নি	সা,রে,গ,ম,প,ধ,নি
Lower Octave	(ˌ) স্,র্,গ্,ম্,প্,ধ্,ন্	(.)স্া,রে্,গ্,ম্,প্,ধ্,নি্	(ˎ)সাঁ,রেঁ,গঁ,মঁ,পঁ,ধঁ,নিঁ
Upper Octave	(ˊ) র্স,র্র,র্গ,র্ম,র্প,র্ধ,র্ন	(ˎ)সাঁ,রেঁ,গঁ,মঁ,পঁ,ধঁ,নিঁ	(ˈ)সা̇,রে̇,গ̇,ম̇,প̇,ধ̇,নি̇
Single Beat	(।) সা,রা,গা,মা,পা,ধা,না	সা,রে,গ,ম,প,ধ,নি	রে্,গ্,ম্,প্,ধ্,নি্
Half (1/2) Beat	(ঃ) সঃ,রঃ,গঃ,মঃ,পঃ,ধঃ,নঃ	গম	গ্ম্
Querter (1/4) Beat	(॰)স॰,র॰,গ॰,ম॰,প॰,ধ॰,ন॰	গমপধ	গ্ম্প্ধ্
Beat Start	১	×	১
Beat Gap	০	০	+
Division	|	|	|
Beat Mark/Beat Number	২,৩,৪	২,৩,৪	১,৫,৯,১৩
Meend	‿	‿	‿
Kan	ধ্প,র্স,গ্র	ধ্প,রে্সা,গ্রে	ধ্প,রে্সা,গ্রে
Khatka		(সা)	(সা)
Enunciation	০	s	-

Figure 8. Notation symbols of Akarmatrik, Bhatkhande and Paluskar notation systems with their properties when the language base is Bengali

3. Bhatkhande upper octave and Paluskar lower octave.
4. Bhatkhande and Paluskar Meend (Portamento).
5. Bhatkhande and Paluskar khatka.
6. Akarmatrik and Paluskar beat start.
7. Kan swaras of all systems
8. Akarmatrik and Bhatkhande beat gap.
9. Bhatkhande flat notes and Paluskar single beat.
10. Bhatkhande sharp note and Paluskar upper octave

The similarities are not only bound in different systems, but similarities do exist in same notation system. The similar symbols or characters are given below

1. Pure, sharp and flat notes and their respective Kan or sparsha swaras in all notation systems.
2. Beat gap and enunciation in Akarmatrik system.
3. Pure, sharp and flat notes and their single beat representation in Bhatkhande system.

The above similarities can be visualized in the following simplified Venn diagram shown in Fig. 9. Here each circle denotes a single notation system. Area denoted by number 1, 2, 3 and 4 describe inter-notational system similarities. They overlap each other in certain cases. There are similarities separately in two different notation systems and some symbols are common in all three notation systems.

Unlike Western Staff notation, Indic music notation systems depend on the languages used to write the lyric of the

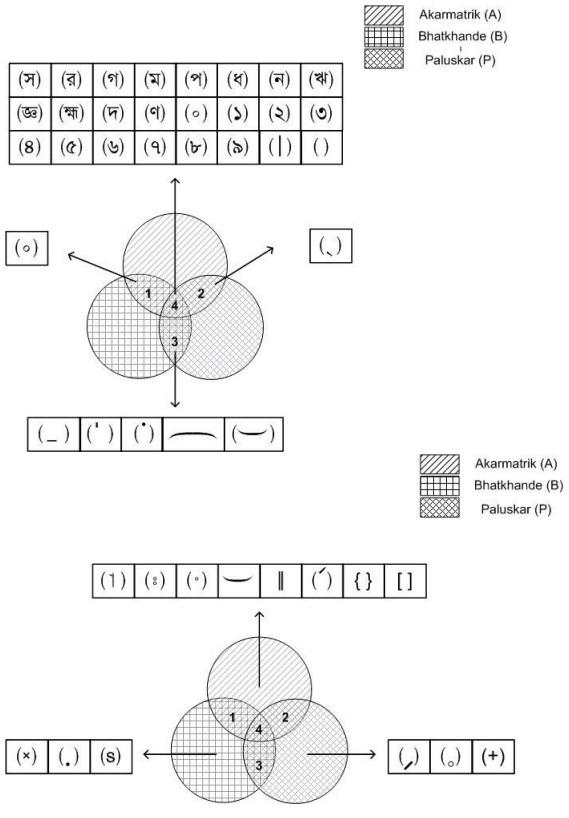

Figure 9. Venn diagram showing inter and intra-notational system similarities and similarities between notation system and Bengali language script present in Akarmatrik, Bhatkhande and Paluskar notation system

Notation System	(Pure Note)-(Unicode Value)-(Pronunciation)						
Akarmatrik	(স)-(09B8)-(*Sa*)	(র)-(09B0)-(*Ra*)	(গ)-(0997)-(*Ga*)	(ম)-(09AE)-(*Ma*)	(প)-(09AA)-(*Pa*)	(ধ)-(09A7)-(*Dha*)	(ন)-(09A8)-(*Na*)
Bhatkhande	(সা)-(09B8+09CD+09BE)-(*Saa*)	(রে)-(09B0+09CD+09C7)-(*Re*)	(গ)-(0997)-(*Ga*)	(ম)-(09AE)-(*Ma*)	(প)-(09AA)-(*Pa*)	(ধ)-(09A7)-(*Dha*)	(নি)-(09A8+09CD+09BF)-(*Ni*)
Paluskar	(সা)-(09B8+09CD+09BE)-(*Saa*)	(রি)-(09B0+09CD+09BF)-(*Ri*)	(গ)-(0997)-(*Ga*)	(ম)-(09AE)-(*Ma*)	(প)-(09AA)-(*Pa*)	(ধ)-(09A7)-(*Dha*)	(নি)-(09A8+09CD+09BF)-(*Ni*)

Figure 10. The Mapping between the glyphs of pure notes of Akarmatrik, Bhatkhande and Paluskar notation system, their Unicode values and respective pronunciations

music piece because, certain music symbols of Indic music are similar to the characters or glyphs of Indic scripts. Observation reveals that the central part (4) in Fig. 9 shows the similarities among all three notation systems which actually describe the similarities between notation symbols and Indic scripts. This common similarity is constant because when the language base changes the same number of similarities can be found between the notation system and the changed language base. We shall describe this constant part with Bengali Indic script next.

2.2.3 Similarities between notation systems and Indic scripts

We have found some similarities among the music notation symbols with Bengali script as shown in Fig. 8. The similar symbols are given below

1. Pure notes and Bengali letters *Sa, Ra, Ga, Ma, Pa, Dha, Na*. There are various pronunciation styles of the main or pure notes. For example — in Akarmatrik system the second and seventh pure note is pronounced or written as *Ra* and *Na*, while in Bhatkhande system it is pronounced or written as *Re* and *Ni*. Figure 10 depicts the mapping between glyphs of the pure notes of three notation systems, their Unicode values and respective pronunciation.

2. Flat and sharp notes and Bengali compound letters

3. Akarmatrik Lower octave and Bengali Hasant symbol (U09CD)

4. Akarmatrik Upper octave and Bengali Ref symbol (proposed in [10])

5. Akarmatrik Single beat and Bengali Akaar symbol (U09BE)

6. Akarmatrik Half beat and Bengali Bisargha (U0983)

7. Akarmatrik Beat marks and Bengali numerical digits (U09E6-U09EF)

2.2.4 Effects of Indic languages on Indic music notation systems

2.2.4.1 Language Base

Music has its own language. But songs which constitute music scores with lyric need additional natural languages. In India different genres of music were born from different places and cultures and they are still in practice majorly in their areas of origin. Every region in India with their unique cultural traditions and languages have influenced their respective notation systems. More particularly, the natural language of the lyric part of the music piece determines the most of the notation symbols. Western music pieces contains no similarity between notes and lyric because they are transcribed in Staff notation system. On the contrary, scores written in Indic music notations have certain characters that resemble with the lyric language. We will call this particular language the *language base* of the corresponding music piece. Some Indic script characters pronounce like pure notes when they are sung. These characters are shown in Fig. 11.

স র গ ম প ধ ন

Figure 11. Seven Bengali script characters pronounced similar with seven pure notes or *Suddha Swaras*

They are pronounced as *Sa, Re, Ga, Ma, Pa, Dha, Na* and the seven pure notes, when sung, produce exactly similar sound. If they are written in Hindi language it will be written Devanagari script and look like Fig. 12. The same is

स र ग म प ध न

Figure 12. Seven Devanagari script characters pronounced similar with seven pure notes or *Suddha Swaras*

true for grace notes and flat and sharp notes. Grace notes or Kan Swaras are similar but smaller in size as pure notes

Notation Properties	Akarmatrik System	Bhatkhande System	Paluskar System
Pure Notes	स,र,ग,म,प,ध,न	सा,रे,ग,म,प,ध,नि	सा,रे,ग,म,प,ध,नि
Flat Notes	ऋ,ऩ,द,ण	(_) रे,ग,ध,नि	(_) सा,रे,ग,म,प,ध,नि
Sharp Notes	ह्म	(') मं	म्म
Middle Octave	स,र ,ग,म,प,ध,न	सा,रे,ग,म,प,ध,नि	सा,रे,ग,म,प,ध,नि
Lower Octave	(.) स्,र्,ग्,म्,प्,ध्,न्	(.) सा,रे,ग,म,प,ध,नि	(˙) सां,रें,गं,मं,पं,धं,निं
Upper Octave	(´) र्स,र्,र्ग,र्म,र्प,र्ध,र्न	(˙) सां,रें,गं,मं,पं,धं,निं	(') सां,रें,गं,मं,पं,धं,निं
Single Beat	(1) सा,रा,गा,मा,पा,धा,ना	सा,रे,ग,म,प,ध,नि	रे,ग,म,प,ध,नि
Half (1/2) Beat	(ः) सः,रः,गः,मः,पः,धः,नः	गम	ग म
Querter (1/4) Beat	(॰) स॰,र॰,ग॰,म॰,प॰,ध॰,न॰	गमपध	ग म प ध
Beat Start	१	×	१
Beat Gap	०	०	+
Division	|	|	|
Beat Mark/Beat Number	२,३,४	२,३,४	१,५,९,१३
Meend	‿	⁀	⁀
Kan	घप	घप	घप
Khatka		(सा)	(सा)
Enunciation	०	s	-

Figure 13. Notation symbols of Akarmatrik, Bhatkhande and Paluskar notation systems with their properties when the language base is Devanagari.

as described earlier in Fig. 8. To demonstrate the findings we have created another table as shown in Fig. 13.

2.2.4.2 Unchanged Musical Characters

Certain notations came from certain regions of India and that is why they got the language base of that region when they were invented. Every Indic script character has a counter part in another Indic script. For example, in Fig. 8 and 13 the seven pure note symbols are one to one mapping of Bengali to Devanagari script. As a result, when the language base changes, the similarities between the notation systems and the base language remains constant.

But there are certain characters which are present in one script and cannot be found in similar form in other scripts. For example the upper and lower octave sign in Akarmatrik notation system is Bengali Ref and Bengali hasant. Some other characters are there to denote the same thing in Devnagri language. If some music piece is written in Akarmatrik and the language base is Devanagari, these Bengali characters might be kept intact to denote the upper and lower octave (Nayar1989). That is why in Fig. 13 these symbols are same as in Bengali. These symbols get permanent musical symbol status and not dependent on language base.

We have developed the guidelines out of the findings stated above for designing the notation fonts for various language scripts. These guidelines will help font designers to create fonts and identify the number of symbols to be designed. The guidelines are as follows (Considering three notation systems as in Fig. 9) —

1. There will be a common notation system for each of the language base.
2. It will contain each symbol of the non-intersected area of three systems
3. It will contain one copy of symbols for each intersected area — part 1, 2, 3 in Fig. 9.
4. It will contain one copy of intersected area —part 4 in Fig. 9 corresponding to the language base.

According to the above guidelines, the full set of symbols/characters for designing Indic music notation font for language base Devanagari is shown in Fig. 14.

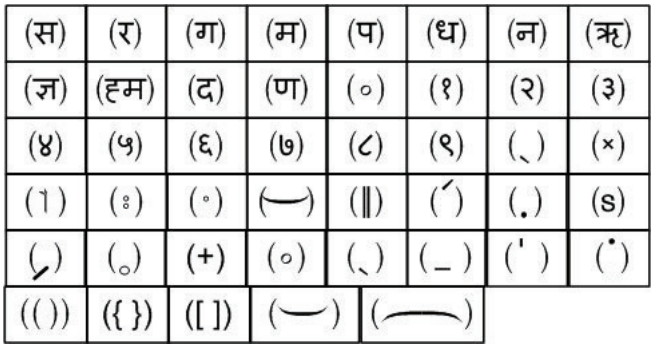

Figure 14. Indic music notation font set for Devanagari language base

2.2.5 Adaptation of New Notation Systems

In West Bengal (state of India), more or less every household has a common practice for music learning, either classical or regional. We have done a rigorous survey in these households and found a notation system called *Dandamatrik* notation system. Books written on music in Bengali

Notation Properties	Dandamatrik System
Pure Notes	স র গ ম প ধ ন
Flat Notes	(∆) is added above the swara or note
Sharp Notes	(~) is added at the tip of the swara or note
Middle Octave	স র গ ম প ধ ন
Lower Octave	(.) is added at the bottom of the swara or note
Upper Octave	(.) is added at the top of the swara or note
Single Beat	Single line (|) above swara or note
Half Beat	Bengali Chandrabindu (ঁ) symbol (U0981) above the swara or note
Quarter Beat	Cross (x) is added above the swara or note
Beat Start	(+) symbol
Division	Double (||) line
Beat Mart/Beat Number	২, ৩, ৪
Meend/Portamento	‿
Kan	Same as pure notes but smaller in size
Khatka	⌊⌋

Figure 15. Notation symbols of Dandamatrik notation system with its properties when the language base is Bengali.

also proved the existence of this notation system. It was invented by Kshetramohan Goswami in the year 1868 as stated in [11]. Dandamatrik notation system has a set of notations, some of which have similarities with other notation systems. Figure 15 shows some of them.

Music researchers are continuously experimenting with the notation systems. This experiment is conducted mainly on Bhatkhande and Paluskar notation system. We have found a new notation system called *Ome Swaralipi* or Ome notation system from ome which has been developed by mixing Bhatkhande and Paluskar notation system. Pt. Vinayak Rao Patwardhan, Pt. Shankar Rao and Pt. Omkarnath Thakur had developed this new notation system with little modification in Bhatkhande and Paluskar notation system. The best feature of Ome notation is that it is independent of any linguistic script which makes it universal. It is currently in a validation process in various music schools and institutions.

In order to make a universal notation system for a particular language base we have taken care of these newly found notation systems. We have experimented with the architecture with various combination of notation systems — language base pairs and found that they can be well described by this architecture. Below we describe some of the experimental results.

2.3 Implementation of the Architecture on Other Notation Systems

Figure 16 depicts an example of the implementation of the architecture with a line of Hindustani Sangeet score written in Bhatkhande notation system. As described, the core architecture will be same for this notation system. However, the order of the rows in the 2-D matrix may be different. For example, the beat marking symbols (Taalanka) are placed at the last row instead of first (as in Akarmatrik). Similarly lyrics line is in 3rd row, not in the last row. Figure 17 shows the experimentation on a Hindustani Sangeet music piece written in Paluskar notation system.

The last experiment was on Carnatic Sangeet and traditional Carnatic notation system written in Tamil script. The implementation of the architecture is shown in Fig.18.

To implement the architecture within an application, we need to have two sets of fonts. The first is for writing the music symbols and the other is for writing the lyric. The lyric of the music piece can be written with the help of Unicode transliteration software like Avro Keyboard [12],

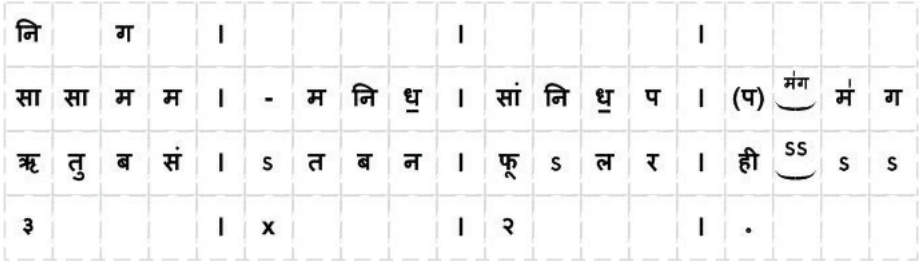

Figure 16. Implementation of a line of Hindustani Classical Music score written in Bhatkhande notation system in the present architecture.

Figure 17. Implementation of a line of Hindustani Classical Music score written in Paluskar notation system in the present architecture

Baishakhi Keyboard [13] for Bengali language. On the other hand, to write music notes we still need to depend on non-Unicode fonts as unlike Staff notation (U1D100—U1D1FF), some of the Indic music notation symbols have not been encoded in Unicode yet. Except some Bhatkhande and Paluskar notation symbols (Bhatkhande Flat Note (U0952), Bhatkhande Sharp Note (U0952), Bhatkhande Lower Octave (U093C), Bhatkhande Upper Octave (U0971), Bhatkhande Beat Gap (U0970), Bhatkhande Abhagraha or Enunciation (U093D) and Paluskar Quarter Beat (U0956)), most of the symbols in Paluskar, Akarmatrik and Dandamatrik systems have not been encoded. Therefore, we need separate non-Unicode fonts for writing music symbols. As a result, to write the score we have to implement mixed format — Unicode and non-Unicode format. Moreover, in the application level the user need to use mixed format into the software and switch between the two for writing notes and lyrics. This cumbersome method can be removed by developing a full set of non-Unicode fonts for each language script along with the language script symbols. This will on the other side makes the music sheet non-standard and without the font set it is not possible to render the score perfectly on different applications.

One solution to this problem is to include all non-Unicode symbols to Unicode. As some of the Bhatkhande symbols have been encoded in Unicode in the Devanagari block (U0900 —U097F), Akarmatrik and Paluskar notation symbols that are not common with the encoded Bhatkhande symbols should be encoded. We have started the process with the proposal of six Akarmatrik symbols among 51 symbols present in the Akarmatrik notation system. These symbols are —Quarter Beat, Meend, Avasan, Taala Bibhaga, Danda and Yugal Danda Symbol as shown in Fig. 8. We proposed eight code points in the Bengali block (U0980 —U09FF) to include these six symbols as described in Table 2 of [10].

We have built a scorewriter implementing the architecture for creating music sheet electronically in Akarmatrik notation system. It has been developed to archive Tagore's songs to set up an online repository. Figure 2.3 shows the original music piece and Fig. 2.3 shows the music sheet rendered by the scorewriter.

3. CONCLUSION AND FUTURE WORK

It is a real challenge to build a software for Indic music and that particularly matches with the framework of the notation systems of different genres and language scripts. The popular Staff system was not a match, as it has a different architecture altogether for representing music. This paper deals with the methods to represent Indic music in computer. The core part of these methods is to design a new architecture for rendering, arranging, displaying an Indic music piece just like published music sheet.

The development of the architecture was carried out using four prominent notation systems in India — namely Bhatkhande, Paluskar, Akarmatrik and Dandamatrik. To make the framework musical genre, notation system and language script independent, we needed a good survey on these three systems. This survey made us collect their similarities and the similarities between them with the language base. We have found the inherent structure of these notation systems which are similar and implemented those similarities to frame the architecture.

The architecture is designed to support only the Indic notation systems and Indic musical genres. There may be other music genres in the world that have same kind of inherent structure as Indic notation systems. Inclusion of these notation systems will make the architecture more sophisticated and universal.

;;	;-ப	ப,-பம	ரி,ரி,	|	ரி;-ஸ	;-நி	|	ஸ,-ரி	;ப,	|
ப;-ப	;-ப	ப,-பம	ரி,ரி,	|	ஸரி;ஸ	;-நி	|	ஸ,-ரி	;ப,	|
பம,-ப	நி,-பம	ப,-பம	ரி,ரி,	|	ஸரி;ஸ	ஸ-நி	|	ஸ,-நிப	;ப,	|

Figure 18. Implementation of a line of South Indian Classical Music piece "Bantureethi" written in Tamil script in the present architecture

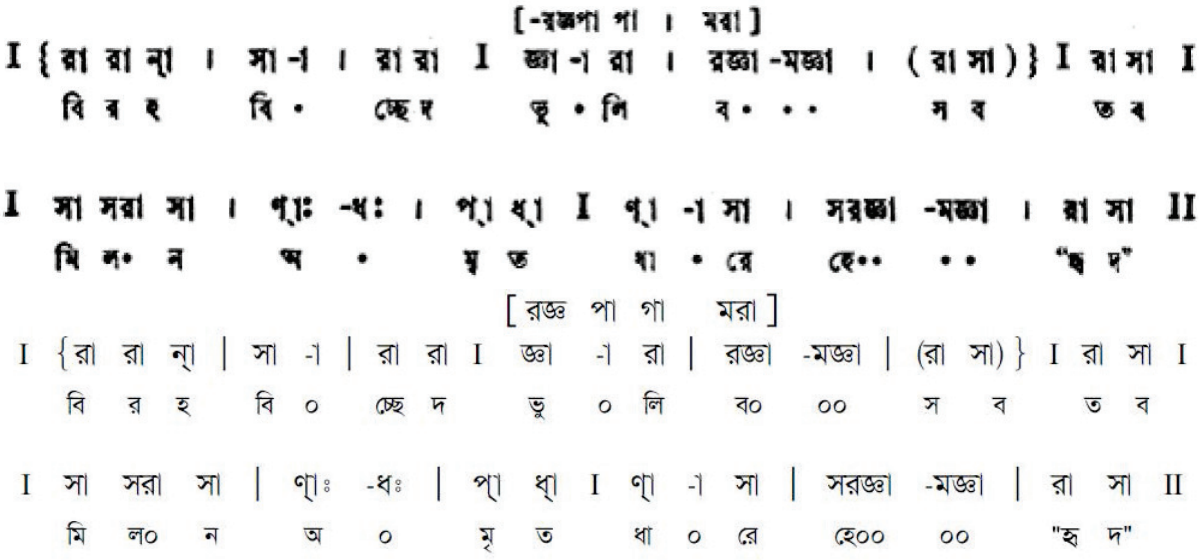

Figure 19. (a) Part of the original Rabindrasangeet music piece "*Hridoy Bedona Bohiya*" written in Akarmatrik notation system and (b) same part as (a) of the music piece generated using the application implementing the present architecture

The architecture provides application developers a model to work on and develop a series of applications on Indic music. Some of them are described below —

1. Music editor that can write, edit, play Indic music with any Indic notation system and with any language. The user can select his intended notation style and language.
2. Application to be used to create and save MIDI files and transfer them between computer and MIDI enabled electronic sitar or tabla.
3. A web environment to learn and teach Indic music system for music lovers and students.
4. A tool that enables social networking sites to write and send music as comments. People can play the written music symbols online and also can download the MIDI version of the music.
5. A portable device that can simulate human humming pattern and with the help of frequency analysis it can map to particular note. With the help of Unicode it can again map notes to respective symbols and finally a printed music sheet.

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