MULTI-DIMENSIONAL MUSICAL ATOMS IN SOUTH INDIAN CLASSICAL MUSIC

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ABSTRACT

The small-scale melodic units of Carnatic music are not all constant-pitch intervals; certain time-varying pitch inflexions are also considered to be separate and distinct musical intervals. These multi-dimensional (dimensions: pitch and time) entities can be detected extracted and synthesized easily with the signal processing capabilities of today. We describe the nature of these inflected intervals as well as report on our discussions with some top musicians on the subject in this paper.

1. INTRODUCTION

A person with enough exposure to South Indian classical (Carnatic) music would realize that not all of the so-called "microtones" that musicologists have written about over the years are constant-pitch intervals. For example, the musical entity referred to by many as the "eka-sruthi rishabham" which indeed yields a sense of an "in-between" pitch, is always rendered as an upward inflexion from Sa. We presented categorized lists of such inflected intervals in [1] and [2]. We also noted that the following were irrelevant or inapplicable to current-day music: the ancient idea of a "sruthi," the number 22 as far as the number of musical entities used today is concerned and the rational values stated by many authors, without any empirical evidence, for the tuning of the various intervals used in Carnatic music [3, 4, 5, 1, 6, 2].

In this paper, we report briefly on some conversations we had with a few distinguished Carnatic musicians as well as present a few pitch track examples we collected from specialized recordings of these musicians. We also highlight the differences between intonation, tuning and musical entities in addition to describing the nature of certain multi-dimensional melodic entities used in Carnatic music.

2. MUSICIANS' OPINIONS

We had the privilege of meeting with some distinguished musicians during our trip to Chennai (Madras) in January 2004. Some of them further obliged us by agreeing to record certain notes, phrases and ragams some of which are later discussed in this paper. A common question we posed many of the musicians was how many constant-pitch musical intervals were employed in Carnatic music. We also requested them to describe the nature of and sing some of the other inflected intervals.

We noticed that many musicians in Chennai referred us to "Prof. SRJ" when they found out that we were investigating Carnatic music theory; a great number of them indicated that they did not know or care much about theory but were willing to stand by what they actually played or performed.

Carnatic		Western	
Sa	S	P1	C
Ri_1	R_1	m2	$D\flat$
Ri_2 or Ga_1	R_2 or G_1	M2	D or $E\flat\flat$
Ga_2 or Ri_3	G_2 or R_3	m3	$E\flat$ or $D\sharp$
Ga_3	G_3	M3	E
Ma_1	M_1	P4	F
Ma_2	M_2	+4	$F\sharp$
Pa	P	P5	G
Da_1	D_1	m6	$A\flat$
Da_2 or Ni_1	D_2 or N_1	M6	A or $B\flat\flat$
Ni_2 or Da_3	N_2 or D_3	m7	$B\flat$ or $A\sharp$
Ni_3	N_3	M7	B

Table 1: Note Names and symbols used in this article for the twelve basic notes in Carnatic music and their Western equivalents if "C" is chosen as the tonic. There are four pairs of enharmonic notes. There is also an alternate convention for numbering Ga and Ni - using the indices 0,1 and 2 instead of 1,2 and 3 - that is used by many people.

A noted musicologist, Prof. S. R. Janakiraman (SRJ) without hesitation stated that as far as constant-pitch tones were concerned, there were 12 of those in Carnatic music. Though he had embraced the idea of "22 sruthis" for a long time, he was also able to immediately accept our observations when we indicated that we had counted easily more than 22 melodic entities and that our pitch tracks showed that the tuning values many authors had stated [7] were unfounded.

Sri T. K. Govinda Rao, a senior musician also had no hesitation in declaring that there were 12 musical intervals, which he also believed was "universal." These 12 could be sharpened or flattened in certain contexts, but that did not make them new entities he indicated. He agreed, for example, that the "lower" Ri_1 that appeared often in certain ragams like Gaulai was an inflexion based on Sa and "mostly Sa" (meaning that the pitch contour was close to Sa most of the time). He also stated that timing was an important aspect of these pitch inflexions.

Younger artists like Chitraveena N. Ravikiran, Sri Sanjay Subramanium who are also top-notch musicians again referred to 12 constant-pitch intervals and agreed that some of these "other" musical entities that people typically mention appeared in conjunction with inflexions. They also agreed that sometimes these 12 intervals may be slightly sharpened or flatted, but that these other musical entities like the "eka-sruthi rishabham" were distinct and unique.

When we asked musicians like Smt. Kalpagam Swaminathan and Mandolin U. Shrinivas, who have fretted instruments, how they produced the "different" constant-pitch Ri_2-s in Bhairavi, Sri, Kara-

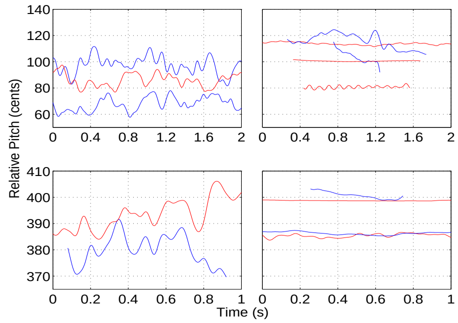

Figure 1: Pitch tracks of various artists rendering the "plain" versions of Ri_1 and Ga_3 (vocalists on the left and instrumentalists on the right).

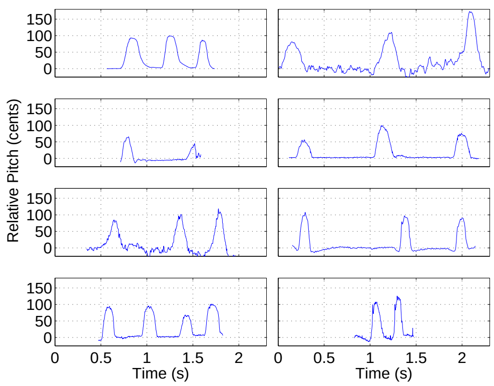

Figure 2: Various artists rendering $S+$ or the "eka-sruthi rishabham." The peaks of the spikes are not really heard, and it is evident that there is no fixed position for these peaks as well. The shape, width and height, all contribute to the perceived pitch in addition to the time between subsequent peaks. This timing is also correlated with the tempo of the larger-scale melody or phrase.

harapriya, Sankarabaranam, Kalyani and other ragams, they were initially confused by the question, as expected. They were obviously not playing any different Ri_2, consciously at least, which agreed with our own observations, and were eventually assuaged when we confessed that we didn't think that there were different types of the constant-pitch Ri_2 either.

We met and recorded many more musicians and also asked them to describe qualitatively what they were singing and how they perceived it, as far as pitch was concerned. We also presented them with synthetically produced Carnatic music for their opinions.

3. INTONATION, TUNING AND MUSICAL ENTITIES

Figure 1 shows two constant-pitch notes, Ri_1 and Ga_3 rendered by some of the musicians we met. As expected, there is a huge variation in the measured intonation of Ri_1. While part of this variation is due to human error or limitations, there are also substantial differences in the preferred tuning of this note by different musicians. This of course was expected and widely accepted; many musicians are aware that for certain notes, like Ri_1, different musicians have different preferred intonations, most of them being equally accept-

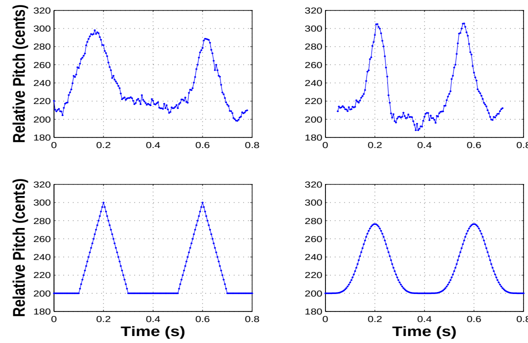

Figure 3: Example of the R_2+ inflexion sung by a leading male vocalist. In the upper left plot, we have an example from the ragam Chintamani where this inflexion is considered to be an alternate version of G_2. In the upper right graph, the segment is drawn from a phrase in the ragam Madhyamavati where this same inflexion is used as an ornamentation of R_2. In the lower left section, we have a synthetic contour that was found to be accurate enough to model or synthesize this inflexion. The lower right plot shows the synthetic contour convolved with a 125ms hanning window, to illustrate what may happen with temporal pitch smoothing.

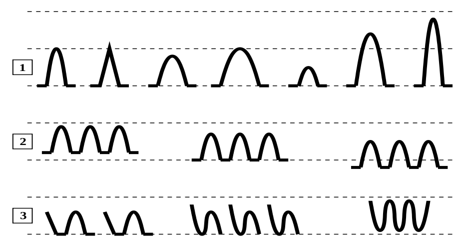

Figure 4: Illustration of some observed (and acceptable) flexibilities in the intonation and phrasing of pitch inflexions.

able. Even the same artist could intonate the same note slightly differently based on context, but may perhaps have certain preferred tunings under particular conditions. However, all of these tracks are of the same musical entity - the "constant-pitch" Ri_1which is what they were asked to and agreed to play.

This figure also shows examples of the constant-pitch Ga_3. Some artists prefer an intonation closer to the rational $5/4$ (386 cents) perhaps because they had trained themselves with acoustic cues such as beats or the harmonics heard from the tambura. Certain other instrumentalists with fretted instruments or flutes were, to a large extent, constrained by or influenced by the "default" intonation of their instrument. In general, however, the instrumentalists we encountered had a more "steady" intonation than the vocalists.

Figure 2 shows several instances of the "eka-sruthi rishabham" rendered by various artists. This inflected interval is characterized by upward spikes anchored below on Sa. As can be seen the width, shape and height of these spikes is highly variable, but are nevertheless considered to be the same musical entity. Though the differences can be heard, they are all still within some acceptable range. These pitch tracks were produced when we asked the musicians to sing "pmgm R;" in the ragam Gaulai or "srgs R;" in the ragam Saveri.

This brings us to an important point: musical entities required to render ragams and phrases should be distinguished from their particular tuning or rendition. The same musical entity may have a large range of acceptable tuning, and each artist may intonate them differently according to their own preferences, for artistic effect or for other reasons. While these differences are noticeable and audible, one should not conclude that different musical entities are being played or that a ragam has many more entities than it actually does. If a particular rendition or intonation of an melodic atom can be substituted with another tuning or intonation, with the result being equally acceptable, one should accept that the variation in intonation observed was artistic preference or even human error too small to make a difference. The human ear seems to be able to adapt easily and be very forgiving at times.

4. PERCEPTUAL EFFECTS

While some of inflected intervals shown in Figure 2 reach pitch values much higher than 100 cents, they all sound distinctly different from and *lower in pitch* than the constant-pitch Ri_1-s. This observation was confirmed with the various artists also.

Figure 3 shows two examples of R_2+. In one case, this inflection is an ornamentation on Ri_2 and in the other case, it is considered as a lower version of Ga_2 [1]. Both of these inflexions can be modeled or synthesized using a pitch contour shown on the bottom left of this figure.

Due to the relatively short time duration of these spikes, the peak pitch of 300 cents is not really heard by human listeners. Though they can hear the upward movement and the time-varying nature of this contour, it is more likely that human listeners hear a smoothed version of this contour, perhaps such as the one shown in the bottom right. In addition, people may sense an overall lower pitch because of the frequent return to Sa. Detailed listening tests and perceptual experiments need to be conducted to investigate such fast, periodic and systematic inflexions.

Now there are several instances where a localized inflexion on one note is considered as an alternate version of an adjacent note. These were documented in [1] and illustrated in Figure 5. Like the R_2+ we discussed previously, G_3+ could both be an ornament on Ga_3 or be considered a lower version of Ma_1. We believe that such localized inflexions are the main source of the belief that alternate versions or shades of various notes exist in Carnatic music [1].

5. TIMING, MORPHING AND MERGING

An important aspect of these pitch inflexions is timing: the time duration of each spike as well as the time between adjacent spikes are crucial to the perceived pitch sensation. The time locations of and separation between various spikes themselves seem to depend strongly on the rhythm and tempo of the larger-scale phrase or melody.

Now, between Sa and Ri_1 we have categorized the localized inflexions into 3 broad categories: $S+$ if the inflexion is anchored on S, R_1- if it is anchored on R_1 and $S * R_1$ if it is neither (Figure 6 and [1]). In doing so, we have been consistent somewhat with the way people have been thinking of these inflexions traditionally. But how sharp is the boundary between $S+$ and $S * R_1$? What if the tempo is fast and the spikes are very close together? Is there always a clear boundary between these two categories? Perhaps not.

In fast phrases, different musical entities or inflected interval categories can merge and be difficult to distinguish from one another. For example, R_1- is sometimes "close" in its appearance and structure to (i) $R_1 : S : R_1$, (ii) $S * R_1$ or (iii) a slide between R_1 and S (definitions of symbols given in [1]). But we have noticed at the same time that usually many of these entities are acceptable in the ragam or phrase. In addition, most phrases in Carnatic music have continuous pitch contours, and musical atoms constantly morph into one another (eg: Figure 8), which makes it hard to segment these entities in time as well. But while it is also possible that some people may insist on more categories of intervals and inflections, whether or not those are required should eventually be answered by psychoacoustic experiments such as those performed by Burns [8] who reported that North Indian musicians were not able to identify more than 12 constant-pitch interval categories.

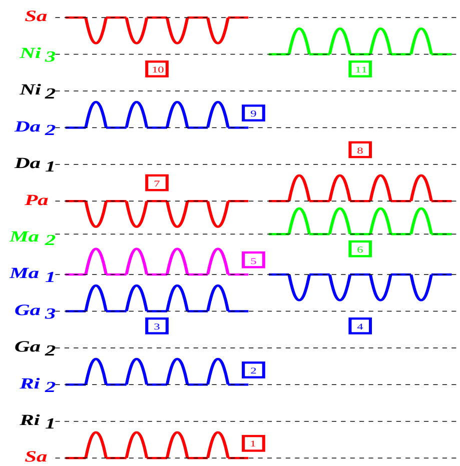

Figure 5: These localized inflexions are sometimes considered to be an alternate version of the adjacent note, and are the primary source of the perception of microtonal or "in-between" intervals in Carnatic music. The inflexions shown in red (1,7,8,10) always assume the adjacent note name. The rest can be both ornamentations as well as "become" the adjacent note. N_3+ and M_2+ are usually ornamentations except in certain fast phrases when they could hint at S and P. M_1+ is also usually an ornamentation except in ragams which employ both M_1 and M_2 in series.

6. CONCLUDING REMARKS

It is possible to have more than 12 melodic entities in an octave even in the presence of highly variable and flexible intonation; the dimension of time is used to produce unique and distinct inflected intervals. In our experience thus far, the dimensions of loudness and spectral shape are not as important as the primary dimensions (of pitch and time in Carnatic music) and may be used by an artist primarily for a personalized or artistic effect. Our efforts at synthesizing Carnatic music artificially using our categorized musical atoms were highly successful, and we hope to begin more detailed listening tests and perceptual experiments in the future.

7. ACKNOWLEDGMENTS

We wish to thank the various artists who took the time and effort to meet and discuss Carnatic music with us during our trip to Chennai in January 2004, including Dr. N. Ramani, Smt. Kalpagam Swaminathan, Sri N. Ravikiran, Sri U. Shrinivas, Sri Sanjay Subramanium, Sri T. M. Krishna and Sri Shashank who were all kind enough to record some audio samples for us. We also thank Prof

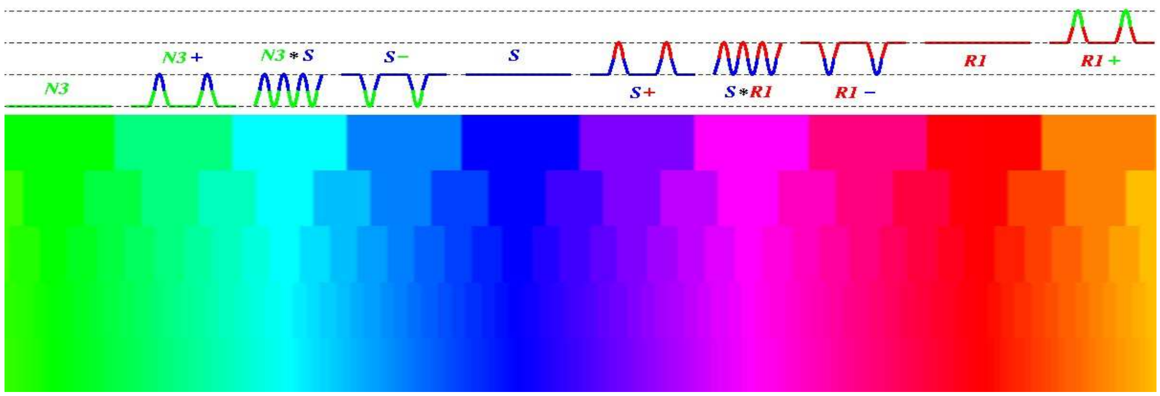

Figure 6: Illustration of various adjacent localized inflexions discussed in [1]. These inflexions may be thought of as mixing adjacent constant-pitch intervals, perhaps like mixing colors. By varying the proportion (time duration) of each color (pitch) one may produce a wide variety of shades of pitch sensations. Despite the infinite or continuous possibilities, we can still pick out and categorize these inflexions consistently to some extent. This is because the "colors" are "mixed" in the fashion shown in Figure 7 rather than above.

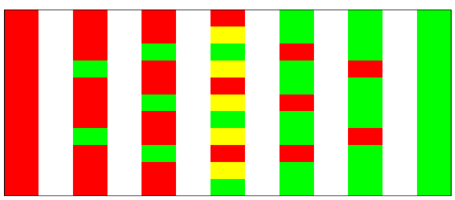

Figure 7: A colorful analog to how an interval may be modified to produce shades of higher or lower pitch. Due to the way the "colors" (pitches) are mixed in space (time), the different categories can easily be distinguished even if the red or green become a shade lighter or darker (sharper or flatter).

S. R. Janakiraman and Sri T. K. Govinda Rao for finding time in their busy schedules to meet with us for discussions. Finally, we acknowledge and thank our guru, Prof. T. N. Krishnan whose instruction we have benefited immensely from, over the years.

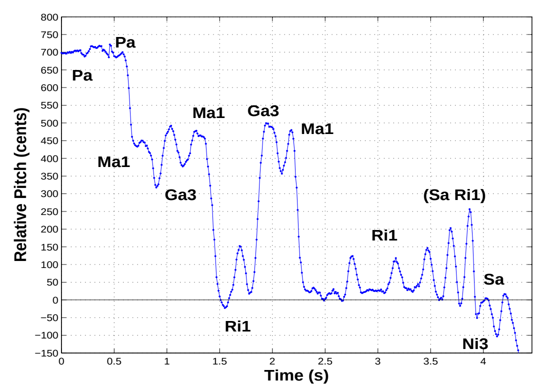

Figure 8: Pitch contour of a leading male vocalist rendering a phrase in the ragam Gaulai.

8. REFERENCES

1. Krishnaswamy, A., "Inflexions and Microtonality in South Indian Classical Music," in Proc of Frontiers of Research on Speech and Music (FRSM), Annamalainagar, India, 2004.
2. Krishnaswamy, A., "Towards Modeling, Computer Analysis and Synthesis of Indian Ragams," in Proc of FRSM, 2004.
3. Krishnaswamy, A., "Application of Pitch Tracking to South Indian Classical Music," in Proc IEEE ICASSP, 2003.
4. Krishnaswamy, A., "Pitch Measurements versus Perception of South Indian Classical Music," in Proc of the Stockholm Music Acoustics Conference (SMAC-03), 2003.
5. Krishnaswamy, A., "On the Twelve Basic Intervals in South Indian Classical Music," in AES 115th Convention, 2003.
6. Krishnaswamy, A., "Results in Music Cognition and Perception and their Application to Indian music," in Proc of FRSM, 2004.
7. Sambamurthy, P., South Indian Music, vol. 4, The Indian Music Publishing House, Madras (Chennai), India, 1982.
8. Burns, E. M., "In search of the Shruti," JASA, vol. 56, no. S26, 1974.

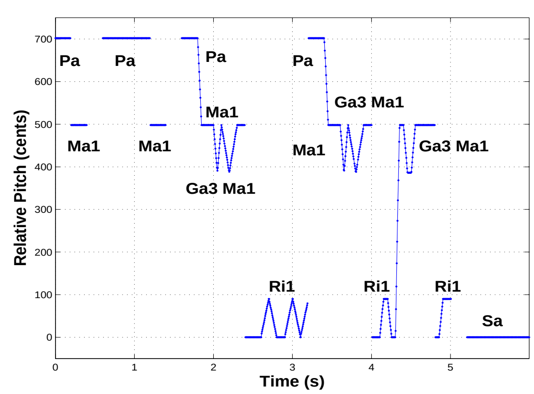

Figure 9: An example pitch contour used to artificially synthesize a phrase from the ragam Gaulai.