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Michele Della Ventura, *editor*

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International Conference on

New Music Concepts Inspired Education and New Computer Science Generation

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Accademia Musicale Studio Musica
Michele Della Ventura
Editor

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Preface

This volume of proceedings from the conference provides an opportunity for readers to engage with a selection of refereed papers that were presented during the International Conference on New Music Concepts, Inspired Education and New Computer Science Generation. The reader will sample here reports of research on topics ranging from a diverse set of disciplines, including mathematical models in music, computer science, learning and conceptual change; teaching strategies, e-learning and innovative learning, neuroscience, engineering and machine learning.

This conference intended to provide a platform for those researchers in music, education, computer science and educational technology to share experiences of effectively applying cutting-edge technologies to learning and to further spark brightening prospects. It is hoped that the findings of each work presented at the conference have enlightened relevant researchers or education practitioners to create more effective learning environments.
This year we received 57 papers from 19 countries worldwide. After a rigorous review process, 24 paper were accepted for presentation or poster display at the conference, yelling an acceptance rate of 42%. All the submissions were reviewed on the basis of their significance, novelty, technical quality, and practical impact.

The Conferece featured three keynote speakers: Prof. **Giuditta Alessandrini** (Università degli Studi Roma TRE, Italy), Prof. **Renee Timmers** (The University of Sheffield, UK) and Prof. **Axel Roebel** (IRCAM Paris, France).
I would like to thank the Organizing Committee for their efforts and time spent to ensure the success of the conference. I would also like to express my gratitude to the program Committee members for their timely and helpful reviews. Last but not least, I would like to thank all the authors for they contribution in maintaining a high-quality conference and I hope in your continued support in playing a significant role in the Innovative Technologies and Learning community in the future.

March 2020

Michele Della Ventura

Conference Chair

Michele Della Ventura, Accademia Musicale Studio Musica, Treviso, Italy

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Renee Timmers, The University of Sheffield, UK
Axel Roebel, IRCAM Paris, France

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Relation between Swara and Animal/Bird Calls: An Analysis

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Abstract. Indian Musicology defines 22 distinct *shrutis* (microtones), 12 *swarasthanas* (semitones) and 7 *swaras* (tones). By implementing the mathematical concepts like cycle of fourths and fifths, these *shrutis* acquire a discrete frequency ratio which justifies the *Bharatha's* 22 *shrutis* experiment. Indian classical music defines the 7 *swaras* and each *swara* is associated to an animal/bird call. The *Grama* system in Indian music distributes the 22 *shrutis* amongst the 7 *swaras*. We based our work on the *Shadja Grama* system. The traversal of pitches in a *swara* are more important in understanding the *swara* as compared to the frequency ratio. This shows us that *swaras* have peculiar properties and an identity independent of the octave.

Keywords. Indian Classical Music, Animal Calls, Pitch Analysis

1 Introduction

Indian Classical music defines 7 *swaras*. *Shadja*, *Rishabha*, *Gandhara*, *Madhyama*, *Panchama*, *Dhaivatha*, and *Nishadha*. In todays' musical system, *Shadja* and *Panchama*, each, are associated to only 1 frequency ratio (1 and 1.5 respectively). The remaining have 2 *swarasthanas* associated with each. The mathematically lower frequency ratios in each *swara* are denoted as ri, ga, ma, dha, ni and the mathematically higher frequency ratios are denoted as Ri, Ga, Ma, Dha, Ni. Thus, there exist a total of 12 *swarasthanas* which help us understand pitch today. The 12 *swarasthanas* are a part of the 22 *shrutis*. The remaining 10 *shrutis* can be recognized when rendering *gamakas* (ornamentations) on the *swarasthanas* in *ragas*.

Bharatha's Shadja grama or *Shadja* scale (as defined in *NatyaSastra*) is a yesteryear scale which dis*tri*butes the 22 *shrutis* among the 7 *swaras*. Accordingly, *Shadja*, *Madhyama* and *Panchama* contain *Chathuh shruti* (4-microtones) . *Rishabha* and *Dhaivatha* contain *Tri shruti* (3-microtones). *Gandhara* and *Nishadha* contain *Dwi shruti* (2-microtones). *Bharatha* has provided us with an elaborate experiment, known as the *Sruti-Nidarsana* experiment [3], to identify these 22 distinct *shrutis*. *NaradiyaShiksha*[1], an

ancient Indian music treatise, introduces us to the concept of *swara*. Dated after *Bharatha's Natyasastra*, it is a basis, containing theory on the origin of sound, human anatomy and sound, sound and color, and jathis (an older equivalent to the present raga system). Later *Sangeeta Ratnakara by Sarangadeva*[2] explains sound, human embodiment, *swara* and *shruti* and discuss the concept of *raga*.
These ancient treatises associate each *swara* to a bird or animal call as shown in the TABLE I below.

TABLE I: *SWARAS* AND CORRESPONDING ANIMAL CALL.

Swara	Sa	Ri	Ga	Ma	Pa	Dha	Ni
Animal/Bird	Peacock	Bull	Goat	Heron	Kokila	Horse	Elephant

The Origins of Music [4] establishes that music has roots in bird and animal calls. Man, over many years, has tried to emulate the sounds produced by other beings of nature with great precision. Animal calls are distinct intraspecies. Hence, when a *swara* is associated to a call, the pattern of traversal of pitch becomes more important than the discrete frequency ratios. The traversal of pitch in these calls and the properties of the *swara* are congruent in nature. The pitch analysis of the above animal/bird sounds has been studied and analyzed. We try to understand the interval of a swara through the analysis of these animal /bird calls.

2 Motivation

As shown in TABLE 1, *Lakshana Grandhas* (Musical treatises) [1-3], correlate a swara to a bird/animal call. The Origins of Music [4] also explains how music is derived from sounds occurring in nature. Our aim is to try and discover how this relationship between *swaras* and the corresponding bird/animal calls is made using the knowledge of sound and mathematical models available today. Studying these animal/bird calls could also inform us about the properties of the *swaras* they are related to.

Human ear perceives sound as a continuous signal. The slightest changes in pitch traversal can be detected by the human ear, despite our ability to distinctly recognize only 22 *shrutis*. Animal/bird calls, comprising of potent pitch patterns, being associated to *swaras* prove that a *swara* is larger than the *swarasthanas* attributed to it. Thus, we put forth that **a swara is an interval.** *A swara is an interval containing many shrutis within it and the relation between these shrutis gives a swara its distinct characteristic.*

Thus, an interval, derived from bird/animal calls, contains within itself not just a finite set of discrete frequencies but also a pattern connecting these discrete frequencies. The shape of the plot or the function of pitch in terms of time, helps us determine how *swara* is perceived by the human ear. We try to understand the interval of a swara and its relation with the corresponding animal /bird calls.

3 Methodology

Audio clips have been collected from online sources. These files are available in [5]. Audio clips collected have minimal noise and disturbance and thus their analysis is devoid of error.

In this study, we use the Equal temperament scale to give values to the 12 *swarasthanas* as $2^{\frac{i}{12}}$ where i is the *swarasthanas* number in the octave. The resulting plots show us the Pitch versus Time of the audio signal.

TABLE II: FREQUENCY RATIO OF *SWARASTHANAS*.

Swara-sthanas	Sa	ri	Ri	ga	Ga	ma	Ma	Pa	dha	Dha	ni	Ni
Western Equivalent	C	C#	D	D#	E	F	F#	G	G#	A	A#	B
Frequency - Ratio	1	1.06	1.125	1.189	1.259	1.335	1.414	1.498	1.587	1.682	1.782	1.887

Average Magnitude Pitch Function (AMDF) is applied on the sampled audio based on algorithm in [6] and the AMDF fractional pitch periods are found [7]. For finding the pitch in the equivalent temperament scale, the frequency ratio - pitch relation for the A above middle C (or A4) is used. In electronic music, pitch is often given by MIDI number p . p for the note A4 is 69 and increases by one for each equal tempered semitone. This gives us a simple conversion between frequencies and MIDI numbers (using 440Hz as the frequency of A4) [8].

The frequency f corresponding to pitch p is given by

$$f = 440.2^{\frac{p-69}{12}}\ \text{Hz} \Rightarrow\ p = 12 \times \log_2 \frac{f}{440} + 69$$

Bharatha's 22 *shrutis* lie within these 12 *swarasthanas* as shown in Fig. 1.

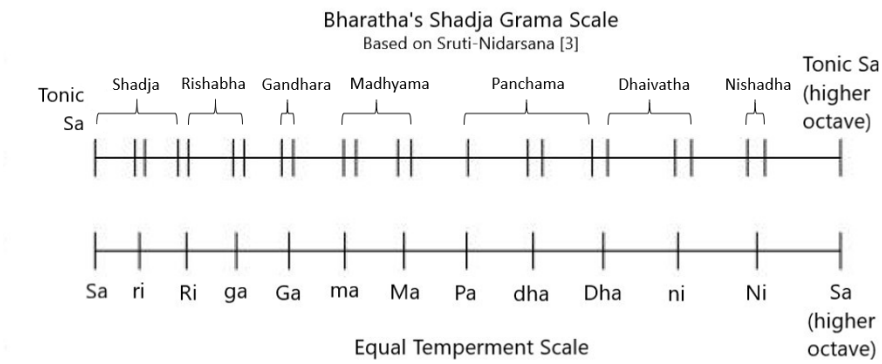


Fig. 1. Relation between *swarasthanas* of ET scale and the distribution of *shrutis* in *Bharatha's* Shadja Scale.

Todays' system of music uses the concept of *aadhaara shadja* or tonic note (key). Hence, the peacock call frequency has been adjusted such that its mean lies along the *Shadja* Sa having frequency ratio 1. All other plots take this Sa as the tonic frequency.

Figure 1 shows us that the understanding of *shrutis* in the *grama* system is different from the present understanding of swarasthanas. This difference shows that some swaras are intersecting intervals. It is to be noted that the braces in Fig. 1. show us the number of distinct *shrutis* attributed to a *swara* and not the interval of the swara. The space between the last *shruti* of one *swara* and the first *shruti* of the next *swara* are utilized in the traversal from one note to the next. This can be observed in the plots obtained through analysis of audio clips. There is no strict demarcation or boundary for a *swara* known as of today.

4 Analysis of Animal/Bird Calls

The following plots were obtained by analyzing the audio files of the 7 animals and birds mentioned in TABLE I.

1. *Shadja*: Peacock

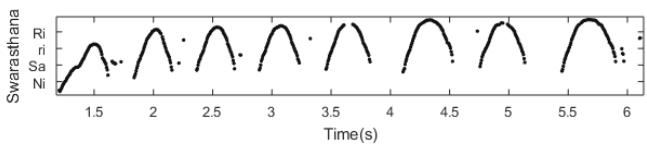


Fig. 2. Peacock Call Pitch v/s Time.

2. *Rishabha*: Bull

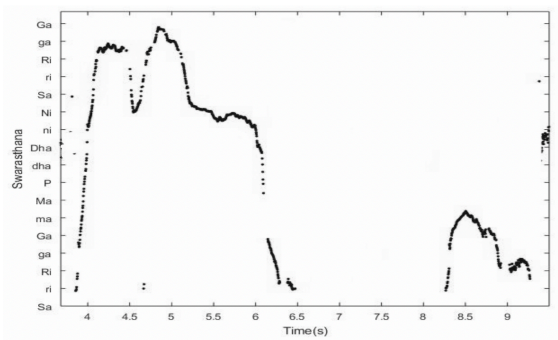


Fig. 3. Bull sound Pitch v/s Time.

3. *Gandhara*: Goat

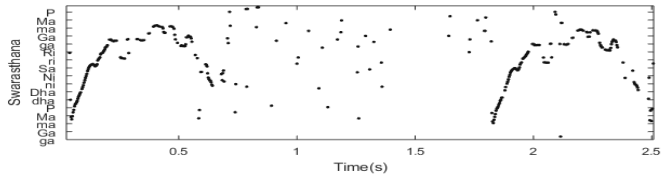
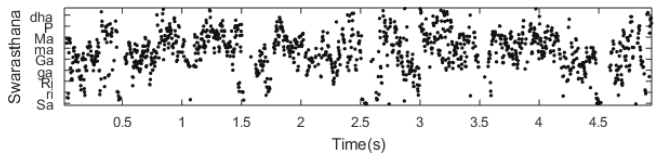


Fig. 4. Goat bleat Pitch v/s Time.

4. *Madhyama*: Heron

Fig. 5. Heron Call Pitch v/s Time.



5. *Panchama*: Kokila/Indian Koel

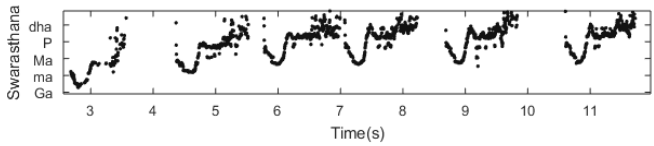


Fig. 6. Koel Call Pitch v/s Time

6. *Dhaivatha*: Horse

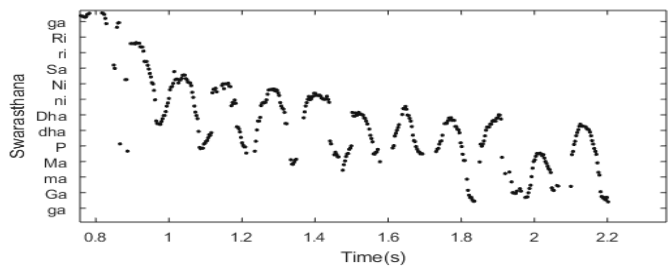


Fig. 7. Horse neigh Pitch v/s Time

7. *Nishadha*: Elephant

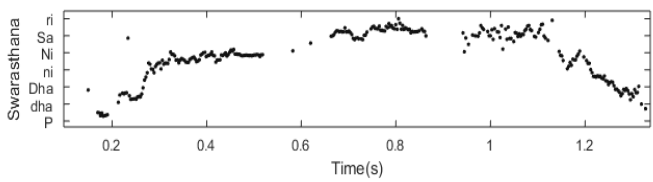


Fig. 8. Elephant trumpet Pitch v/s Time

5 Discussion on Results

Based on the plots, one can say that swaras are not confined to their *swarasthana* boundaries. *All plots resonate within the boundary of the swara interval*. Resonance is understood as places having maximum point density. This also goes in hand with *Naradiya shiksha* and *Sangeeta Ratnakara*, which say "*swara* is padded by *shrutis* and the most resonant of the *shrutis* is the *swara*".
The animal/bird calls lie across many octaves. When all 7 sounds are heard together one does not hear the procession of tones through one octave. Hence, we can say that a *swara*, independent of the octave, has peculiar properties as a standalone entity. Based on this, we can conclude that the traversal of pitches in a *swara* are more important in understanding the *swara* rather than the frequency ratio alone.

The *chathuh shruti* interval *swaras* are associated to bird calls. Evolutionarily, bird calls contain more pitches and patterns. These 3 *swaras* are also potent with pitch values and mathematically semicircular as seen in Fig. 9.

Fig. 9. *Chathuh shruti* plots. Left to right, Peacock, Heron, Koel.

Tri-shruti intervals are similar in nature. Their plots have multiple descending peaks.

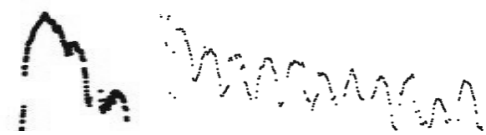


Fig. 10. *Tri Shruti* plots. Left to right, Bull, Horse

Dwi-shruthi intervals are spiky and resonate at a small range bounded by the *swarasthana*.

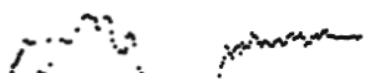


Fig. 11. *Dwi Shruti* plots. Left to right, Goat, Elephant.

Based on the above results we can say *Bharatha's shadja grama* is congruent to the animal/bird calls. These similarities within *shruti* groups show that pitch traversal patterns play a large role in understanding *swara*. It also shows that *Bharatha's shadja grama* was an appropriate scale for *shruti* dis*tri*bution among the 7 *swaras*.

6 Conclusion

Through this study we tried to find a relation between the seven *swaras* and the animal/bird call associated to them through our understanding of the 12 *swarasthanas*. The pitch traversal through the *swara* has been established as its peculiar property. If the study of music through *swarasthanas* was limited to discrete pitches, these results wouldn't be justified. The above results reinstate that all *shrutis* within the interval play a role in understanding a *swara*.

Today's understanding of *swara* and *shruti* are very different from *Bharatha's shadja grama*. Sa and Pa are defined as *chathuh shruti* intervals in *Bharatha's Shadja grama*. In practice, today these *swaras* have been reduced to *swarasthanas* with fixed positions. Today *swarasthanas* are predominantly used to understand music, because of the homogeneity in the concept of a 12-semitone octave, globally. The *swara* being an interval is the basis for all the explorations in Indian music. Thus, to see the range of swaras as similar to that of the bird/ animal sound, establishes an origin to these *swaras* and also describes their characteristics. So, this experiment gives us an interesting understanding about the associations mentioned in the *lakshana grandhas*.

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This book presents a collection of selected papers that present the current variety of all aspect of the research at a high level, in the fields of music, education and computer science. The book meets the growing demand of practitioners, researchers, scientists, educators and students for a comprehensive introduction to key topics in these fields. The volume focuses on easy-to-understand examples and a guide to additional literature.

Michele Della Ventura, editor

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