Journal of AppliedMath 2023; 1(1): 85.
Original Research Article

Statistical analysis of a Tagore song based on Raga Kafi

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ARTICLE INFO

Received: 19 February 2023
Accepted: 17 March 2023
Available online: 25 April 2023

http://dx.doi.org/10.59400/jam.v1i1.85

ABSTRACT: *Rabindra Sangeet* or Tagore songs encompass a wide variety of human emotions. Most of these songs are based on Hindustani ragas. Kafi is a joyful raga and therefore could be helpful to combat stress. We are motivated to analyse a popular Tagore song, namely, *Momo Chitte*, which is based on this raga. Statistical analysis compares two phases of 30 s each of a vocal recording of this song. Several statistical features are considered including note duration, inter onset interval, rate of change of pitch, statistical parameterization of melody and rhythm in addition to analysis of spectrogram and pitch profile. The experimental results are encouraging.

KEYWORDS: note duration; inter onset interval; rate of change of pitch; statistical parameterization of melody and rhythm; spectrogram

1. Introduction

Rabindra Sangeet or Tagore songs are songs written and composed by the great laureate of literature, poet Gurudev Rabindranath Tagore. He was the first Nobel laureate from the Asian origin who received the Nobel prize in literature in 1913. While the lyrics of all these songs are credited to Tagore, there are a few exceptions in which the tunes are composed by someone else, e.g., Pankaj Mallick composed the tune of the Tagore song *Diner Sheshe Ghumer Deshe* and the tune was highly appreciated by Tagore.

Indian classical music has two forms—Hindustani and Carnatic (or North Indian and South Indian classical music respectively). In either form, the central focus is the raga which is a melodic structure with fixed notes and a set of rules that characterises a particular mood which is conveyed by performance.

Rabindra Sangeet has a great impact on human emotion. Kafi, being a joyful raga, motivated us to study the statistical properties of a *Rabindra Sangeet*, namely, *Momo Chitte* based on this raga. This song would be used in subsequent studies in music intervention for therapeutic purpose to combat stress. Statistical analysis compares two phases of 30 s each of a vocal recording of this song. Several statistical features are considered including note duration, inter onset interval, rate of change of pitch, statistical parameterization of melody and rhythm in addition to analysis of spectrogram and pitch profile.

2. State of the art

Rabindranath Tagore received his initial training in music from Jyotirindranath, his elder brother. Jyotirindranath was an accomplished classical musician specializing in dhrupad, dhamar and khayal. Since the days of initial training, Tagore started composing verses and attempted to place them in the melodic framework of the Ragas. That was how *Rabindra Sangeet* or Tagore Songs germinated[1].

Musical composition and background history of the song:

Parjaay: Bichitro (6)
Taal: Kashmiri Khemta
Raag: Kafi
Written on: 1910
Collection: Arupratan, Raja, Shrabon-gatha

Swarabitan: 42 (Arupratan)
Notation by: Surendranath Bandopadhyay
Lyrics:

Mamo chitte niti nritye ke je naache
Taata thoi thoi, taata thoi thoi, taata thoi thoi,
Taari sange ki mridange sada baaje
Taata thoi thoi, taata thoi thoi, taata thoi thoi.
Haasi kaanna hira paanna dole bhaale,
Knaape chhande bhaalomondo taale taale,
Naache janmo naache mrityu paachhe paachhe,
Taata thoi thoi, taata thoi thoi, taata thoi thoi.
Ki anondo, ki anondo, ki anondo
Dibaraatri naache mukti naache bandho
Se taronge chhuti range paachhe paachhe
Taata thoi thoi, taata thoi thoi, taata thoi thoi.

Further literature on the song lyrics of *Momo Chitte* and its background information can be found from the website[2]. An English translation of this song by Anjan Ganguly is given in the Appendix.

Music researchers have been using statistics for studying the musical patterns. Beran's book[3] gives an account of the applications of statistics in Western Art Music (WAM) while the book by Chakraborty *et al.*[4] provides the same in Hindustani music. The book by Jairazbhoy[5] may be consulted for further literature on Hindustani ragas. See also the book of Bor et al.[6].

3. Methodology

3.1 Notes duration

The length of time for which a note is played in any music is called the note duration. It can be understood more precisely by saying that it is the difference between the time of departure and time of arrival of a note. Note duration analysis is important to depict the restfulness or restlessness in the concerned regions in the musical piece where there is greater stay or lesser stay respectively on the notes.

3.2 Inter onset interval (IOI)

IOI is the difference in arrival times of two successive notes. IOI analysis is necessary to depict rhythm. Equal peaks in the IOI graph indicate that the notes are coming periodically and hence are in rhythm. If the mean IOI is less, it implies that notes have arrived more rapidly in the recording. If the standard deviation of IOI is less, it implies there is more rhythm in the notes.

3.3 Pitch velocity

Pitch velocity is the rate of change of pitch with respect to time obtained by dividing the absolute value of pitch difference of two successive notes by the corresponding inter onset interval (IOI).

3.4 Statistical parameterization

The structural attributes of a musical phrase can be efficiently described by using the designed statistical parameterization approach[7]. The method is mathematically valid and it gives precise results. In what follows, P_1, P_2 and P_3 measure melody while P_4 and P_5 measure rhythm. Let P_1 be the difference between weighted average note pitch and the pitch of the lowest note of a musical phrase and can be defined as:

$$P_1 = \frac{\sum_{i=1}^{N} p_i d_i}{\sum_{i=1}^{N} d_i} - \mathrm{Min}(p_i)$$

where p_i denotes the pitch (at the onset) of the i-th note and d_i denotes the duration of the i-th note (departure time of the i-th note-onset time of the i-th note), N denotes the number of notes in a musical phrase.

Let P_2 be the difference between the pitch of the highest and the lowest note of a musical phrase and can be defined as:

$$P_2 = \mathrm{Max}(p_i) - \mathrm{Min}(p_i)$$

Let P_3 be the average absolute difference of the pitches of subsequent notes and can be defined as:

$$P_3 = \frac{1}{N-1}\sum_{i=1}^{N-1}|p_i - p_{i-1}|$$

Let P_4 be the duration of the longest note of a musical phrase and can be defined as:

$$P_4 = \mathrm{Max}(d_i)$$

Let P_5 be the average note duration and can be defined as:

$$P_5 = \frac{1}{N}\sum_{i=1}^{N} d_i$$

3.5 Spectrogram

A spectrogram is a visual representation of voice (in our case) graphically in which a two-dimensional spectrogram shows frequency on one axis with respect to time on the other axis and in 3-D spectrogram depicts one of the axis representing amplitude of sound. By the use of spectrogram, it is easy to analyse the intensity of different sounds like music, sonar, radar, speech processing, and linguistics, by varying the colour or brightness in the image.

3.6 Pitch profile

Pitch is the perceived fundamental frequency which determines the shrillness or hoarseness of sound. Musical notes are characterised by their pitch and pitch class. The pitch profile provides the pattern in the note progression in the musical piece.

4. Experimental results

Figures 1 and **2** give the note duration in seconds for the first 30 s and the next 30 s respectively of the recording.

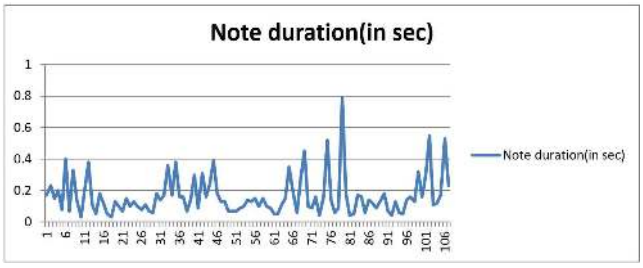

Figure 1. Note duration graph for the first 30 s.
Mean note duration = 0.157029703 s, SD (standard deviation) note duration = 0.118106262 s.

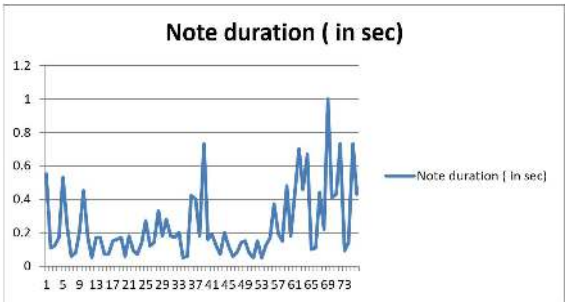

Figure 2. Note duration graph for the next 30 s.
Mean note duration = 0.240789474 s, SD (standard deviation) Note duration = 0.202239219 s.

Figures 3 and **4** give the IOI for the first 30 s and the next 30 s respectively.

Figure 3. IOI graph for the first 30 s.
Mean IOI = 0.289705882 s, SD (standard deviation) IOI = 0.175245796 s.

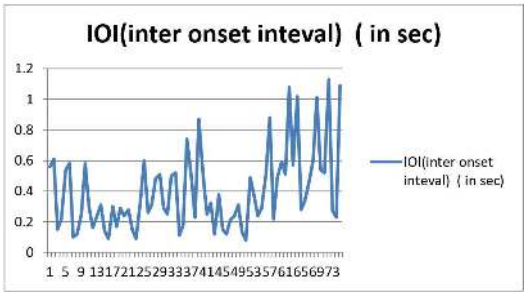

Figure 4. IOI graph for the next 30 s.
Mean IOI = 0.395333333 s, SD (standard deviation) = 0.257814795 s.

Figures 5 and **6** give the pitch velocity for the first 30 s and the next 30 s respectively.

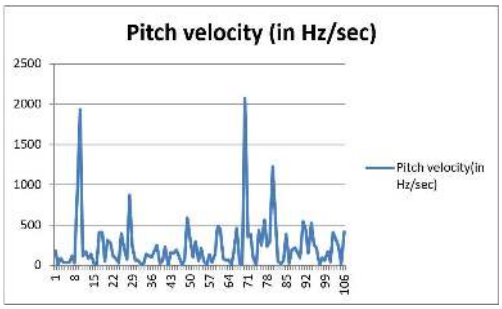

Figure 5. Graph showing pitch velocity for the first 30 s.
Mean of pitch velocity = 234.0169307 Hz/s, SD (standard deviation) of pitch velocity = 331.5644264 Hz/s.

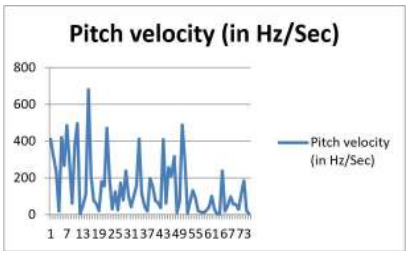

Figure 6. Graph showing pitch velocity for the next 30 s.
Mean of pitch velocity = 150.4494667 Hz/s, SD (standard deviation) of pitch velocity = 152.4132939 Hz/s.

Table 1 gives the values of statistical parameters P_1, P_2, P_3, P_4 and P_5 for the first 30 s and next 30 s of the recording.

Table 1. Comparison of statistical parameters P_1, P_2, P_3, P_4 and P_5 for the first and next 30 s.

	P_1	P_2	P_3	P_4	P_5
First 30 s	56.797	233.94	48.003	0.79	0.157
Next 30 s	55.668	230.06	150.449	1	0.241

Spectrogram analysis: The spectrogram for the first 30 s and the second 30 s are given in **Figures 7** and **8**, respectively.

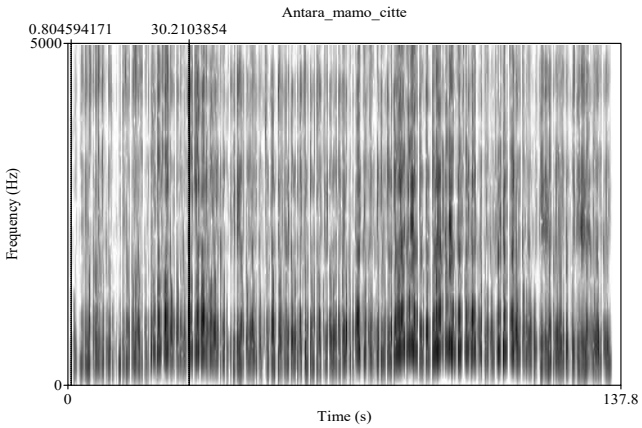

Figure 7. Spectrogram of Tagore song *Momo Chitte* for first 30 s.

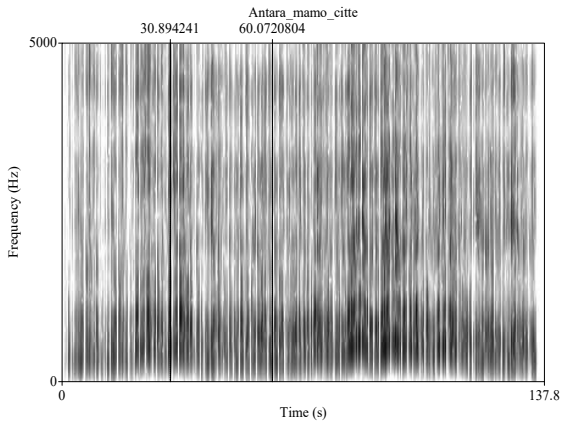

Figure 8. Spectrogram of Tagore song Momo Chitte for next 30 s.

Pitch profile: The pitch profile for the first 30 s and the second 30 s are given in **Figures 9** and **10**, respectively.

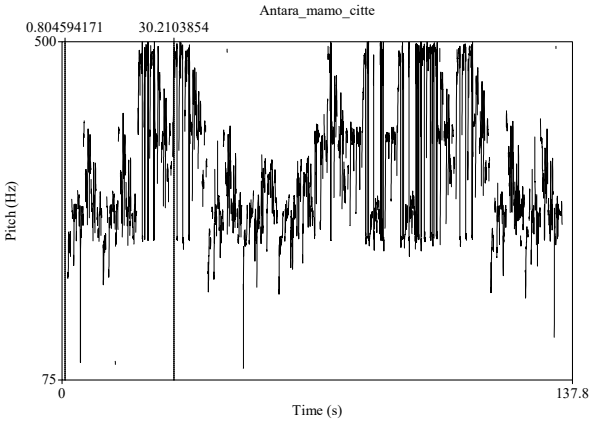

Figure 9. Pitch profile of Tagore song *Momo Chitte* for first 30 s.

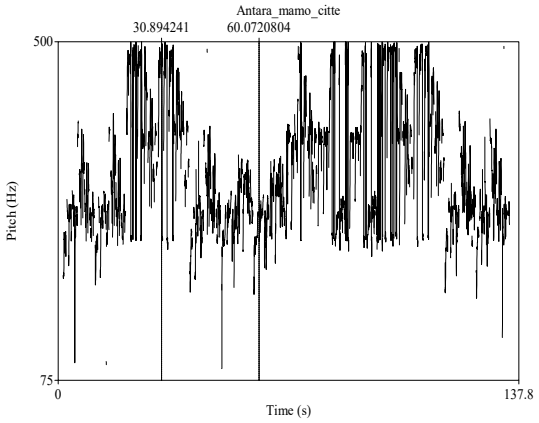

Figure 10. Pitch profile of Tagore song Momo Chitte for second 30 s.

5. Discussion

From **Figures 1** and **2**, it is clear that the peaks of note duration are greater and higher in the second 30 s of the recording implying more restfulness or stay on the notes in the second 30 s as compared to the first 30 s. The mean note duration is more in the second 30 s. However, the standard deviation is less in the first 30 s implying less variation in the duration times of the notes in the first 30 s.

From **Figures 3** and **4**, it is evident that notes are coming more rapidly and also have more rhythm in the first 30 s as compared to the second 30 s of the recording which is also numerically endorsed by the fact that both the mean and standard deviation of IOI is less in the first 30 s.

From **Figures 5** and **6**, the rate of change of pitch is less in the second 30 s of the recording as

compared to the first 30 s. Both the mean and standard deviation of the pitch velocity is lesser in the second 30 s.

From **Table 1**, the parameters P_1 and P_2 are close in the first 30 s and second 30 s, but the parameter P_3 is more in the second 30 s. It is interesting to observe that, while the rate of change of pitch is less in the second 30 s, the average pitch difference between successive notes is more. Also, the parameters P_4 and P_5 are more in the second 30 s depicting that both the maximum and the average note duration are more in the second 30 s.

From **Figures 7** and **8**, it is evident that the intensity is more in the first 30 s. Also, there is varying intensity in the first 30 s as compared to the second 30 s.

From **Figures 9** and **10**, we notice the contrasting pitch profile in the first 30 s showing an upward trend as compared to that of the second 30 s showing a downward trend of note progression.

6. Conclusion

We conclude that:

1) There is more restfulness or stay on the notes in the second 30 s but less variation in the duration times of the notes in the first 30 s.

2) Notes are coming more rapidly and also have more rhythm in the first 30 s as compared to the second 30 s.

3) The rate of change of pitch is less in the second 30 s of the recording with lesser standard deviation as compared to the first 30 s.

4) The parameters P_1 and P_2 are close in the first 30 s and second 30 s, but the parameter P_3 is more in the second 30 s. It is interesting to observe that, while the rate of change of pitch is less in the second 30 s, the average pitch difference between successive notes is more. Also, the parameters P_4 and P_5 are more in the second 30 s depicting that both the maximum and the average note duration are more in the second 30 s.

5) The intensity is more in the first 30 s. Also, there is varying intensity in the first 30 s as compared to the second 30 s.

6) The pitch profile in the first 30 s shows an upward trend as compared to that of the second 30 s showing a downward trend of note progression.

Author contributions

Conceptualization, SC; methodology, SC; software, SC and PS; validation, SC and PS; formal analysis, PS; investigation, SC and PS; resources, PS; data curation, PS; writing—original draft preparation, SC and PS; writing—review and editing, SC; visualization, SC; supervision, SC; project administration, SC; funding acquisition, SC. All authors have read and agreed to the published version of the manuscript.

Acknowledgment

The authors would like to thank IDEA: Technology Innovation Hub @ Indian Statistical Institute, Kolkata for sponsoring this research.

It is also a pleasure to thank Antara Sengupta for sharing her vocal recording of the Tagore song *Momo Chitte* for our research.

Conflict of interest

The authors declare no conflict of interest.

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Appendix

English translation of the song *Momo Chitte*[8] by Anjan Ganguly:

I wonder, who is that dances in my mind
The eternal dance, rhythmically.
I wonder, how well my soul and body respond
To the meter of the 'MRIDANGA',
The eternal dance, rhythmically.

Swings smile and tears upon the temple jewel-like
Good and the evil pulsate with the rhythm
Keenly follow life and death, dancing along
The eternal dance, rhythmically.
O, what a delight, what a delight,
Confinement and liberation dance alongside day and night,
I follow the wave closely, enjoy running behind it
The eternal dance, rhythmically.