Spectral analysis of Gamaka Swaras of Indian music

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In Indian classical music, there are a huge number of modes (Ragas). There are also pieces (Ragamala or Ragamalikai in which modulations are employed. In both Hindustani & Carnatic (Karnataka) music, songs are usually preceded by an improvised unmeasured prelude (Alap), which is sometimes extensive. Individual pieces are shorter in Karnataka music, so recitals are constructed by selecting items in contrasting ragas. Gamaka Swaras, the subtle decorations of musical notes, usually referred to as the shaking of notes or vibration of Swaras come in various forms. Gamaka plays a very essential role in Indian music. Spectral analysis of the seven notes of Indian music has been reported. The work reported in the paper is a continuation of that work, extending it to Gamaka Swaras. Report of the preliminary study giving a glimpse into spectral intricacies of Arohana Gamaka has also been discussed.

Keywords: Gamaka Swaras, Indian music, Karnataka music, Spectral analysis

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Gamaka Swaras are subtle decorations of musical notes, usually referred to as the shaking of notes or vibration of Swaras. They come in various forms and are incorporated into Ragas, giving each note a unique characteristic and delicate beauty. Gamaka plays a very essential role in Indian music, whether Hindustani or Karnataka, classical or otherwise. It is even considered the very essence of music, without which music tends to become flat, pale and unesthetic. Recently, the Spectral analysis of the seven notes of Indian Music has been reported. The work reported in the paper is a continuation of the earlier work, extending it to Gamaka Swaras. There are various types of Gamakas in use. Gamaka Swaras of the ascending scale of the Raga Mayamalavagowla, which uses the seven notes in a sequence and is the basis for the commencement of training in Karnataka music of southern India, has been discussed. Indian music owes its origin to the Samaveda. The evolution of Music from the Samaveda has been the subject of study by many scholars and a good number of literatures are available on this subject. Some of them give a bird’s eye view of the development of music down the ages until it reached its current form.

Indian music is one of the oldest musical traditions in the world and its origin go back to Vedas (ancient Indian scripts). Many different legends have grown up concerning the origin and development of Indian classical music. Indian music has developed within a very complex interaction between different peoples of different races and cultures. The basis for Indian music is Sangeet. Sangeet is a combination of three art forms: vocal, instrumental and dance. Although these three art forms were originally derived from the single field of stagecraft, today these three forms have differentiated into complex and highly refined individual art forms. Indian music is based upon: Rag and Tal. Rag is the melodic form while Tal is the rhythmic. Rag may be roughly equated with the Western term mode or scale. There is a system of seven notes, which are arranged in a means not unlike Western scales. Tal (rhythmic form) is also very complex. Many common rhythmic patterns exist. They revolve around repeating patterns of beats. All of this makes up the complex and exciting field of Indian classical music. Its understanding easily consumes an entire lifetime.

Speech and sound analysis, on the other hand, is of recent origin. The impetus for this came from the famous work of Fourier, leading to the study of sound patterns by splitting them into sinusoidal and
co-sinusoidal components, now called Fourier analysis or spectral analysis. However, the analysis of human voice itself commenced only about half-a-century ago, with the invention of the Sound Spectrograph in 1946. Today, it has become a highly developed technical domain.\(^1\)

The analysis of sound patterns is usually done either in the frequency domain or in the time domain. The former gives information about the distribution of the energy of sound over a range of frequencies. For human voices, the range is 20-20,000 Hz. However, the contribution above 8,000 Hz. is usually negligible. In the case of slow speech, the shape of the vocal tract remains steady up to about 200 millisec. Hence, it is the usual practice to do time domain studies in the range of 30-100 millisec. Frequency domain analysis leads to the energy spectrum, where the initial waveform is Fourier-analysed. This has the handicap of losing information about variations with time. Therefore, it is the usual practice to supplement the spectrum by a Spectrogram, which is a plot of frequency as a function of time. The spectrogram consists of a set of horizontal lines of varying thickness and intensity, which are an index of the energy level. In this sense, the spectrogram is a parametric representation, with the energy as the parameter. Between them, the energy spectrum and the corresponding spectrogram provide enough information for the analysis of the sound pattern.\(^5,6\)

Methodology

The experimental procedure consisted of the following steps: (1) recording the Gamaka Swaras with a sensitive microphone in a quiet ambience, (2) digitizing the waveforms using a sampling rate of 44100 per sec, (3) analyzing the digitized data to extract the energy-frequency and frequency-time spectra, and (4) identifying the predominant frequencies through spectrograms. The procedure for recording was essentially the same as described earlier.\(^2\) Even though the human voice normally does not use frequencies higher than 8000 Hz., it was still decided to digitize the signals with a sampling rate of 44100 per second for the sake of fidelity. Trials showed that with a threshold level of 7500 Hz., the spectrograms showed very clear lines, easy for analysis. Using a higher threshold made the lines too thin and difficult to analyze.

The recording was done for a total of 5 male voices and 5 female voices, choosing the ascending scale of the raga Mayamalavagowla of Karnataka music and was supervised and checked for fidelity by the first author, a trained singer of Karnataka classical music. The seven notes were sung in the ascending order, giving long runs to each note. Three criteria were used for selecting the best recordings - steadiness of the pitch, perfection of the notes and breath control of the reciter leading to the steadiness of the voice. Based on these criteria, three male and three female recordings were selected for further study. The most important segment of the recording is the exact location in the waveform of the Gamaka Swaras. The identification was done as follows: The signal was expanded in the time scale and the cursor was moved from one end of the waveform to the other, using the play icon in the Sound Forge software. The musical notes were scanned with the help of a headphone. Wherever the Gamaka note was heard, the cursor was stopped to note down the precise location in the waveform. This position was highlighted and that portion of the waveform was used for further analysis. In this manner, the position before the Gamaka, during the Gamaka, after the Gamaka and the transition from one note to the next were identified.

Results

The results are presented in the form of sample waveforms, short-time window patterns, sample energy-frequency spectra and sonograms of the seven notes as well as of the transitions. The waveform of the seven notes with Gamaka for a female voice (Fig. 1) and that for a male voice (Fig. 2) has been presented. The analysis reported is based on all waveforms recorded, but only two of them are displayed to give an idea as to what the waveforms look like. A short-time window pattern for a female voice (Fig. 3) and that for a male voice (Fig. 4) have been displayed. These patterns demonstrate the periodic nature of the signals, indicating that no random analysis is needed. Sample energy-frequency spectra are shown in figs 5 & 6. Fig. 5 shows the spectrum for the note Sa of a female voice during Gamaka. The same spectrum for a male voice is displayed in Fig. 6. A sample set of sonograms has been displayed (Figs 7-14). The sonogram for all seven notes for a female voice (Fig. 7) and that for a male voice (Fig. 8) have been displayed. There are in all seven transitions between the notes and the sonogram of these transitions for the female voice (Fig. 9) and that for the male voice (Fig. 10). Lastly,
Fig. 1 Female voice waveform

Fig. 2 Male voice waveform

Fig. 3 Short-time window pattern for female voice

Fig. 4 Short-time window pattern for male voice

Fig. 5 Female sa during gamaka - energy spectrum

Fig. 6 Male sa during gamaka - energy spectrum

Fig. 7 Sonogram for all the seven notes: female voice

Fig. 8 Sonogram for all the seven notes: male voice
the sonograms for the seven notes before Gamaka for the female voice in (Fig. 11) and the male voice in (Fig. 12) and the corresponding sonograms for the seven notes after Gamaka (Figs 13-14) have also been displayed. Of the total 390 figures, only sample figures to illustrate the kind of data analysis, which has been used to draw the conclusions, have been presented.

Discussion
Musical notes are periodic in nature and differ from noise, which is non-periodical. It is the periodic nature of the musical notes, which makes them so pleasant to hear even for long periods of time. Noise, on the other hand, creates mental disturbances leading to discomfort. This is a common experience. The advantage of musical notes is their periodicity, which makes working with them and their analysis much simpler. Therefore, before working on any musical waveform for its periodicity, not only to ensure its fidelity but also to see that there is no intrusion by external or internal noise is checked. With this end in view, all recorded waveforms (Figs 1-2), were checked for periodicity by taking several 100 millise
windows. It is said that the human voice finds it difficult to be stable beyond a time period of 200 milliseconds. But during the study, all the singers were well trained and could hold their voice steady. Nevertheless, windows of 100 milliseconds were used to ensure that all the waveforms were periodic.

The signals can be analyzed by the energy-frequency spectrum and the frequency-time sonogram. The former gives a static picture and the latter gives a dynamic picture. Both the representations are equally useful if the spectra are independent of time. But where the energy spectra vary with time, the sonogram representation is more useful, since it gives information about variations with time, which tend to get masked in the energy spectra. In the current study, the focus of attention was the Gamaka, which represents minute variations in the voice resorted to by musicians to bring out emotions more effectively. Therefore, sonograms were considered to be more appropriate medium for the study and hence they have been used primarily for drawing the conclusions. While studying the sonograms, the abscissa represents time and the ordinate the frequency, with the energy level serving as a parameter. The lowest line represents the fundamental frequency and successive lines are harmonic frequencies, which are integral multiples of the fundamental. Black and white sonograms have been used rather than coloured ones, since they show predominant time variation. It appears as if the notes form a staircase, alternate notes representing the rise and the tread. In this sense, the word Arohana, meaning ascent, is indeed appropriate.

Conclusion

Male voices have a richer timbre, which many a time, plays the same role as Gamaka. Hence, there is no need for the male voice to use or emphasize Gamaka. The female voice on the other hand, with a shallower timbre, needs to emphasize Gamaka more, to bring out the same effect. This has been noticed in the recitation of Mantras also. In the case of any flat note, the fundamental frequency remains unchanging with time. However, it is also a function of the pitch. When the human voice moves over the ascending scale of notes, the fundamental frequency gradually increases. This is irrespective of whether the voice is male or female. The notes with Gamaka appear to form a staircase, with the alternate notes representing a rise or the step, thus justifying the use of the technical word Arohana. This is a preliminary study giving a glimpse into the spectral intricacies of Arohana Gamaka. A more detailed study would have to take into account the actual variations in the frequency during Gamaka, the peak frequency reached and its relation to the transition between the notes. The study has been undertaken and the results will be reported later.

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References