Proceedings of the Stockholm Music Acoustics Conference, August 6-9, 2003 (SMAC 03), Stockholm, Sweden

PITCH MEASUREMENTS VERSUS PERCEPTION OF SOUTH INDIAN CLASSICAL MUSIC

Arvindh Krishnaswamy

Center for Computer Research in Music and Acoustics
Dept of Electrical Engineering, Stanford University
arvindh@ccrma.stanford.edu

ABSTRACT

Certain pitch inflexions used in South Indian Classical (Carnatic) music are discussed. It is proposed that these inflexions should be considered as time-varying, inflected intervals, equal in importance to constant-pitch intervals. Transient notes and inflexions are also introduced and examined. Possible reasons for some misconceptions relating to the number and the nature of the musical intervals used in Carnatic music today are also suggested. Sample pitch tracks are presented to illustrate our arguments.

1. INTRODUCTION

It should hardly be surprising if theories not based on experimental evidence are eventually discovered to have serious problems. It should also not be alarming if inadequate or incorrect system models yield confusing or contradictory results. We believe that many historic and contemporary theories of Indian music that propose divisions of the octave into more than 12 constant-pitch notes suffer from both of these pitfalls *when applied to present-day Indian music*.

There is a prevalent notion among practitioners and fans of Indian music that more than 12 musical intervals are used, where some of these intervals are "microtonal." While we agree with this belief "in spirit," we argue that the very definition of the term "interval" needs to be expanded before application to Indian music today.

While we would strongly object to the idea that Carnatic music uses more than 12 *distinct* constant-pitch notes, we would still claim that it would be inaccurate to say that Carnatic music uses 12 notes only: how would one then account for the Ga_3 in Aarabhi?

We believe that certain pitch inflexions (gamakams) used in Carnatic music are "equal in stature" to the 12 basic constant-pitch notes. Our assertion with respect to some of these gamakams is that they are *not* mere ornamentations: is there any possibility at all that the Ga_3 in Aarabhi can be played without an inflexion from Ma_1? Would it still be Aarabhi ragam if this Ga_3 was played similar to the constant-pitch Ga_3 in Hamsadwani? Can this same Ga_3 in Aarabhi be held (sounded) indefinitely? The answer to all three questions is negative.

Many people seem to readily associate the term "gamakam" with embellishments or ornamentations. However, this characterization implies an optional nature to these inflexions. We stress that playing the Ri_1 in Gaulai in the phrase "$pmgmR;$" without an oscillating, inflected pitch from Sa is neither optional nor tolerable. While in certain phrases a particular type of gamakam *has* to be used when rendering a particular note, in some other situations the musician may have many possible gamakams to choose from or may even decide not to use any gamakam at all. In these cases, the gamakams involved may be regarded as ornamentations. However, the distinction between what is optional and what is required may not always be clear since gamakams have become an integral part of Carnatic music today.

Intonation was found to be "variable" even among top musicians in Carnatic music [1]. Given the caliber of some of these musicians, it should be understood that there is indeed *some* flexibility in intonation that is musically insignificant in Carnatic music. But poor intonation (apaswaram or pisiru) can indeed be glaring and annoying at times, and so there are obviously some implicit limits in the range of acceptable intonation. These limits may depend on a lot of factors such as the note being played, its duration, the melodic context, the ragam, the underlying tempo and the instrument being used. Sometimes, a note that is vocalized or notated on paper may not directly correspond to the pitch that is actually sounded to make a phrase sound correct and acceptable [1].

Despite these intonational variances, an important point to note is that the pitch inflexions frequently used in Carnatic music are by no means "drowned" or obscured. Rather, these inflexions are distinctly audible (or visible on graphs of pitch) and can be easily recognized and reproduced by a sufficiently trained Carnatic musician.

In this paper, continuing the work described in [1], we present additional pitch tracks and examine a few pitch inflexions in more detail. We also introduce the ideas of "inflected intervals," "transient notes" and "transient inflexions" to more appropriately categorize the different "musical atoms" used in Carnatic music. Possible reasons as to why certain people might still believe that more than 12 distinct constant-pitch notes are used in Carnatic music are also suggested.

In the graphs of pitch tracks presented in this paper, the solid horizontal lines with circles at both ends on each graph correspond to an interval value from [2]. The equal temperament intervals are also depicted with solid lines but without the terminating circles. Relative pitch with respect to Sa is plotted in cents versus time. The time-gaps which occur in some plots are due to instances in the associated sound where pitch is not well-defined. These instances include periods of silence or too low a signal amplitude and "unvoiced" sounds (like when the violin bow changes direction). The STFT-based pitch tracking method described in [1] was used to produce all the graphs in this paper.

2. PITCH INFLEXIONS

Figure 1 shows two examples of Ri_1 in the ragam Saaveri. In the plot on the left, we have a time-varying pitch whose "base" is Sa

(0 cents). The distinct feature which differentiates this pitch track from any constant-pitch note is the presence of the inflexions going up from Sa. And it is not a vibrato-like pitch variation centered around Sa or a constant-pitch Ri_1 either. Roughly speaking, this pitch track can be segmented into "flat portions" and "spikes."

The variability in the shapes and peak heights of the three spikes shown should be noted. If we calculated the average value (in cents) of these spikes, we would end up roughly in the quartertonal range or less. It is clear, even by simple visual inspection, that neither the peak heights nor the average values of these spikes are in any sense consistent with the interval values stated in [2] (which are also indicated in the graph). Quartertones (constant-pitch intervals bisecting the semitones) are not used in Carnatic music, and it is possible that they may even sound strange or unmusical to many Carnatic musicians. On the whole, we argue that this (roughly) one second pitch track can't be substituted with any constant-pitch interval, with the same time duration, to achieve a similar and *acceptable* perceptual effect.

The differences in the peak heights of the spikes are not really important in the overall perception of this sound: the pitch is slewing rapidly within a spike, and lingers close to its peak value only for a very small time duration, which is really too short to be perceptually significant. The pitch sensation felt when listening to this sound is probably more influenced by the overall effect of each spike.

The variances in the spike shapes or heights can be noticed, of course, with careful and repeated listening, but as long as the *perceived* smoothness and consistency of the inflexion is within musically acceptable limits, no audience would complain. Determining exactly what these limits are may be a very difficult task, but with enough empirical data, it may be possible to come up with a range that would work well enough for applications like computer sound analysis and synthesis.

On the right in Figure 1 another time-varying Ri_1 is shown, obtained from the same recording as before. The spikes look a little higher and wider. (Or they may even be interpreted as being inverted or "downward spikes" from around 100 cents or as symmetric oscillations between two constant-pitch note levels). Indeed, the corresponding audio also sounds "higher in pitch."

3. TIME-VARYING, INFLECTED INTERVALS

The Western concept of an interval may not be sufficient or appropriate to explain some of the "musical atoms" used in Carnatic music like those in Figure 1. The idea of a time-varying, inflected interval may be required to accommodate them, rather than simply dismissing them as ornamentations.

Though the time-varying nature of such inflexions can be easily detected by the human ear, they may also have an interesting perceptual effect if a listener chooses to place such sounds into categories alongside the constant-pitch notes. Obviously the inflexions in Figure 1 will end up, if classified based on mean pitch value for example, in-between Sa and the constant-pitch Ri_1.

However, we stress that while a classification based on mean value may indeed be very convenient, and informative to some extent, a single numerical value alone will fail to capture the true nature and the perceptual effect of these inflexions. Rather, we feel that the following dimensions need to be considered, at a minimum, when analyzing or characterizing such inflexions: pitch and time. The amplitude (loudness) modulation of a phrase or inflexion may also be musically important. Different parts of an inflexion (like the spikes and flat regions for example) may also scale in time non-uniformly and independently, if the underlying tempo of the phrase in consideration is varied.

It should be possible to come up with a set of parametric models for these inflexions. Perhaps the two inflexions in Figure 1 can be represented as variations of the same underlying pitch inflexion model. Or it may be more convenient, perhaps even necessary, to introduce more than one model for different inflexions between Sa and the constant-pitch Ri_1 depending on the ragam, melodic context or intended effect of the inflexion.

Of course this idea of inflected intervals might make it very inconvenient to compare Carnatic music to other musical systems in the world, like Western music. However, this inconvenience should be the least of one's concern when trying to model Carnatic music accurately.

4. TRANSIENTS

In fast passages, or even in phrases with a slow tempo but where a note appears only briefly, the ideas of a transient note and a transient inflexion are useful. We distinguish between these two categories, and we also classify them separately from "prolonged intervals" like constant-pitch intervals or inflexions like those in Figure 1.

The distinction made between a transient note and a transient inflexion is as follows: while a transient note was *meant* to be played by the musician without any gamakams, a transient inflexion can be described as one cycle of an inflexion or one spike. The first and third occurrences of Ni_2 shown in Figure 8 are examples of transient inflexions. The perceived pitch of Ni_2 in these cases is higher than Da_2 but lower than a constant-pitch Ni_2. However, it is possible that some people may fail to realize the time-varying nature of this inflexion and hear it as a lower-pitched version of a constant-pitch Ni_2. The situation sometimes could become even more confusing when such inflexions are halted near their peak or decreased in loudness immediately after reaching the peak. Doing so makes an inflected note appear just like a transient note to a casual listener. Another cause of confusion may be fingering techniques that some instrumentalists may use to produce such inflexions. For example, in the phrase "$rgrs$" in Sri ragam, a violinist may use two different fingers to play the Ri_2 and the Ga_2. This may lead to the impression that a lower-pitched version of a constant-pitch Ga_2 is being played. However, this Ga_2 is more accurately classified as another example of a transient inflexion. Nevertheless, we certainly do not disagree that the pitch sensation felt when listening to this Ga_2 is lower than that of a prolonged constant-pitch Ga_2 appearing in some other ragams like Kapi.

The two most important features of a transient inflexion are that (1) its pitch or intonation is very much tied to the base or starting note (which could be above or below the inflexion) and (2) the pitch sensation perceived will be in-between two of the 12 basic constant-pitch notes. Gamakams are used so often that transient notes may be particularly rare when a note is followed by another one just one semitone higher or lower. In these cases, the second note may frequently be played with an inflexion from the first. The boundary between a transient inflection and a transient note may not *always* be distinct. To distinguish between the two types of transients without some musical insight or knowledge of what the musician intended to do may be difficult. It is also possible that certain musicians are not even aware that they are using an inflexion sometimes. But in some cases, it is very clear what is played:

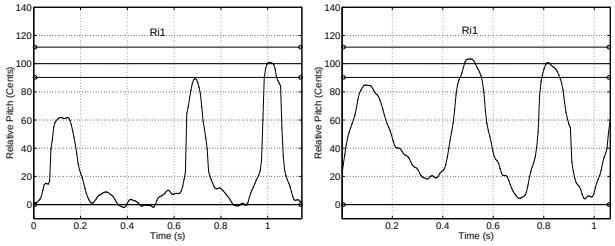

Figure 1: *Lalgudi Jayaraman - Violin - Saaveri - Inflected Ri_1*

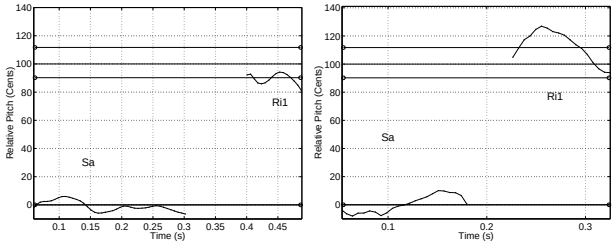

Figure 2: *Lalgudi Jayaraman - Violin - Saaveri - Transient Ri_1*

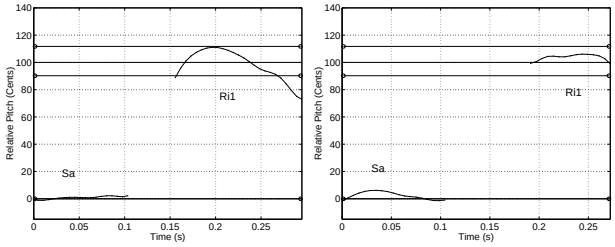

Figure 3: *Lalgudi Jayaraman - Violin - Saaveri - Transient Ri_1*

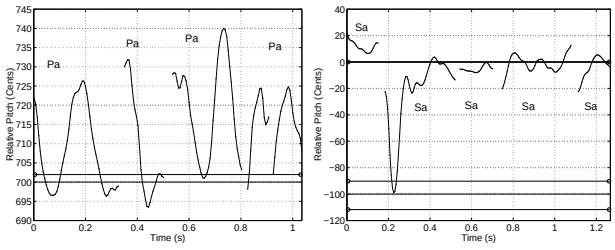

Figure 4: *Lalgudi Jayaraman - Violin - Saaveri*

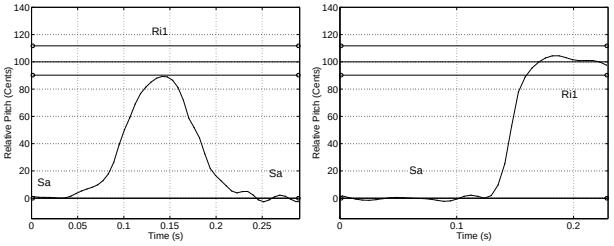

Figure 5: *U. Srinivas - Mandolin - Thodi*

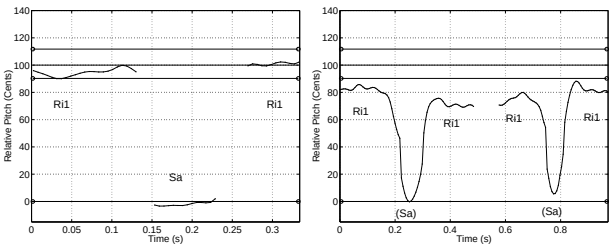

Figure 6: *T.N.Krishnan - Violin - Thodi*

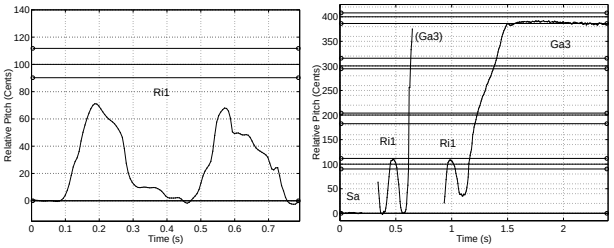

Figure 7: *M.S.Gopalakrishnan - Violin - Malayamaarutham*

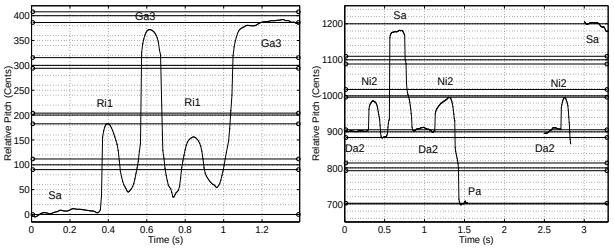

Figure 8: *N.Ramani - Flute - Poorvikalyani (L) & Kamas (R)*

the Ga_3 in Aarabhi certainly always belongs to the transient inflexion category.

Figures 2 and 3 show four transient Ri_1 examples, drawn from a 20 second audio clip of Saaveri. As can be seen, intonation is variable, but precise intonation may be unnecessary especially in such fast passages.

5. THE SAME NOTE IN DIFFERENT RAGAMS

Different versions of the same note may appear in one ragam. For example, in Saaveri, there are various types of an upward-inflected Ri_1 from Sa, there is a constant-pitch Ri_1 played in certain other phrases, and then there is yet another version of Ri_1 which involves an inflexion upward from the constant-pitch version of Ri_1, similar to what is shown in Figure 8. Incidentally, though the base of the Ri_1 inflexions shown in Figure 8 is much lower than 100 cents, this observation simply illustrates the flexibility in intonation discussed before. Based on our musical knowledge and experience, we claim that this is not intended to be a centered vibrato around a constant-pitch Ri_1, as it may appear at first.

Different ragams using Ri_1, like Thodi or Malayamaarutham, also may use many different versions of Ri_1. For example, Figure 5 shows a Sa-based inflected Ri_1 appearing in Thodi and Figure 7 shows the same type of inflexion appearing in Malaya-

maarutham. Figures 5 and 6 contain more examples of Ri_1 appearing in Thodi.

The constant-pitch version of Ri_1 is similar in all ragams using Ri_1, allowing for the ever-present variability in intonation [1]. Similarly, there are common inflected intervals among different ragams as well. Though the tempo or the shape of inflexions may be adjusted by artists to suit different phrases, it is not correct in general to say that a particular inflexion is unique to one ragam alone.

Why do some people feel that the inflected Ri_1 appearing in Saaveri or Gaulai is unique in some sense? The explanation might be that the frequency of occurrence of or the prominence given to such inflexions may be different in various ragams. Furthermore, the overall tempo and phrasing of certain inflexions may also be affected by the ragam. Certain ragams may also require a particular kind of inflexion in a phrase while other ragams may require an alternate inflexion in a similar phrase. There are also ragams which may use only a limited subset of the possible note variations, like Aarabhi employing only the inflected Ga_3.

6. OTHER SOURCES OF CONFUSION

In addition to previously discussed reasons, there may be additional sources of confusion that could lead people to a misunderstanding of the nature of the notes used in Carnatic music. We now discuss some possibilities.

6.1. Current popularity of the 22-sruthi theory

There have been many authors on Indian music theory who have put forth differing ideas [3]. But the most popular theory today seems to be the idea of "22 sruthis" [2]. This theory seems to have "mass appeal" for many reasons. It purports a connection to ancient Indian texts on music, which gives it a certain mystic charm. It also seems to accommodate the different pitch sensations felt when listening to the same note in different phrases and ragams by offering, for 10 of the 12 basic notes, two variations each. Also, a list of 22 rational numbers is both simple to grasp and appears mathematically rigorous at the same time. It would therefore be very difficult to even imagine that such an attractive theory could be invalid, when many people have promoted it with conviction.

6.2. Vocalization of inflexions using one syllable only

When a sound similar to those shown in Figure 1 is sung, only one syllable, "Ri" is used to vocalize it, instead of "Sa - Ri - Sa - Ri - Sa - Ri - Sa." This may perhaps lead an unwary person to believe that a constant-pitch note is being sung which has a lower pitch than the "usual" Ri_1. This phenomenon is probably more pronounced in transient inflexions like the Ga_3 in Aarabhi, where the time-varying pitch inflexion is sung using only the syllable "Ga."

6.3. Unfamiliarity with "small" intervals

Many people may not be aware of how small some interval differences in the "22-sruthi" theory are, compared to the variances in intonation of even top musicians. They may not even know what a 20-cent interval difference sounds like. Even the intonation of Sa and Pa can vary considerably as shown in Figure 4 without causing any distress to listeners. It is clear from the audio that at least the Pa in the left plot is modified intentionally by a vibrato-like ornament. The downward spike in the plot of Sa is due to a "janta" (double note) phrasing and is also intentional.

6.4. Dearth of empirical pitch data and plots

The unfortunate effects of the dearth of empirical data on Indian music can't be overstated. Most people simply haven't been confronted with compelling evidence, that is easily understood or digested, to dispute various incorrect beliefs.

7. PAST, PRESENT AND FUTURE WORK

Jairazbhoy and Stone [4] have done some remarkable, painstaking work, given the nature of pitch tracking equipment then available to them. Though they analyzed North Indian music only, their results and conclusions are similar to what we have observed with respect to Carnatic music. Near the end of his article, Jairazbhoy makes an important point which agrees with our own observations and conclusions: current-day Indian musicians seem to use the term "sruthi" to indicate variations of a note due to pitch inflexions. Levy's work [3] is also noteworthy: the comprehensive review of historical theories is very impressive and points made in various discussions are very insightful. While we believe that these two publications are very significant pieces of work on Indian music thus far, the notable missing elements are: (1) high-resolution, detailed pitch tracks and (2) the explicit categorization and treatment of inflexions separately from constant-pitch notes. Though these authors were obviously aware of the pitch inflexions appearing in Indian music, and even commented on them, their main goal seems to have been to disprove the validity of certain theories. We believe they accomplished this goal successfully. Since none of the theories they were examining dealt directly with pitch inflexions, they certainly weren't obliged to consider them separately either. It was also clear that they didn't intend to provide an alternate, detailed and comprehensive theory of North Indian music.

While Levy suggested that the North Indian music recordings he had analyzed seemed to be based on a flexible system of 12 semitones, we have explicitly stated that Carnatic music uses more than 12 "musical atoms" by elevating certain pitch inflexions to the status of musical intervals. We believe that doing so would eventually lead to a more accurate model of Carnatic music. Finally, though our findings are incompatible with lists of 22 or more numerical interval values like those given in [2], we would point out that such lists do indeed contain some very reasonable values like $3/2$, $4/3$ and $5/4$, but we defer the discussion of such theoretical intervals to a future report.

8. REFERENCES

[1] Krishnaswamy, "Application of pitch tracking to south indian classical music," in *Proc IEEE ICASSP*, 2003.

[2] Sambamurthy, *South Indian Music*, vol. 4, The Indian Music Publishing House, Madras, India, 1982.

[3] Levy, *Intonation in North Indian Music: A Select Comparison of Theories with Contemporary Practice*, Biblia Impex Private Limited, New Delhi, India, 1982.

[4] Jairazbhoy and Stone, "Intonation in present-day north indian classical music," *Bulletin of the School of Oriental and African Studies*, vol. 26, pp. 119–132, 1963.