Real Time
Raga Detection and Analysis
Using Computer

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DOCTOR OF PHILOSOPHY

under the faculty of Technology

By
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Under the guidance of
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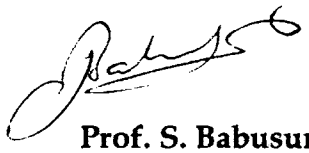
March 2008

CERTIFICATE

Certified that the work presented in this thesis entitled **"Real Time Raga Detection and Analysis Using Computer"** is based on the bona fide research work done by **James K.N.** under my guidance in the Department of Computer Applications, Cochin University of Science and Technology, Cochin 682022, and has not been included in any other thesis submitted previously for the award of any degree.



Cochin-22
March 24, 2008

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DECLARATION

I hereby declare that the present work entitled "**Real Time Raga Detection and Analysis Using Computer**" is based on the original work done by me under the guidance of Dr. S. Babusundar, Department of Computer Applications, Cochin University of Science and Technology, Cochin 682022 and has not been included in any other thesis submitted previously for the award of any degree.

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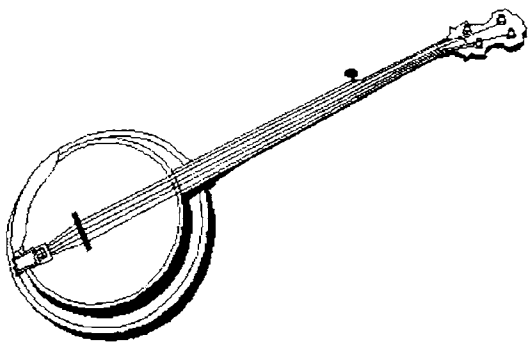


Introduction

"For meaningful appreciation of the nuances of music, the very process of understanding this fine art should be subjected to scientific scrutiny."

Let me begin with a quotation of **Vidya Shankar**, a great Veena artist and musicologist,

> *"For meaningful appreciation of the nuances of music, the very process of understanding this fine art should be subjected to scientific scrutiny."* [1]

This thesis attempts to explain how the "72 Melakartha Ragas" of South Indian Music can be identified and the performance of a musician analysed with the help of a computer. Throughout the work, an objective approach is used to reach the goal. The results are very much interesting and there is enough scope for further study.

1.1 Indian Classical Music

Indian Classical Music can be classified into two, South Indian Classical Music (Carnatic Music) and Hindustani Classical Music [25]. This project deals with the identification of Ragas in Carnatic Music. Carnatic Music is based on melody rather than harmony. The basis of melody lies in the numerous Ragas available in Carnatic Music. Many schemes of Ragas existed in India. In the 17^{th} century, **Venkatamakhin** put forward a scheme of 72 Melakartha Ragas on a scientific basis [2, 3]. These 72 Ragas can generate a number of Janya Ragas, which are derived from the Melakartha Ragas. This scheme is very popular and is widely accepted as a standard.

It takes many years for a student of music to understand and distinguish between different Ragas. Understanding the nature of all Ragas is difficult. It requires continuous and dedicated effort for a very long period to pick up this ability. Moreover, this skill depends very much on the musical sense of a person. When a Raga is sung by a musician, it is appreciated at different levels by different listeners. Some can distinguish a variation of 1 or 2 frequencies, while some others cannot even distinguish differences of 5, 10 or 20 frequencies.

Often the decisions of the judges of a Classical Music competition are controversial. This is because; there is no standard tool with which one can evaluate a Classical Music performance with precision. This is what prompted us to pursue this study and to think of developing an automated system to evaluate musical performance, which would eventually be acceptable to all.

1.2 Initial Studies

Initial study began with the help of Creative Lab's Multimedia card installed in a Multimedia Personal Computer, based on the design of Sound Blaster Card [4]. Analog sound signals were fed to the card through a microphone and the digital sound signals so obtained from the sound card were stored as wave files. With the help of a C language program, the wave file was analysed. From the wave file, header information were identified and isolated. The actual data of the signal was subjected to further analysis. A wave file of 1 minute duration will have a size of 10 MB, approximately. Handling data of this size was a problem at that time. The analysis did not produce anything significant.

Another study conducted was on Musical Instrument Digital Interface (MIDI) files[21]. MIDI files contain information of digitally generated Notes of different instruments. These files were created digitally with the help of a synthesizer, and cannot handle voices. If analog signals can be converted into MIDI

format, then musical Notes can be extracted from it. But no good utility was available to convert the analog sound files into MIDI files. Hence this method was also dropped. Another tool CSound [5] was tried in this study. Csound is a very good programming language for music. But it is found more suitable for production of music than for the analysis of music.

1.3 Fast Fourier Transform

In acoustics, sound is the fluctuations in pressure which exists in the path of a sound wave. Mathematically, sound signals can be represented by Fourier series. The Fast Fourier Transform (FFT) of these signals can effectively break down the sound into pure tones, as recognized by musicians, as a Note of definite pitch. The Fourier transform, in essence, decomposes a waveform or function into sinusoids of different frequency which sum to the original waveform. It identifies the different frequency sinusoids and their respective amplitudes [6].

Matlab (Matrix Laboratory) is a technical computing language and is very useful for the analysis of sound signals [7]. Matlab can be used to perform Fast Fourier Transform on a signal. FFT can convert the raw input signal data received through a sound card, which is measured in volts in the range from +1 to -1, into frequencies and amplitudes. In our study the size of data to be handled is very large. The size of data depends on sample rate and time duration. For a sample rate of 8000/Sec. and duration 10 Sec., the data size will be 80000. Using Matlab it was made possible to sort out the frequency and amplitude components of an analog sound signal. With suitable statistical methods the Notes in a Raga rendered were found out, leading to the identification of the Raga. Graph can be plotted to show different Swara positions used in the rendering. This will give an idea of the Swaras used in the rendering and the deviation from the Raga.

In this project, a program was developed to find the FFT of sound signals. With the help of a computer, sounds generated by male and female subjects were analyzed. This analysis revealed some very interesting facts of male and female voices. Similarly sounds generated by different types of musical instruments were also studied. Integrating all the information obtained from this analysis, a computer algorithm for the identification of Ragas was derived and suitable programs were developed. After initial trial runs, the algorithm and the program had to undergo several modifications before arriving at the final version. This program after many modifications was found to give good results.

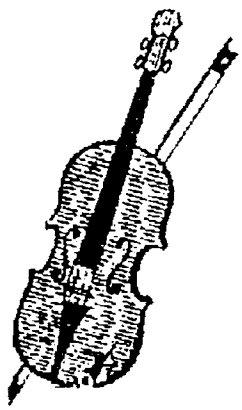
1.4 Raga Identification

When a musician renders a Raga, the sound signals generated are fed to a microphone. These analog signals can be converted into digital format with the help of an analogue to digital converter. The digital signals can be analyzed using the program and the Raga will be displayed on the computer screen. Normally this gives a real time identification of Raga within a period of 2 to 3 minutes. A sound file (.wav) also can be used as an input. After reading and analyzing the file, the Raga will be displayed on the screen. The time required for identification depends on the way in which the musician renders the Raga. This program can be used to identify all the 72 Melakartha Ragas.

The study reveals that popular practices in the rendering of a number of Ragas, clearly deviates from its definition as available in the literature.

The thesis is presented in eight chapters and the list of reference and abbreviations are given at the end.

Chapter 2



Physics of Carnatic Music

Indian Music is based on the Raga system. In Classical Carnatic Music, we have 72 Melakartha Ragas, which are the mother Ragas.

Indian Music is based on the Raga system. In Classical Carnatic Music, we have 72 Melakartha Ragas, which are the mother Ragas. Each of these Ragas can generate a number of Janya Ragas. Mathematically, this system has a potential of producing about 35,000 Ragas. But only about 150 to 200 Ragas are extant in actual practice [8]. The reason for the limited number is that only these Ragas have combinations of Notes which are musical in sound and are capable of creating an artistic air.

When we go through the literature related to acoustics and Carnatic Music, very little is available about the physics of Raga. In Acoustics we come across terms like frequency, amplitude, loudness, pitch, velocity, timbre, quality etc. In Carnatic Music we always come across the terms like Sruti, Swara, Gamaka, and Raga etc.

Musical Sound has three identifying characteristics; loudness, pitch and timbre (or quality). Loudness is power, as it depends on the amplitude or the intensity of the corresponding wave, and is measured in decibels. The pitch of a musical sound is determined mainly by its frequency [9] and is a measure of how "high" or "low" a tone is, and is measured in hertz (Hz). The third identifying feature, timbre, stems from the fact that musical sounds are made up of many different sine waves. Each instrument has a characteristic pattern of sine waves. Timbre (quality) essentially depends on the number, intensity and distribution of the harmonic components of a tone. The Notes of the same pitch from a Guitar, Sitar, Violin and a Flute are entirely different in quality and are instantly

recognizable. We have used a program: **Sruti**, developed by us for studying the performance of musical instruments. The details of **Sruti** are available in later chapters.

The eminent scientist Ohm stated that the ear recognises music only in terms of pure tones, and that it resolves any other complex vibrations into its harmonic components, perceiving them as a summation of pure tones [10]. It means that the ear is capable of converting a complex tone into a Fourier harmonic series of simple tones. This is achieved by the complex structure of Cochlea in the ears.

2.1 Cochlea

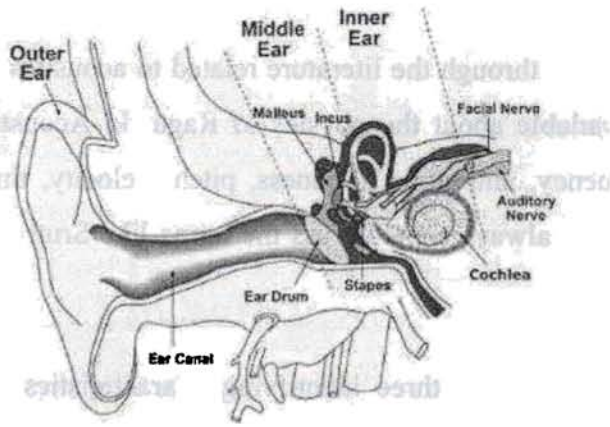


Fig 2.1 Human ear

In our inner ears, the Cochlea enables us to hear subtle differences in the sounds coming to our ears. The Cochlea consists of a spiral of tissue filled with liquid and thousands of tiny hairs which gradually become smaller from the outside of the spiral to the inside. Each hair is connected to a nerve which feeds into the auditory nerve bundle going to the brain. The longer hairs resonate with lower frequency sounds, and the shorter hairs with higher frequencies. Thus the Cochlea serves to

transform the air pressure signal experienced by the ear drum into frequency information which can be interpreted by the brain as tonality and texture.

2.2 Sruti

The frequencies of Notes used in music lie between 30 Hz and 5000 Hz. This frequency range is divided into many octaves. In western music we have the Notes C, C#, D, D#, E, F, F#, G, G#, A, A#, and B [11]. The Frequency of these Notes is fixed. The frequency of the middle octave C4 is 261.63, C#4 is 277.18, etc. The frequency of C5 in the next octave is 2 x 261.63. Sruti ordinarily refers to frequency. It can be said as a group of frequencies with varying amplitudes. But the one with maximum amplitude will represent a Sruti.

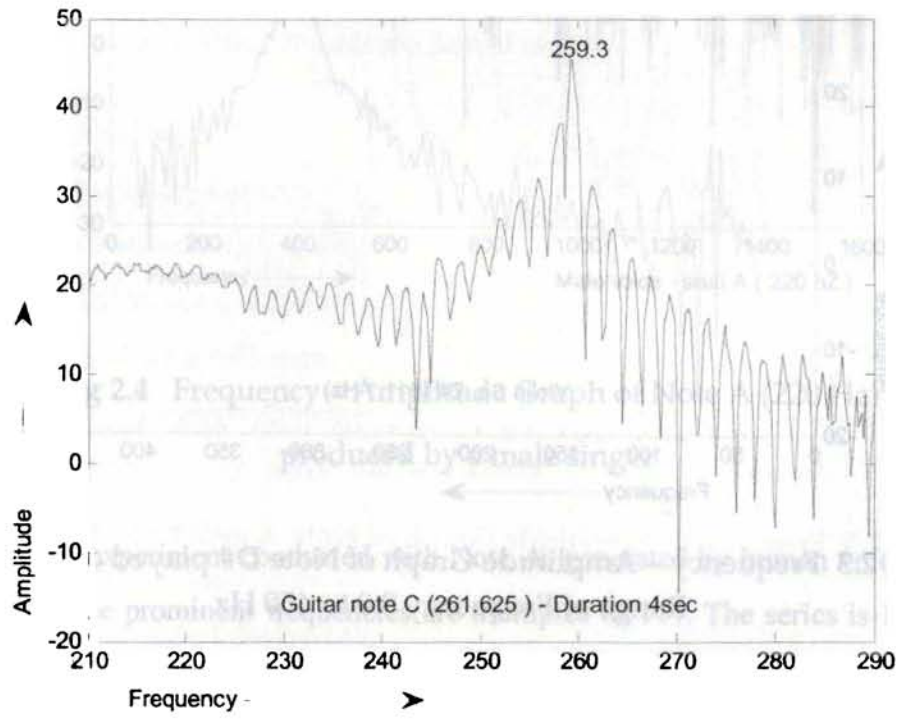


Fig 2.2 Frequency - Amplitude graph of Guitar Note C

The experiments conducted using Guitar and Violin, explain how we can find out the frequency of a Swara with the help of **Sruti**.

Fig 2.2 refers to the C Note produced by the second string of a Guitar. The frequencies generated were found out using the program **Sruti** and a graph was plotted with frequency on the x-axis and amplitude on the y-axis. The frequency corresponding to maximum amplitude was found to be 260, which is the frequency of the C Note (261.625). The error accounts for the lack of fine tuning of the strings of the guitar used. The program is capable of detecting frequency at any level of accuracy, with the appropriate hardware. However, fractions of frequency can be neglected for the purpose of this study.

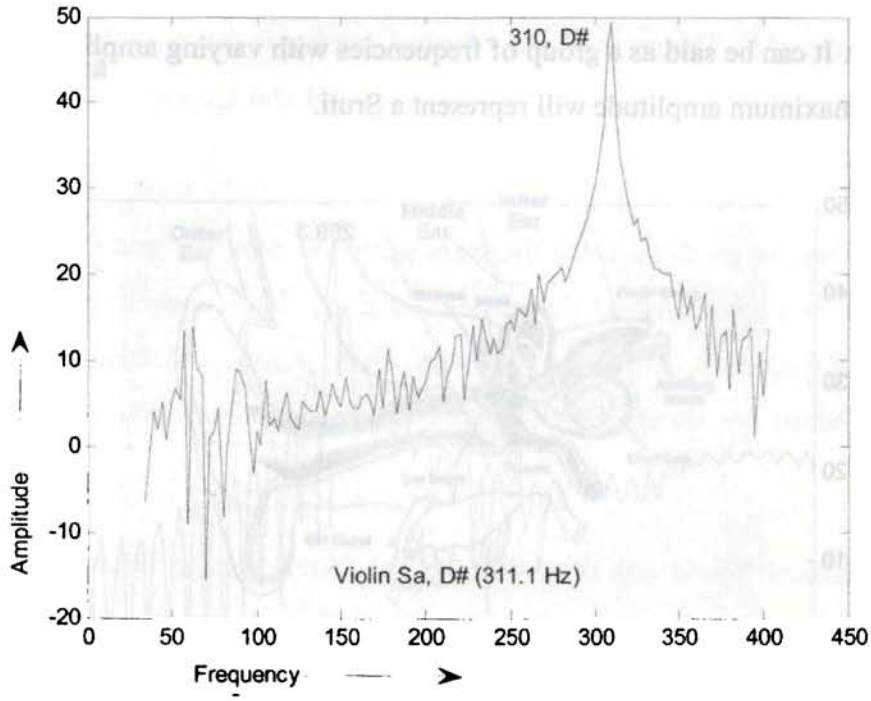


Fig 2.3 Frequency - Amplitude Graph of Note D# played on Violin Range of Frequency 0.0 to 450 Hz

Fig 2.3 shows the D# Note played with Violin was identified almost correctly by the program **Sruti**. The detected value is 310 Hz and the standard value of D# is 311.1 Hz.

2.3 Fundamental frequency and overtones

When a string fixed at both ends is plucked or bowed at the centre, it generates a fundamental frequency and its overtones, which are integral multiples of the fundamental frequency.

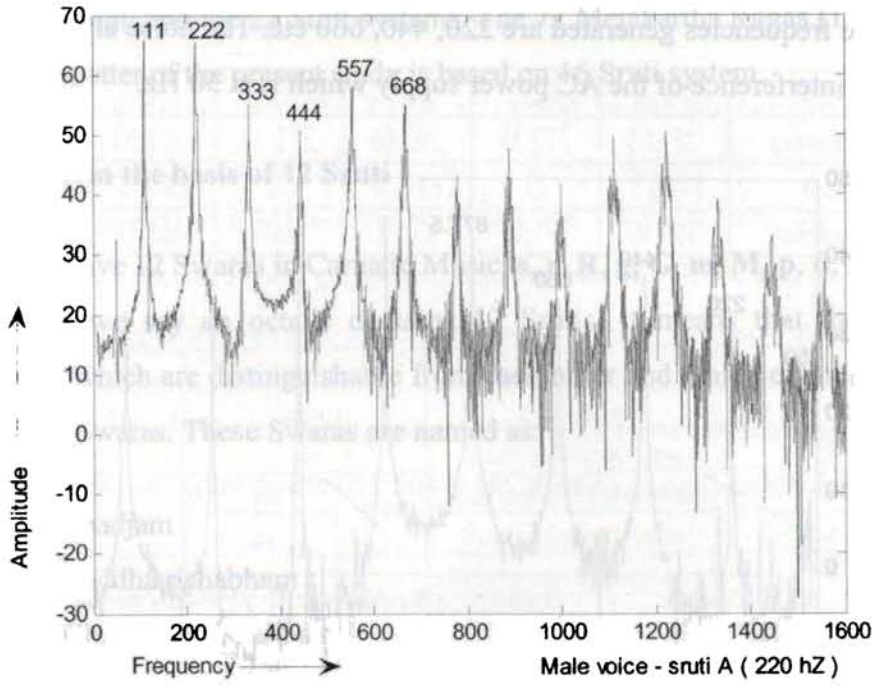


Fig 2.4 Frequency - Amplitude Graph of Note A (220 Hz) produced by a male singer

The experiment conducted with Note **A,** generated by human voice (male) found that the prominent frequencies are multiples of 111. The series is 111, 222, 333, 444 etc. as seen in Fig 2.4. Practically this may not be exactly as estimated. For example the next frequency observed is 557 instead of 555. The slight variation may be because of the limitation of the sample rate. It is also noted that it contains not only the above frequencies, but many other frequencies as well, with less amplitude. The frequency allotted to Note **A**3 is 220. The difference of 2 Hz (222-

220) is only an error in the singing. But when **A** (here 222Hz) is sounded, another lower frequency 111 Hz is also generated, which is the fundamental frequency. But when the same Note **A** is played with Violin on the 2nd string, it doesn't generate a lower frequency of 111 Hz, Fig 2.5. In other words, there is a mismatch in the fundamental frequencies generated by a male vocalist and a Violin in a music concert, even though they are using the same base Sruti **A.** In the case of the Violin, the frequencies generated are 220, 440, 660 etc. The noise at 50 Hz may be due to the interference of the AC power supply which is at 50 Hz.

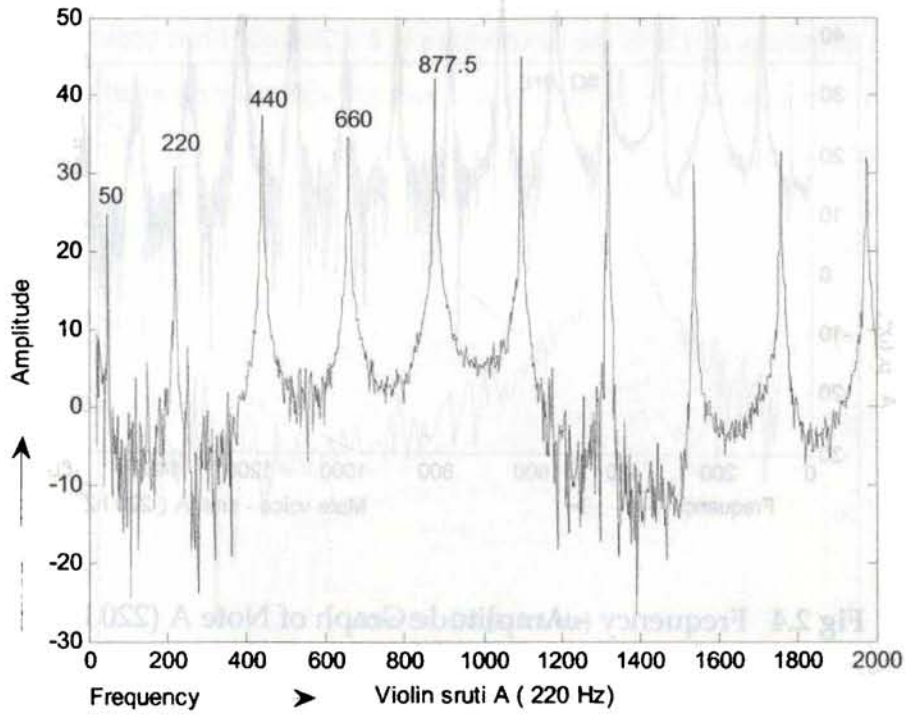


Fig.2.5 Frequency- Amplitude Graph of Note **A** generated by Violin

Now consider the octave starting from 220 to 440. Since Note A is the Sruti, when the vocalist sings **sa**, frequencies 220, 330 and 440 will be present, where 220 is **sa**, 330 is **pa** and 440 is the top **Sa** (thara shadjam). For each Swara sung by the vocalist, its **pa** is automatically generated. For **sa, pa** is generated, for **ri, da** and for **ga, ni** etc. But Violin generates only **sa** (220) and top **Sa** (440) in this

octave. Notes played by Violin don't generate **pa, da, ni** etc. corresponding to **sa, ri, ga** in this range.

2.4 Sruti systems

In Carnatic Music, three types of Sruti systems are discussed. They are the 12 Sruti, 16 Sruti and the 22 Sruti systems. The 72 Melakartha Ragas [12] which is the subject matter of the present study is based on 16 Sruti system.

2.4.1 Ragas on the basis of 12 Sruti

We have 12 Swaras in Carnatic Music, **s**, **r**, **R**, **g**, **G**, **m**, **M**, **p**, **d**, **D**, **n** and **N** [13]. When we say an octave contains 12 Srutis, it means that there are 12 frequencies which are distinguishable from each other and which can represent the 12 Srutis or Swaras. These Swaras are named as:

1. Shadjam
2. Suddha rishabham
3. Chatusruti rishabham
4. Sadharana gandharam
5. Anthara gandharam
6. Suddha madhyamam
7. Prathi madhyamam
8. Panchamam
9. Suddha dhaivatham
10. Chathusruti dhaivatham
11. Kaishiki nishadam
12. Kakali nishadam

Here the frequency assigned to each Swara is not fixed, but is relative. The frequency of all Swaras depends on the frequency of the basic Swara **sa**, and other

Swaras have a fixed ratio with **sa**. That is, we have 12 Swaras having 12 different frequencies depending on the frequency of **sa**. In Western Music we have 12 Notes C Db D Eb E F F# G Ab A Bb B . The notation 'b' is spelled as 'flat'. frequencies of the western Notes are fixed. They are equally divided in an octave [14]. The middle octave frequencies are shown in table 2.1. The frequency of C is 261.63 and that of other Notes are given by C * $2^{\wedge (n/12)}$, n=1,2,3,...11.

Note	C	C#/D b	D	D #/E b	E	F
Frequency	261.63	277.18	293.66	311.13	329.63	349.23
Note	F#/G b	G	G #/A b	A	A#/B b	B
Frequency	369.99	391.99	415.3	440	466.16	493.88

Table 2.1 Western Music Notes and their corresponding frequencies

The frequency ratio of 12 Swaras in Carnatic Music [15] and the frequencies of Swaras corresponding to **sa** with 261.6 and 220 are given in the table 2.2 below:

Swara	Ratio	Frequency1	Frequency2
s	1	220	261.6
r	16/15	234.70	279.1
R	9/8	247.5	294.3
g	6/5	264	314.0
G	5/4	275	327.0
m	4/3	293.3	348.8
M	45/32	312.9	372.1
p	3/2	330	392.5
d	8/5	352	418.6
D	27/16	371.3	441.5
n	9/5	396	470.9
N	15/8	412.5	490.1

Table 2.2 Carnatic Music Swaras, their frequency ratios & frequency

We can see that there are two **ri** (**r** and **R**), two **ga** (**g** and **G**), two **ma** (**m** and **M**), two **dha** (**d** and **D**) and two **ni** (**n** and **N**). To form a Raga, we take only one Swara each from the pair. That is from the 12 Srutis we choose 7 Swaras (saptha Swaras) and we name it **sa, ri, ga, ma, pa, dha, ni**. From the above we get 32 combinations and 32 Ragas.

2.4.2 Ragas on the basis of 16 Sruti

Venkatamakhin classified Ragas according to the Melakartha scheme. In this scheme there are 72 Melakartha Ragas. Each Melakartha Raga is given a Melakartha number. In a Melakartha Raga we use 7 Swaras from the available16 Swara positions, **sa, ra, ri, ru, ga, gi, gu, ma, mi, pa, da, di, du, na, ni, nu** [16].

Semitone step	Swara name		Technical name	Swara positions
1	sa		Shadjam	1
2	ra		Sudha Rishabham	2
3	ri	OR	Chathusruti Rishabham	3
	ga		Sudha Gandharam	4
4	ru	OR	Shadsruti Rishabham	5
	gi		Sadharana Gandharam	6
5	gu		Anthara Gandharam	7
6	ma		Sudha Madhyamam	8
7	mi		Prathi Madhyamam	9
8	pa		Panchamam	10
9	dha		Sudha Dhaivatam	11
10	dhi	OR	Chathusruti Dhaivatam	12
	na		Sudha Nishadam	13
11	dhu		Shadsruti Dhaivatam	14
	ni	OR	Kaisiki Nishadam	15
12	nu		Kakali Nishadam	16

Table 2.3 16 Srutis of Carnatic Music and their Swara names

Here Swaras **sa** and **pa** are one each only. Swara **Ma** has two positions, **ma** and **mi**. But **Ri**, **Ga**, **Dha** and **Ni** have three positions each. The frequency of **ri**

and **ga** are the same. Frequency of **ru** and **gi** are the same. Frequency of **di** and **na** are the same. Similarly frequency of **du** and **ni** are the same. Considering the above fact, we have only 12 frequencies available for 16 Swara positions. We name these 12 frequencies as **s**, **r**, **R** (ri or ga), **g**,**G** (ru or gi), **m**, **M**, **p**, **d**, **D** (di or na), **n** (du or ni), and **N**. The frequency of **s** can be chosen according to the convenience of the singer. The other frequencies depend on **s**. The different Swara names and their technical names on the basis of sixteen Srutis are given in Table 2.3

2.4.3 Ragas on the basis of 22 Sruti

No	Name of the sruti	Sym-bol	Sruti ratio	Raga which uses the sruti
1	Shadjam	sa	1	All
2	Ekasruti Rishabham	r1	256/243	Gaula
3	Dvisruti Rishabham	r2	16/15	Mayamalava Gaula
4	Trisruti Rishabham	r3	10/9	Bhairavi
5	Chatusruti Rishabham	r4	9/8	Sankarabharana
6	Sudda Gandharam	g1	32/27	Bhairavi
7	Sadharana Gandharam	g2	6/5	Kharaharapriya
8	Antara Gandharam	g3	5/4	Sankarabharana
9	Chyuta Madhyama Gandharam	g4	81/64	Devagandhari
10	Suddha Madhyama	m1	4/3	Kunthalavarali
11	Tivra suddha Madhyamam	m2	27/20	Begada, Gaulipanthu
12	Prati Madhyamam	m3	45/32	Kalyani
13	Chyuta Panchama Madhyama	m4	64/45	Varaali
14	Panchamam	pa	3/2	All
15	Ekasruti Dhaivatam	d1	128/81	Saaveri
16	Dvisruti Dhaivatam	d2	8/5	Mayamalavagaula
17	Trisruti Dhaivatam	d3	5/3	Kamboji
18	Chatusruti Dhaivatam	d4	27/16	Kalyani
19	Suddha Nishadam	n1	16/9	Bhairavi
20	Kaishiki Nishadam	n2	9/5	Kharaharapriya
21	Kakali Nishadam	n3	15/8	Sankarabharana
22	Chyuta Shadja Nishadam	n4	243/128	Kuranji

Table 2.4 Names of the 22 Srutis of the Carnatic Music & freq. ratios

Carnatic Music uses micro tones. It is the use of micro tones that give a peculiar charm to the Ragas. In the 22 Sruti system, each Swara ri, **ga, ma, dha** and **ni** has four Srutis. **sa** and **pa** has only one Sruti, to a total of 22. We can arrive at these Srutis, by taking the cycles of fourth and fifths in progression. In the cycle of fifths, the frequency of **sa** is multiplied with 3/2 giving **pa**. Again when **pa** is multiplied with 3/2 we get **ri** (chathur sruti rishabham) of the next octave. In the cycle of fourths, the frequency of **sa** is multiplied with 4/3 giving sudha madhyama ma. When ma is multiplied with 4/3, we get suddha nishada. We can repeat this cyclic operation to get the other Swaras in the 22 Sruti. The names of the 22 Sruti and their frequency ratio are given in the table 2.4. This method of finding the 22 Srutis was put forward by Bharatha [17].

Another method of generating 22 Srutis and its frequencies are explained in The mystic citadel of 22 Srutis music [18]. But the present day teachings are based on Bharatha's theory.

2.5 Gamaka

Gamaka shakes the Notes (Swaras) resulting in a musical effect. The individual shade and colour of a Raga becomes clear only with the proper usage of the Gamakas. Gamaka plays a vital part in Indian Music, and they determine the melodic part of a Raga. It has been classified mainly into ten [19].

Dr. P.T. Chelladurai, speaks about Dasavidha (ten) Gamakas in his book, "The Splendour of South Indian Music" [20], as follows:

1. Arohana Gamaka: This is employed when we sing or play a Raga in the ascending order properly. Eg. **s r g m p d n S**.
2. Avarohana Gamaka: This occurs when we sing in the descending order. Eg. **S n d p m g r s**

3. Ahatha Gamaka: This is noticed when we sing the musical phrases like **sr rg gm mp pd dn nS**.
4. Pratyahatha Gamaka: The same as the above, but in the descending order. Eg **Sn nd dp pm mg gr rs**
5. Sphuritha Gamaka: This occurs when we sing Janta varisa like **ss rr gg mm pp dd nn SS**.
6. Tripucha Gamaka: This is obtained when we sing the Swaras in triplets. Eg. **sss rrr ggg mmm** etc.
7. Dhalu Gamaka: This is produced when a person starting on a basic Swara reaches the higher Swara in conformity with the Raga bhavam. Eg. **ss sg sm sp** etc.
8. Andolitha Gamaka: When played Swaras in the following manner – **srs dd, srs pp, srs mm**
9. Kampitha Gamaka: This is produced when we lengthen the duration of the Swaras and sing them with stress like in **s r g m** in Hanumathodi Raga.
10. Murchchanai Gamaka: Start on shadjam, proceed regularly in the Arohana Kramam and finish on the Dirgha Nishadam; then start on Rishabham and finish on Dirgha Nishadam and so on. Eg. **s r g m p d n – r g m p d n S.**

By applying Gamaka to a Swara, the Sruti position of the Swara changes momentarily. The frequency may go up or down. It depends on what type of Gamaka has been used. But whatever be the type of Gamaka, the actual frequency of the Swara will be the one having maximum amplitude within a range. It is found that after applying Gamaka, the identified Swara using the program **Sruti** is the same as the original Swara in almost all the cases except in the case of Kampitha Gamaka. This can be seen from the figures - Fig 2.6 to 2.15 given below. The various Gamakas were played on a Violin and was tested using **Sruti.m**

Figure 2.6 given below shows the frequency detected when Arohana Gamaka is played. Swaras **sa**, **ri**, **ga**, **ma**, **pa**, **da** and **ni** of Sankarabharana Raga, with base Sruti C# (280 Hz) are played in the ascending order with Gamaka. The frequency of Swara **ga** was measured using the program. The measured frequency is 352 Hz. The calculated value of **ga** is 350 Hz. and will be identified as **ga**.

Fig 2.7 shows the frequency detected when avarohana Gamaka is played. Swara tested is tara shadjam **Sa**. The calculated frequency is 560 Hz and the measured frequency is 564 Hz. Swara detected will be **Sa**.

For testing Ahata Gamaka, phrases like **sr rg gm mp pd dn nS** in Sankarabharana Raga were tested. The Swara detected was any one in the Sankarabharana Raga. In the test it is **Ri**, Fig 2.8. In Pratyahata Gamaka also a Swara of Sankarabharana was detected.

In Sphuritha Gamaka phrases like **ss rr gg mm pp dd nn SS** were tested. When frequency of **rr** was measured, it was found to be 314 Hz, while the calculated value was 315 Hz.. See Fig 2.9.

In Tripucha Gamaka, phrases like **sss rrr ggg mmm ppp ddd nnn SSS** were used. Gamaka in **Ni** was tested and the experimental value found was 530 Hz which was identified as **Ni** of Sankarabharana Raga. See Fig 2.10.

In Dhalu Gamaka, phrases like **sS**, **sg**, **sm** and **sp** were tested. When **sp** was tested for detection, frequency measured was 420 Hz which is **pa** while the calculated frequency is 418 Hz. See Fig 2.11.

Andolitha Gamaka uses phrases like **srsmm**, **srspp** and **srsdd**. When the phrase **srsmm** was tested, the detected frequency was 374Hz, while the calculated was 373 Hz, which is **ma** of Sankarabharana Raga. See Fig 2.12.

Kampitha Gamaka uses phrases like **s r g m** played as in Hanumathodi (Thodi) Raga. For testing, Thodi Raga in popular form was played on a Violin. This Gamaka is seen in **ga** and **ni** of Thodi Raga. First the Gamaka in **ga** was tested. The expected frequency was 336 Hz (**ga**), but the detected was 294 Hz (**ri**), fig 2.13. Similarly the Kampitha Gamaka was tested for Swara **ni**. The expected frequency was 504 Hz (**ni**), but the detected was 440 Hz (**da**), fig 2.14.

In Murchchanai Gamaka, phrases like **s r g m p d n – r g m p d n S** etc. are used. When s **r g m p d n** phrase of Sankarabharana Raga was used for testing, and for five repetitions, frequencies 416 Hz, 538 Hz, 416 Hz, 278 Hz and 314 Hz were obtained. These are the Swaras **pa**, **ni**, **pa**, **sa** and **ri** of Sankarabharana Raga. That is in all cases the Swara detected was one of the Swaras of Sankarabharana Raga. Figure 2.15 shows the result of the last testing, where **ri** was obtained.

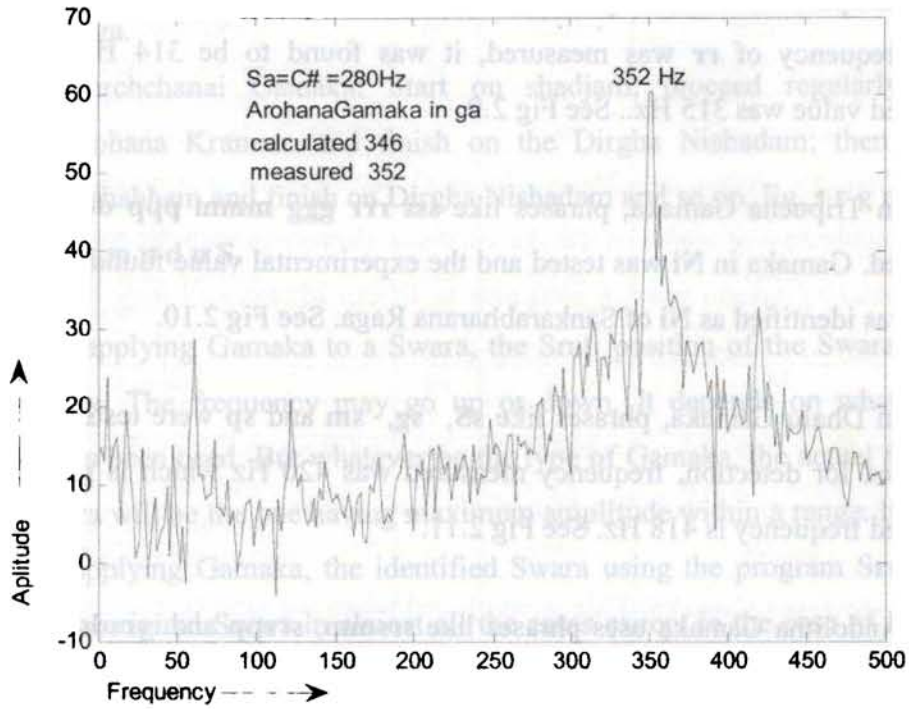


Fig 2.6 Frequency – Amplitude Graph of Swara **ga** after applying Arohana Gamaka

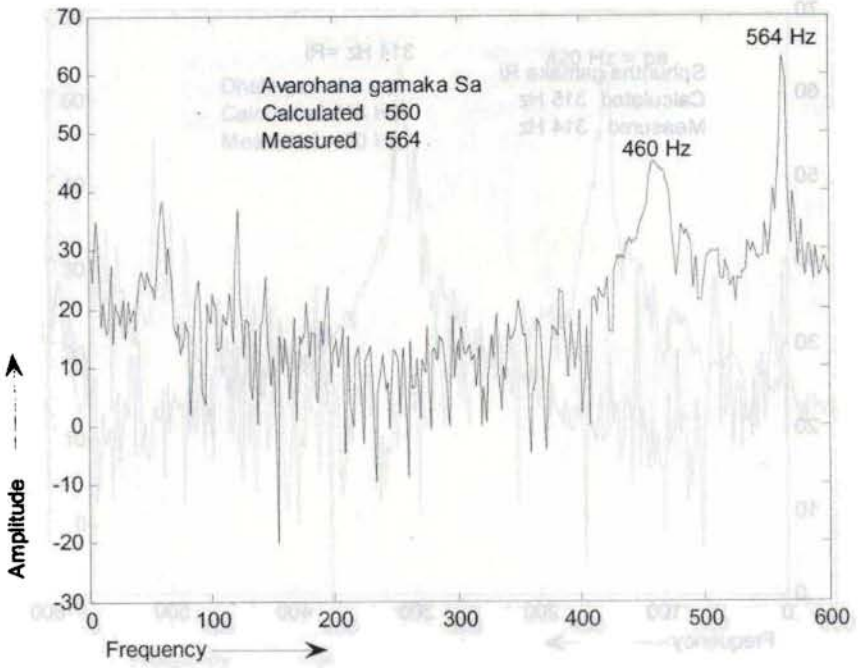


Fig 2.7 Graph shows Avarohana Gamaka

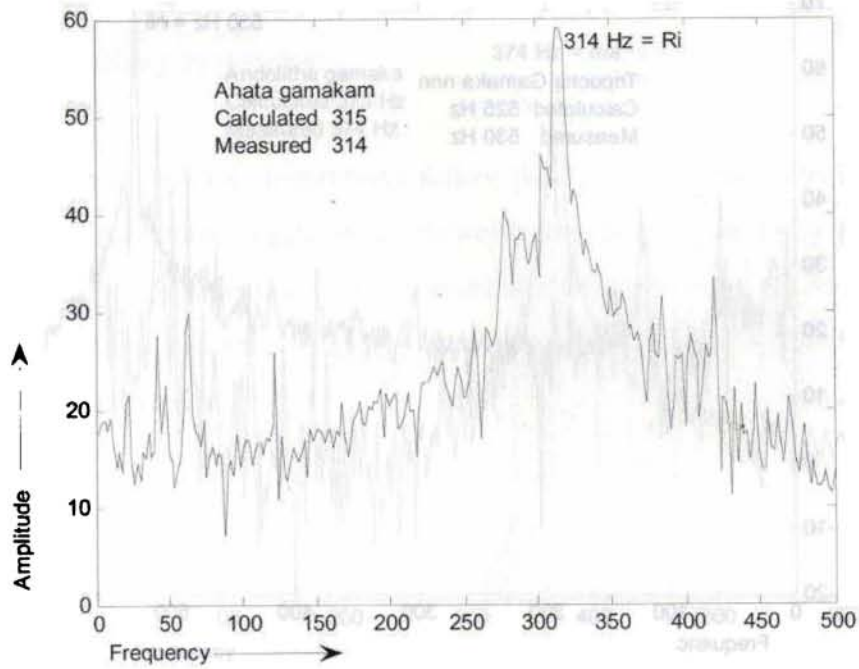


Fig 2.8 Graph shows Ahata Gamaka

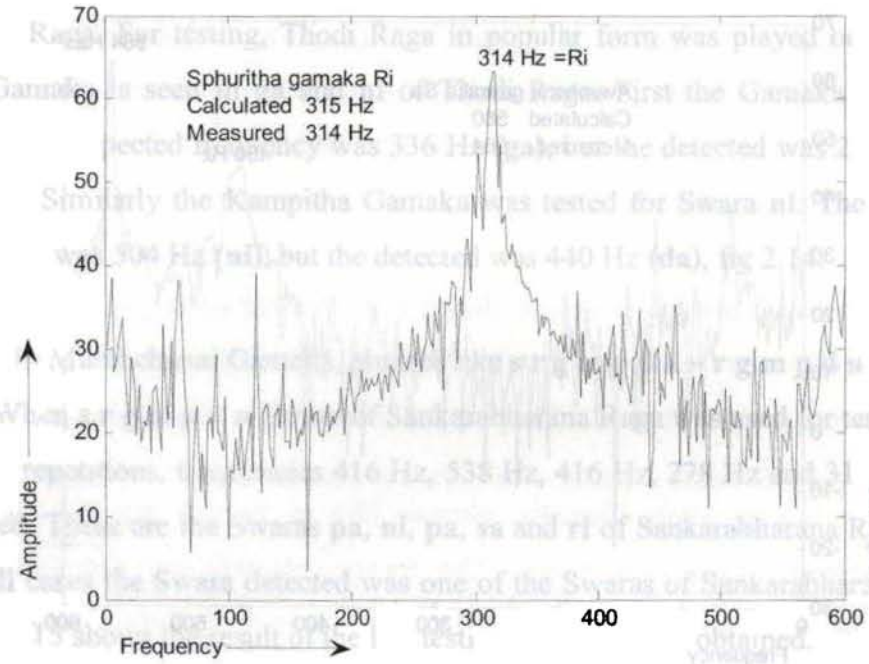


Fig 2.9 Graph shows Sphuritha Gamaka

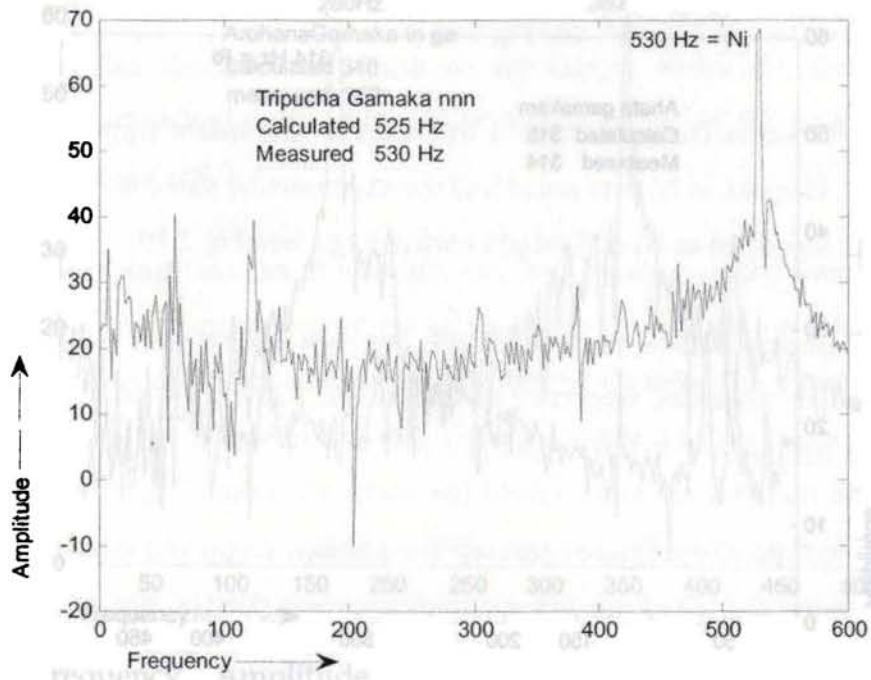


Fig 2.10 Graph showing Tripucha Gamaka

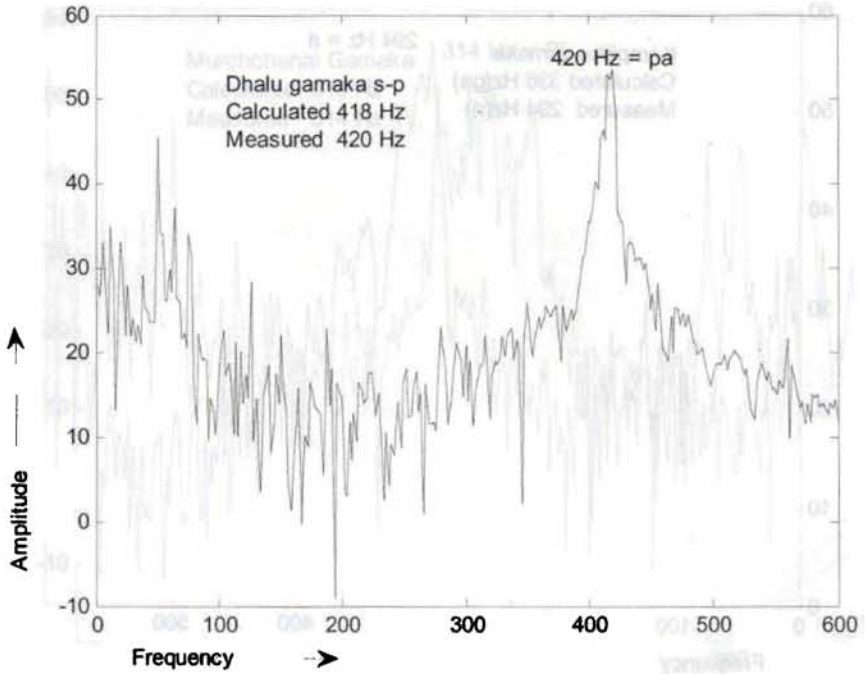


Fig 2.11 Graph showing Dhalu Gamaka

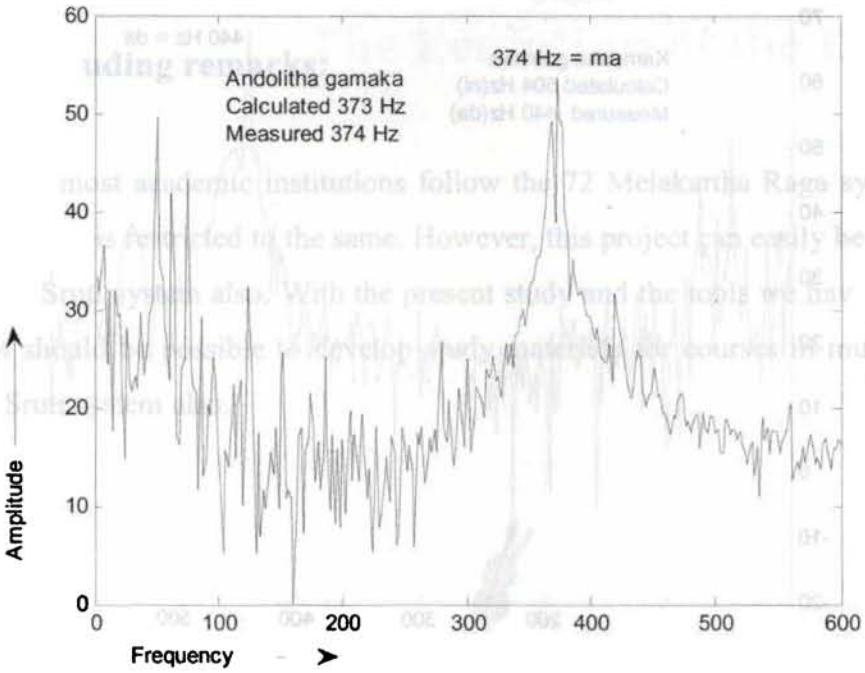


Fig 2.12 Graph shows Andolitha Gamaka

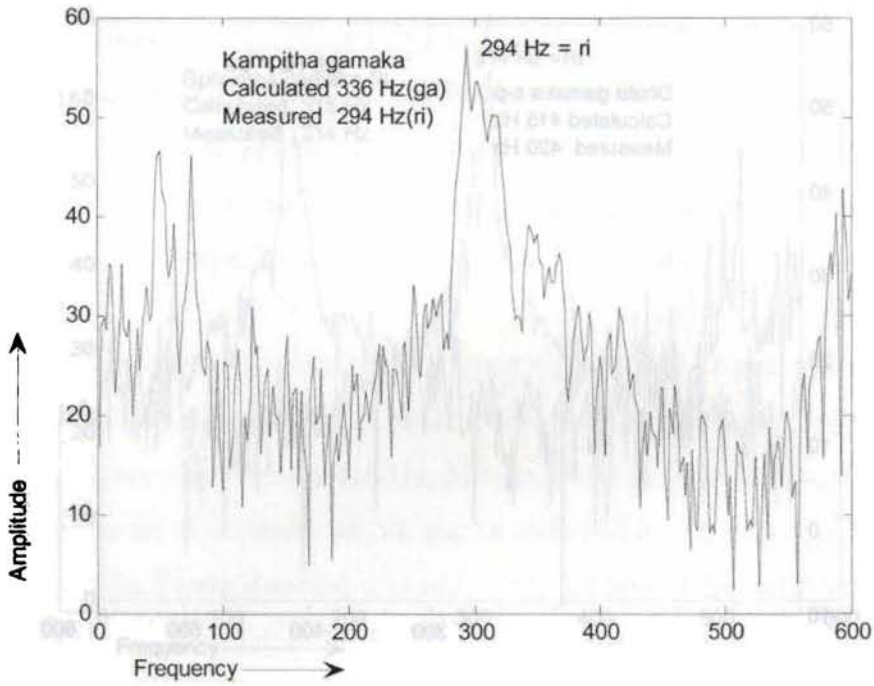


Fig 2.13 Graph shows Kampitha Gamaka applied to Swara **ga**

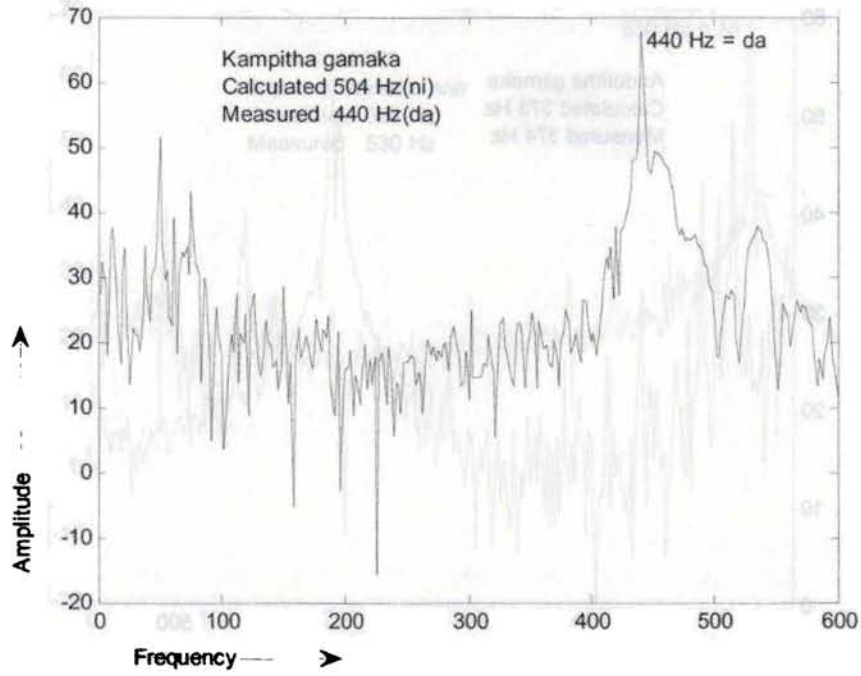


Fig 2.14 Graph shows Kampitha Gamaka applied to Swara **ni**

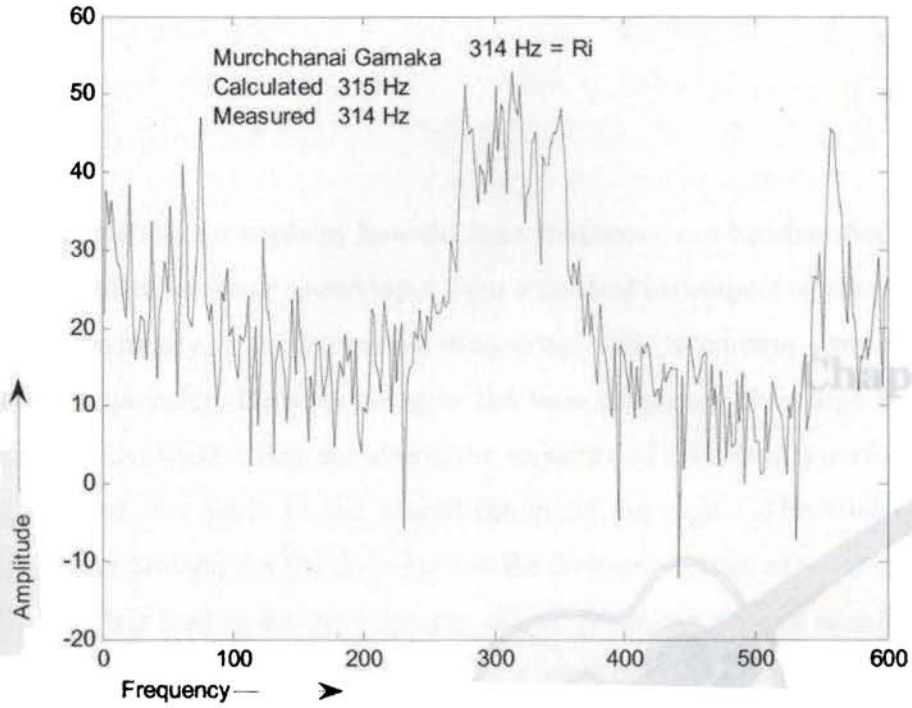
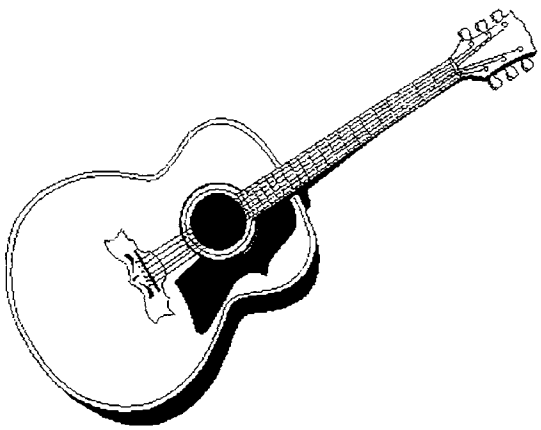


Fig 2.15 Graph explains Murchanai Gamaka

2.6 Concluding remarks:

As most academic institutions follow the 72 Melakartha Raga system, the present study is restricted to the same. However, this project can easily be extended to the 22 Sruti system also. With the present study and the tools we have come up with, it should be possible to develop study materials for courses in music under the 22 Sruti system also.

Chapter 3



The Evolution of the Design

This chapter explains how the base frequency can be identified from the voice input of an artiste or sound input from a musical instrument.

This chapter explains how the base frequency can be identified from the voice input of an artiste or sound input from a musical instrument of short duration. The base frequency is the prominent frequency, with maximum amplitude, in a group of frequencies. Corresponding to the base frequency the range of various Swaras are calculated. Using the above, the sequence of Swaras in a performance is identified and this leads to the identification of the raga. The study of base frequency has brought out the difference in the frequency range of male and female artiste. This has lead to the development of two programs namely **mrag** and **frag** for the study of male and female voice. As a byproduct the above study helped in the classification of musical instruments into two: male and female musical instruments. **Sruti** is another program developed for study of frequencies corresponding to voice/sound inputs. Using **Sruti** we can identify the frequency and classify the source as male or female. **Sruti** can also be used for benchmarking the quality of musical instruments.

3.1 Identification of Raga

To identify the Raga, the first thing to be done is to find out the base Sruti (**sa**) with which the artist sings or plays an instrument. The program asks for the base Sruti. The artiste inputs the base Sruti as, a, A, b, c, C etc. These notations are used for the simplicity in programming. Western Musical Notes A, A#, B etc. having fixed frequencies and the corresponding notations used in the program are given in table 3.1. MIDI in the table 3.1 is the MIDI number allotted to different Notes in all the octaves, here only two octaves are given. The program verifies the

base Sruti, taking inputs from the performance and makes finer adjustments, if necessary.

There can be slight variation in Sruti while singing, due to the lack of expertise of the singer or due to a variation in the frequency of the Sruti Box itself. After scanning the input through the microphone, the program will determine the actual base Sruti in which the artiste sings or plays an instrument. Thus the exact frequency of the base Sruti played is found out. The observed range of the frequency corresponding to different notes is given in table 3.2.

Western Notes	Notation used in program	MIDI	Frequency	MIDI	Frequency
C	c	48	130.81	60	261.63
C# or D♭	C	49	138.59	61	277.18
D	d	50	146.83	62	293.66
D# or E♭	D	51	155.56	63	311.13
E	e	52	164.81	64	329.63
F	f	53	174.61	65	349.23
F# or G♭	F	54	185.00	66	369.99
G	g	55	196.00	67	392.00
G# or A♭	G	56	207.65	68	415.30
A	a	57	220.00	69	440.00
A# or B♭	A	58	233.08	70	466.16
B	b	59	246.94	71	493.88

Table 3.1 Western Musical Notes and the corresponding notation used in the program developed

a	215.5 - 226.5	d	285.4 - 302.3	g	381.0 - 403.5
A	226.6 - 239.9	D	302.4 - 320.3	G	403.6 - 427.5
b	240.0 - 252.5	e	320.4 - 339.3		
c	252.6 - 269.5	f	339.4 - 359.4		
C	269.6 - 285.3	F	359.5 - 380.9		

Table 3.2 Range of frequency assigned to different notes

With the help of the base Sruti (**sa**), the frequencies and permissible ranges of the other Swaras are calculated. For example, if the frequency of **sa** is 220Hz, the ranges of the other Swaras will be as shown in table 3.3, below. This table is temporarily prepared for base Sruti while the performance of an artiste is being analysed by the program.

Swara	Frequency	Range
s	220	213.2 to 227.2
r	234.7	227.3 to 241.0
R	247.5	241.1 to 255.7
g	264	255.8 to 269.5
G	275	269.6 to 284.1
m	293.3	284.2 to 303.1
M	312.9	303.2 to 321.4
p	330	321.5 to 341.0
d	352	341.1 to 361.6
D	371.3	361.7 to 383.6
n	396	383.7 to 404.2
N	412.5	404.3 to 426.2

Table 3.3 Range allotted temporarily for Swara sequence with sa equal to 220 Hz

From the input of the performance, the prominent frequencies of **s**, **r**, **R**, **g**, **G**, **m**, **M**, **p**, **d**, **D**, **n** and **N** are identified. Since there can be only one **ri** either **r** or **R**, and one **ga** either **g** or **G**, etc., in a Melakartha Raga, we have to choose one **ri** from **r** and **R** etc. This is achieved by considering the number of appearances of **r** and **R** in a specific period of time. The prominent frequencies are those with greater amplitude. The one with greater number of appearances among the prominent frequencies will be identified as the Swara in that position. Continuing

this process we can determine the sequence of 7 Swaras in the performance. The Swaras-sequence thus obtained is compared with those of the 72 Melakartha Ragas as given in table 3.4, to identify the Raga. For example, if the Swaras identified are **srGmpdN**, the corresponding Raga is Mela number 15: Mayamalavagaula. This procedure holds good only for the Melakartha Ragas which are based on the 12 Sruti system. However there are many Melakartha Ragas which can be explained only by the 16 Sruti system as discussed in Chapter 2 (2.4.2). The programs developed by us have taken care of these situations. The programs are capable of analysing all the 72 Melakartha Ragas.

The 72 Melakartha Ragas and their corresponding Swara-sequences are given below in table 3.4.

Mela No.	Ragam	Swaras
1	Kanakangi	srRmpdD
2	Ratnangi	srRmpdn
3	Ganamurti	srRmpdN
4	Vanaspati	srRmpDn
5	Manavati	srRmpDN
6	Thanarupi	srRmpnN
7	Senavati	srgmpdD
8	Hanumathodi	srgmpdn
9	Dhenuka	srgmpdN
10	Natakapriya	srgmpDn
11	Kokilapriya	srgmpDN
12	Rupavathi	srgmpnN
13	Gayakapriya	srGmpdD
14	Vakulabharanam	srGmpdn
15	Mayamalavagaula	srGmpdN
16	Chakravakam	srGmpDn

17	Suryakantham	srGmpDN
18	Hatakambari	srGmpnN
19	Jhankaradhwani	sRgmpdD
20	Natabhairavi	sRgmpdn
21	Keeravani	sRgmpdN
22	Kharaharapriya	sRgmpDn
23	Gaurimanohari	sRgmpDN
24	Varunapriya	sRgmpnN
25	Mararanjani	sRGmpdD
26	Charukesi	sRGmpdn
27	Sarasangi	sRGmpdN
28	Harikamboji	sRGmpDn
29	Dheerasankarabharanam	sRGmpDN
30	Naganandini	sRGmpnN
31	Yagapriya	sgGmpdD
32	Ragavardhini	sgGmpdn
33	Gangeyabhushani	sgGmpdN
34	Vagadheeswari	sgGmpDn
35	Sulini	sgGmpDN
36	Chalanata	sgGmpnN
37	Saalagam	srRMpdD
38	Jalarnavam	srRMpdn
39	Jhalavarali	srRMpdN
40	Navaneetham	srRMpDn
41	Pavani	srRMpDN
42	Raghupriya	srRMpnN
43	Gavambodhi	srgMpdD
44	Bhavapriya	srgMpdn
45	Subhapanthuvarali	srgMpdN

46	Shadvidhamargini	srgMpDn
47	Suvarnangi	srgMpDN
48	Divyamani	srgMpnN
49	Dhavalambari	srGMpdD
50	Namanarayani	srGMpdn
51	Kamavardhani	srGMpdN
52	Ramapriya	srGMpDn
53	Gamanasrama	srGMpDN
54	Visvambhari	srGMpnN
55	Syamalangi	sRgMpdD
56	Shanmukhapriya	sRgMpdn
57	Simhendramadhyamam	sRgMpdN
58	Hemavathi	sRgMpDn
59	Dharmavathi	sRgMpDN
60	Nithimathi	sRgMpnN
61	Kanthamani	sRGMpdD
62	Rishabhapriya	sRGMpdn
63	Lathangi	sRGMpdN
64	Vachaspathi	sRGMpDn
65	Mechakalyani	sRGMpDN
66	Chithrambari	sRGMpnN
67	Sucharithra	sgGMpdD
68	Jyothiswarupini	sgGMpdn
69	Dhathuvardhini	sgGMpdN
70	Nasikabhushani	sgGMpDn
71	Kosalam	sgGMpDN
72	Rasikapriya	sgGMpnN

Table 3.4 The 72 Melakartha Ragas and their Swara sequence

3.2 Female and Male Voices

There is substantial difference in the quality of voice of female and male artistes in respect to the parameters such as fundamental frequency and overtones. Male singers can sing at low frequencies while female voices are always at a higher frequency.

For example the normal fundamental frequency generated when note A is sounded by a male is 110 Hz, while the same produced by a female is 220 Hz. So if we are not taking suitable range for detection, some frequencies will be missing which will lead to wrong identification of the Raga. Figure 3.1 is a plot of the sound generated by a male with note A. It can be seen that the observed fundamental frequency is 111 Hz. Figure 3.2 is the plot of the sound generated by a female with the same note A. Here the observed fundamental frequency is 223Hz.

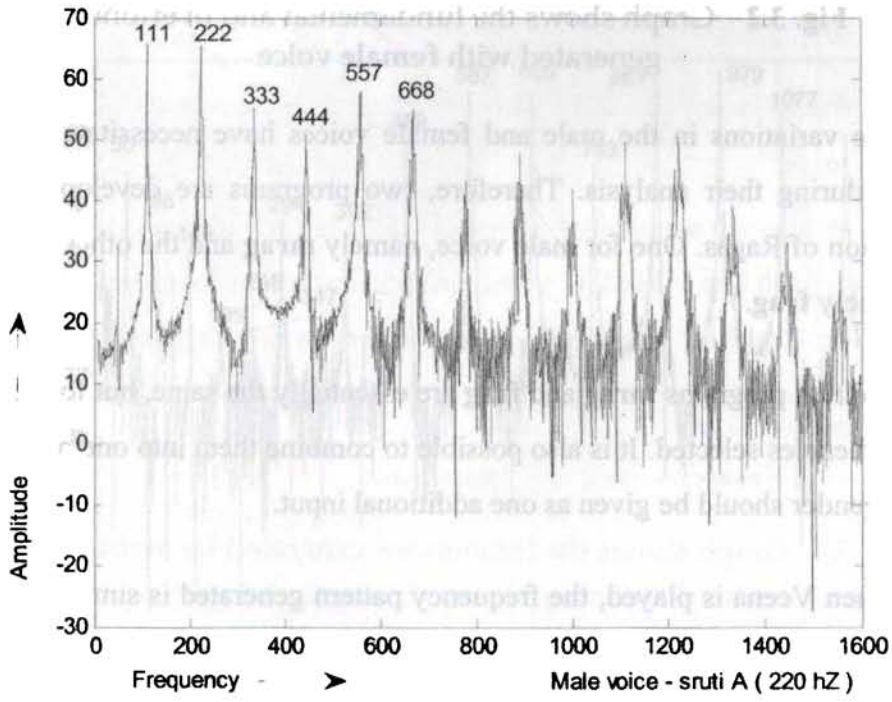


Fig. 3.1 Graph shows the fundamental and overtones generated with **male** voice

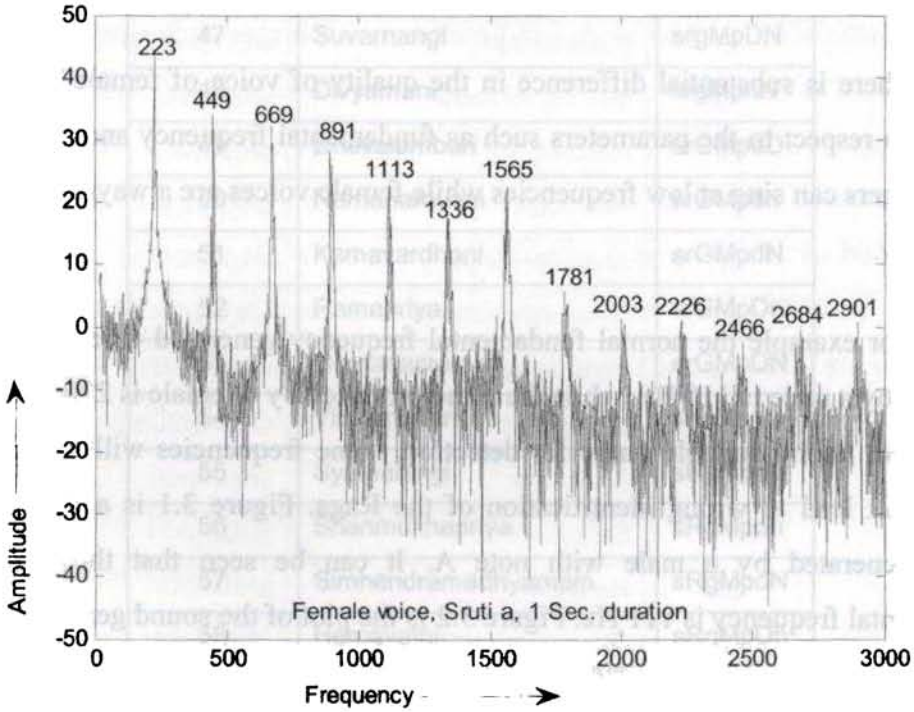


Fig. 3.2 Graph shows the fundamental and overtones generated with **female** voice

The variations in the male and female voices have necessitated different treatment during their analysis. Therefore, two programs are developed for the identification of Ragas. One for male voice, namely **mrag** and the other for female voice, namely **frag**.

The two programs **mrag** and **frag** are essentially the same, but for the range of the frequencies selected. It is also possible to combine them into one program. In that case gender should be given as one additional input.

When Veena is played, the frequency pattern generated is similar to that of the male voice. So for the identification of the Raga, we have to use the program for male voice, **mrag**. But when Violin, Mandolin or Flute is played, the frequency pattern generated is similar to that of the female voice. So for identification of Raga **frag** must be used. Every Musical instrument like the Santoor, Clarinet,

Saxophone, Guitar, Sarod etc. can be tested and classified as **male or female** instrument.

3.3 Analysis of musical instruments

For the purpose of identifying the quality of sound output from musical instruments, we have developed a program called **Sruti**. The program processes the sound input and identifies the base Sruti. This program can be used to benchmark the quality of musical instruments. For example, using this program frequency generated by the strings of a Guitar or a Sitar at various fret positions can be determined to check the quality of the instrument. The quality of a few instruments are analysed using the program **Sruti** and the results are given below in the form of graphs.

3.3.1 Tampura

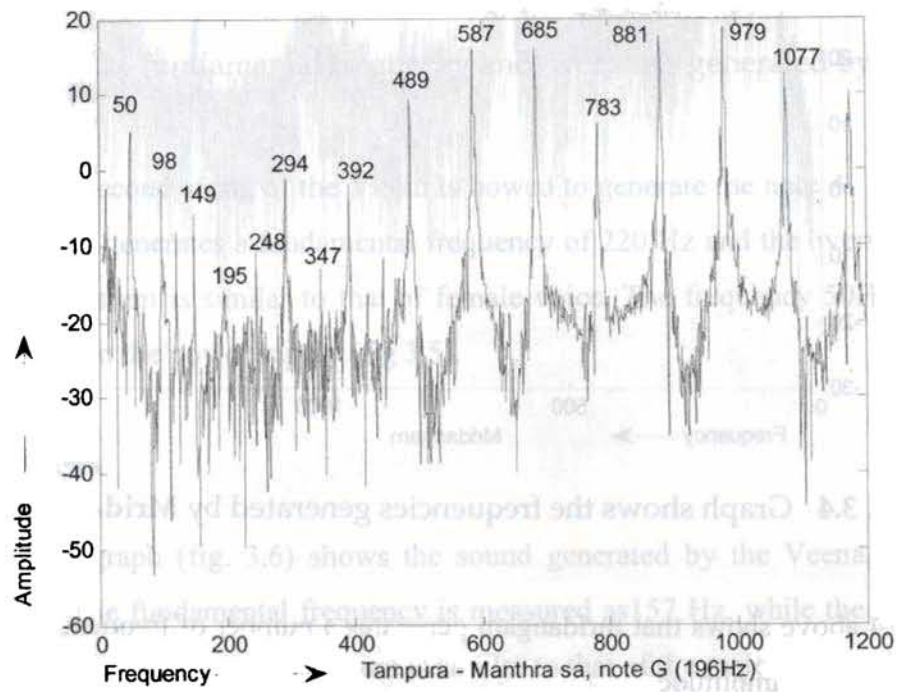


Fig. 3.3 Frequencies generated when the manthra **sa** of **Tampura** is played

Figure 3.3 is a graph generated by playing the string: manthra **Sa** (lower octave) of a Tampura with Sruti g. It generates frequencies 50, 98, 149, 195, 248, 294, 347, 392 etc. The frequency 195 Hz represents Shadjam, **Sa** (G3 note), 294 Hz represents Panchamam, **Pa**, 248 Hz represents Chyuta Madhyama Gandharam, **Ga**, 347 Hz represents Suddha Nishadam, **Ni** (ref. table 2.5). The tone generated by different Tampuras are not the same and hence, the frequencies generated also may differ. For a better understanding of the Tampura, experiments will have to be conducted with more sample inputs.

3.3.2 Mridangam

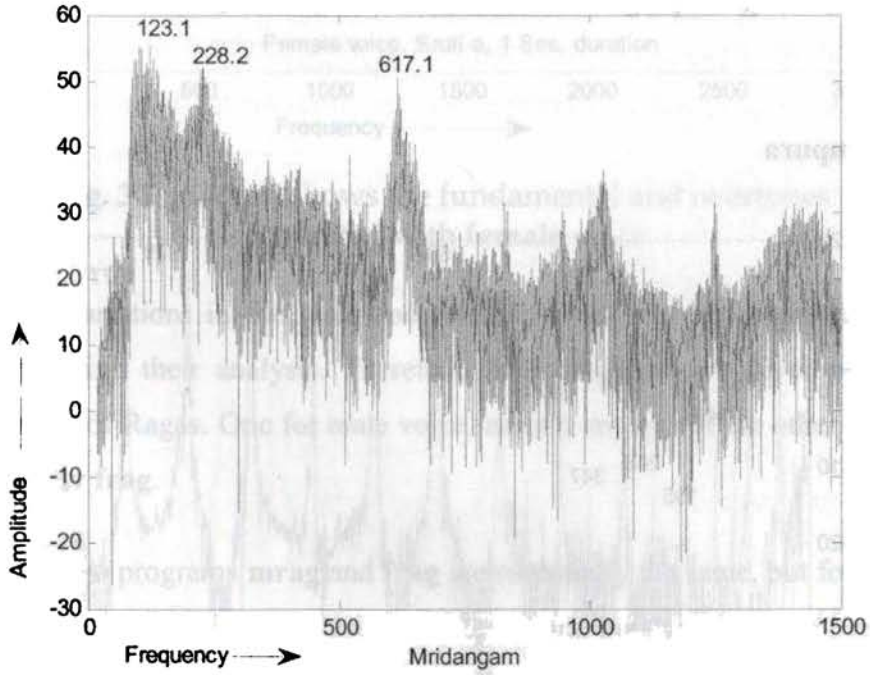


Fig. 3.4 Graph shows the frequencies generated by **Mridangam**

Figure 3.4 above shows that mridangam generates a number of frequencies having almost the same amplitude.

3.3.3 Violin

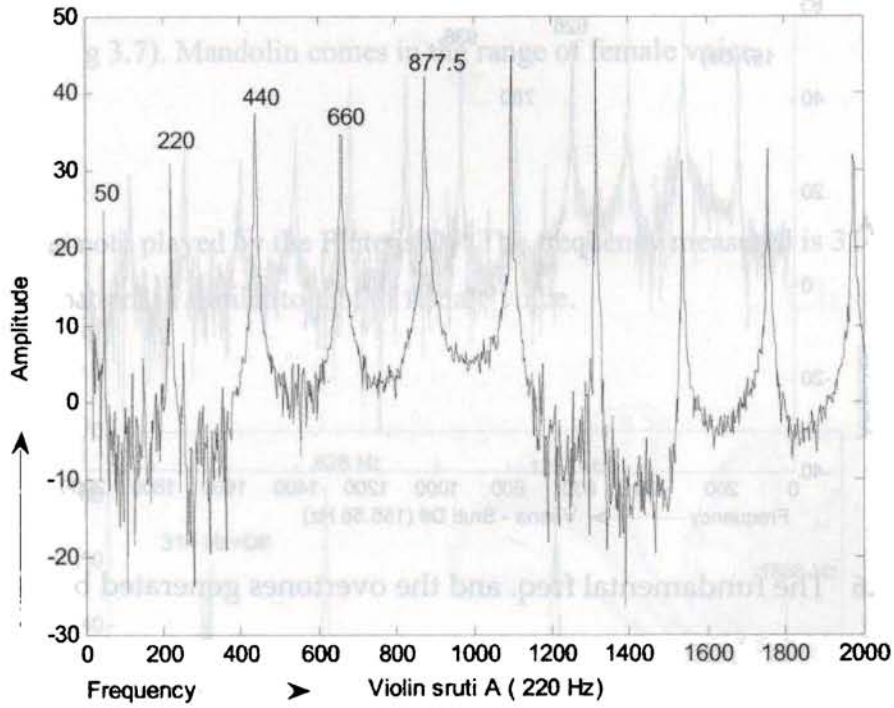


Fig. 3.5 The fundamental frequency and overtones generated by **Violin**

The second string of the Violin is bowed to generate the note A. The graph shows that it generates a fundamental frequency of 220 Hz and the overtones. The frequency pattern is similar to that of female voice. The frequency 50Hz may be the noise from the power supply (fig 3.5).

3.3.4 Veena

The graph (fig. 3.6) shows the sound generated by the Veena, the Sruti being D#. The fundamental frequency is measured as157 Hz, while the others are the overtones. The frequency pattern is similar to that of the male voice.

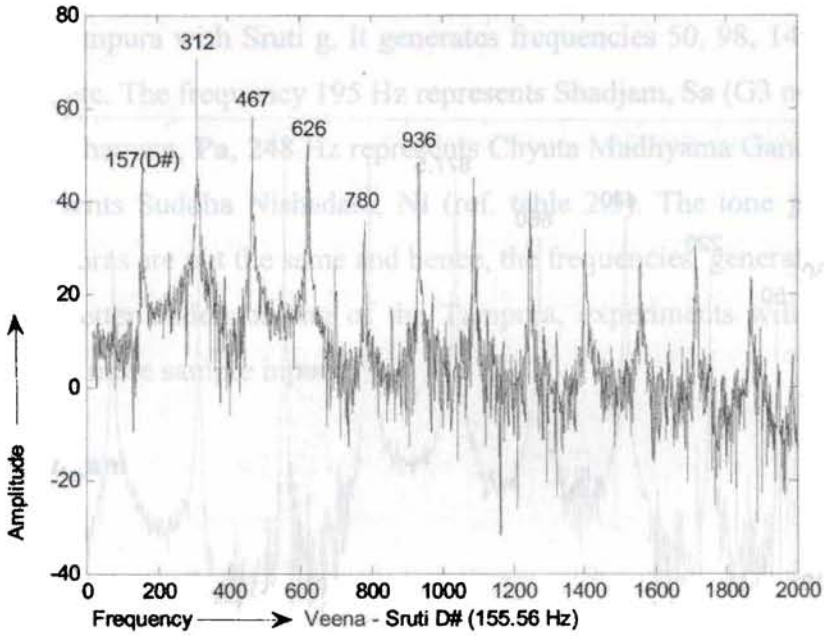


Fig. 3.6 The fundamental freq. and the overtones generated by **Veena**

3.2.5 Mandolin

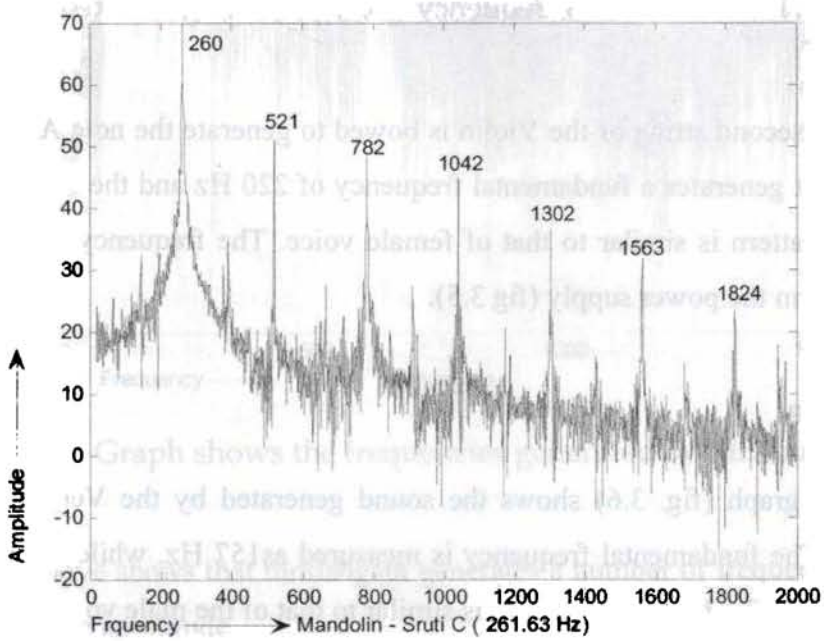


Fig. 3.7 The fundamental freq. and the overtones generated by **Mandolin**

Here Mandolin is tuned to the Note C and is measured as 260 Hz. The actual frequency of the C note is 261.63 Hz. The difference in the frequency may be due to the error in the tuning of the Mandolin. The other frequencies are the overtones (fig 3.7). Mandolin comes in the range of female voice.

3.2.6 Flute

The note played by the Flute is D#. The frequency measured is 314 Hz. The frequency pattern is similar to that of female voice.

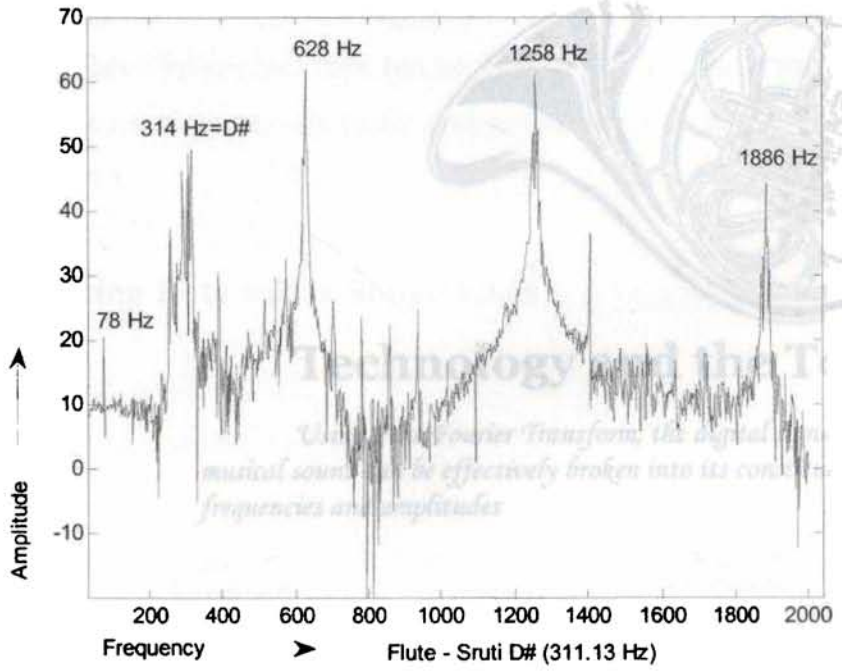
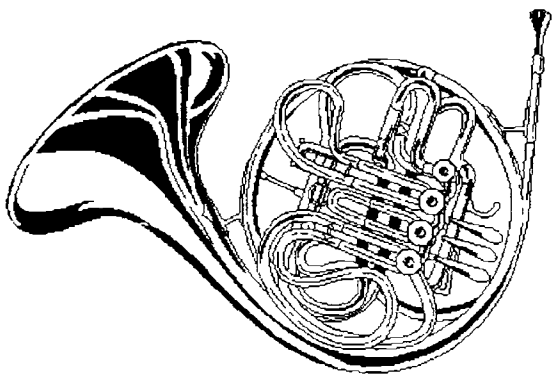


Fig 3.8 The fundamental freq. and the overtones generated by **Flute**

From the above experiments, we conclude that Tampura is an instrument which produces many Swaras, even when one string alone is plucked. Mridangam, which is a percussion instrument, generates a large number of different frequencies, with almost the same amplitude. The Violin, Mandolin and Flute belong to the

category of female voice and can be considered as female instruments. But in the case of the Veena, the frequency pattern is similar to the male voice. So Veena is considered as a male instrument.

Chapter 4



Technology and the Tools

Using Fast Fourier Transform, the digital signals of a musical sound can be effectively broken into its constituent frequencies and amplitudes

Sound signals induce fluctuations in pressure along the path of a sound wave. When sound waves fall on a microphone, the microphone converts the sound signal into electrical pulses. These pulses are fed to a sound card which converts these analog signals into digital signals. Using the Fast Fourier Transform (FFT), these digital signals can be effectively broken into its constituent frequencies and amplitudes. These frequencies then can be used to find out the Swaras in a Raga rendered by a musician. A schematic diagram of Raga identification process is shown in Fig 4.1.

4.1 Acquiring Data with a Sound Card

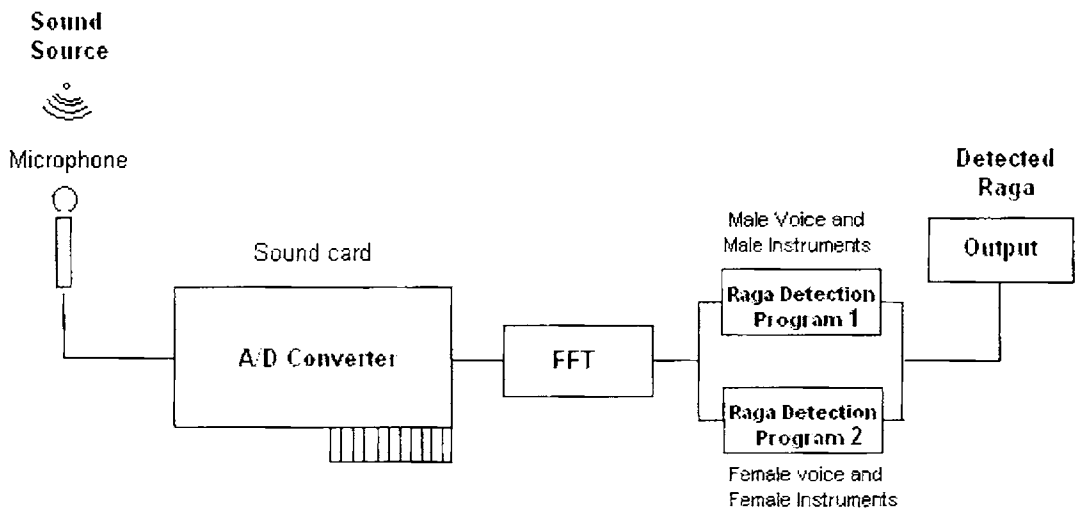


Fig 4.1 Schematic diagram of Raga identification procedure

A multimedia personal computer is used to identify Raga. Nowadays all personal computers are having built-in sound card. A microphone can be externally

connected to the sound card. The sound card converts the analog signals to digital signals, so that the computer can handle these signals. Using Fast Fourier Transform, a mathematical tool, we can convert digital signals into its constituents, namely, frequency and amplitude. Many computer languages offer FFT functions or we can write a program in C or C++ for this purpose. Matlab, Mathematica etc. have built in FFT functions. The FFT based programs help us to sort out the frequency and amplitude parts of the signal. Program1 and Program2 in the figure are two computer programs, one used for the analysis of male voice and male instruments and the other for female voice and female instruments. These programs can be used to find out the Swara-positions and hence the Raga in a sound signal. After scanning the signal for about 3 minutes, the detected frequency, amplitude, Swaras and the Raga will be displayed on the screen. A graph with frequency on the x-axis and amplitude on the y- axis also can be displayed. After analyzing the Swara positions the best match among the Ragas will be identified and the graph is plotted. The Swaras belonging to the Raga will be displayed as green dots and the Swaras which does not belong to the Raga as red dots.

4.2 Fourier theorem [22]

According to this theorem, any periodic function F(t) of the period T, however complex it may be, can be represented by a unique combination of the function $f_n(t)$ and $g_n(t)$

where $f_n(t)=\sin(2\pi nt/T)$ and $g_n(t)=\cos(2\pi nt/T)$ where, n=0,1,2,3, ...

Mathematically, Fourier theorem can be written as

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos nt + b_n \sin nt)$$

4.2.1 The Fourier Transform [24]

The *Fourier transform*, in essence, decomposes or separates a waveform or function into sinusoids of different frequency which sum to the original waveform. It identifies or distinguishes the different frequency sinusoids and their respective amplitudes.

4.3 Program to find the frequency and amplitude of a sound signal

To find the frequency and amplitude of a sound signal, a program developed for this, **Sruti.m,** is used and is given below.

```
AI=analoginput( 'winsound' );
chan=addchannel(AI,1);
du=1;
set(AI,'SampleRate',44100)
ActualRate=get(AI,'SampleRate');
set(AI,'SamplesPerTrigger',du*ActualRate);
set(AI,'TriggerType','Manual');
blocksize=get(AI,'SamplesPerTrigger');
Fs=ActualRate;
start(AI);
trigger(AI);
data=getdata(AI);
delete(AI)
clear AI
 [f,mag]=daqdocfft(data,Fs,blocksize);
plot(f,mag)
grid on
ylabel('Magnitude (dB)')
xlabel('Frequency (Hz)')
```

```
title('Frequency Components of Tuning Fork')
```

Here, winsound is the name of the analog input hardware driver adaptor. The number of channels used is one. Time duration is 1 sec. Sample rate is 44100/sec. TriggerType can be Immediate, Manual, or Software. If TriggerType is Manual, the trigger occurs immediately after the trigger function is issued.

[f,mag] = daqdocfft(data,Fs,blocksize) calculates the FFT of data, using sampling frequency FS and the SamplesPerTrigger provided in blocksize.

daqdocfft( ) outputs the frequency and magnitude of data. The details of Daqdocfft( ) is shown below.

```
xfft = abs(fft(data));
index = find(xfft = = 0);
xfft(index) = 1e-17;
mag = 20*log10(xfft);
mag = mag(1:floor(blocksize/2));
f = (0:length(mag)-1)*Fs/blocksize;
```

4.3.1 An experiment for finding the frequency of a turning fork

Hold the turning fork in front of the microphone attached to the computer. The sound generated by the tuning fork will be input into the program which in turn will identify the frequency and amplitude. For example, let us consider a turning fork of frequency 256 Hz. We will acquire data for 1 second through one channel of the sound card. Because the tuning fork vibrates at a frequency of 256 Hz, we can configure the sound card to its lowest sampling rate of 8000 Hz. Even at this lowest rate, we should not experience any aliasing effects because the tuning fork will not have significant spectral content above 4000 Hz, which is the Nyquist frequency.

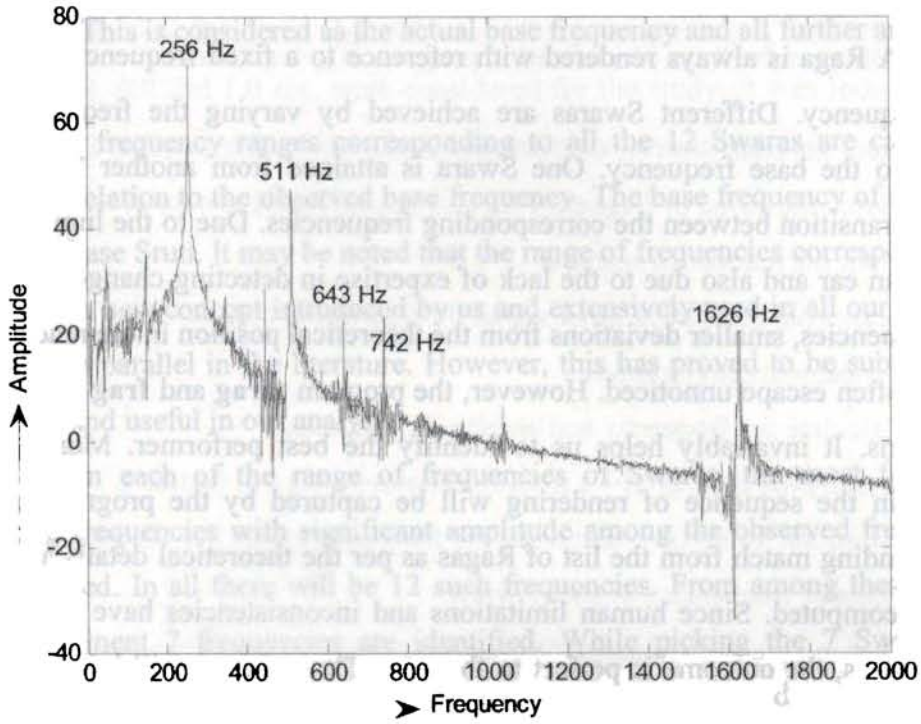


Fig 4.2 Experimentally finding the frequency of a turning fork using the program **Sruti**

After we set the tuning fork vibrating, place it near the microphone, and run the program Sruti.m. Now the analog data will be scanned for 1 Sec. Then it will be converted into digital data. By applying the FFT, the data will be split into frequency and amplitude. A graph is plotted with Frequency on the x-axis and Amplitude on the y-axis. The frequency with maximum amplitude can be found out and normally, it represents the frequency of the turning fork. But it is not necessary that it is the fundamental frequency. The graph shows the frequency obtained, with a turning fork of frequency 256 Hz in the actual run.

From the graph we can see that the fundamental frequency is 256 Hz and it is having maximum amplitude. The second maximum amplitude is for 511 Hz which is the first overtone.

4.4 The Fundamentals of Raga rendering

A Raga is always rendered with reference to a fixed frequency called the base frequency. Different Swaras are achieved by varying the frequency with respect to the base frequency. One Swara is attained from another Swara by a smooth transition between the corresponding frequencies. Due to the limitations of the human ear and also due to the lack of expertise in detecting changes of one or two frequencies, smaller deviations from the theoretical position in the rendering of Swaras often escape unnoticed. However, the program **mrag** and **frag** has no such limitations. It invariably helps us to identify the best performer. Moreover the Swaras in the sequence of rendering will be captured by the program and the corresponding match from the list of Ragas as per the theoretical details available, will be computed. Since human limitations and inconsistencies have no room in this analysis, the outcome is perfect to the core. The program will bring out even the smallest deviations from the theoretical model of the Ragas. By improving the sample rate and the duration for analysis, the accuracy can be improved to any desired level.

4.5 Identifying the Raga in a rendering

Raga can be identified either using a live input through a microphone attached to the sound card or a recorded performance from a compact disk or hard disk. Depending on the gender of the performer either the **mrag** or the **frag** program is used. Let us assume that we use **mrag**.

The base frequency, the number of scans and the duration of the scans are given as the initial input to the program. Let us scan the input signal continuously for 300 times, with a scan duration of 0.5 sec. The sound is input to the program and the analysis begins.

The program first identifies the most frequently occurring frequencies with significant amplitude in each scan. At first the program picks up the most

significant frequencies among the observed frequencies and close to the given base frequency. This is considered as the actual base frequency and all further analysis is based on it.

The frequency ranges corresponding to all the 12 Swaras are calculated, apriori, in relation to the observed base frequency. The base frequency of **sa** is also termed as base Sruti. It may be noted that the range of frequencies corresponding to a Swara is a new concept introduced by us and extensively used in all our analysis. This has no parallel in the literature. However, this has proved to be substantially important and useful in our analysis.

From each of the range of frequencies of Swaras, the most frequently occurring frequencies with significant amplitude among the observed frequencies are identified. In all there will be 12 such frequencies. From among these 12 the most prominent 7 frequencies are identified. While picking the 7 Swaras, the sequence relevant to the 72 Melakartha Ragas alone are considered. Hence, the program will always identify a Raga from among the 72 Melakartha Ragas which is the closest match to the observed sequence of Swaras. If there are mistakes in the rendering of a Raga then the program will either identify the rendering as a different raga or the same Raga with one or more red spots in the graphical representation of the result of the analysis. The red spots in the graph correspond to significant Swaras among the 12 Swaras in excess to the required 7 Swaras for a Raga. The seven Swaras picked up from among the observed significant frequencies as a result of the analysis are represented by green spots in the graphical display of the out put.

The absence of any red spot in the graphical display of the entire scan is a clear indication of the perfection in rendering. The lesser the number of red spots, the more perfect is the rendering. Our study has gone further to evaluate the level of artistes' perfection by devising two scales, namely, Sruti Consistency Coefficient (SCC) and Raga Consistency Coefficient (RCC). The details are given in chapter 6.

4.6 Algorithm of Raga identification program

The algorithm of the Raga identification program is given below:

1) Input the base Sruti (c, C, d corresponding to western notation C, C#, D): **s**
   Match the range of frequency for this Sruti: (f1, f2)
2) Input the number of scans, **n**
3) Scan: read the analog input signal for a period of 0.5 sec.
4) Repeat scanning **n** times
5) Calculate the frequency and amplitude of **n** scans.
6) Identify the base Sruti – **s** from the scanned data and update **s**.
7) Using the value of **s**, calculate the frequency of all the 12 Swaras and the range of frequencies of each Swara.
8) Find out the Swaras of the frequencies stored from the data.
9) Select 7 Swaras from among the 12 Swaras, which constitute the Raga.
10) Identify the Raga from the Swara - Raga - table.

4.7 The Relevance of Scan Duration

For Raga identification, usually we take a minimum of 300 scans from the input signal with scan duration of 0.5sec. The time taken to scan each sample is very important in the Raga detection process. A study was made to determine the most suitable scan duration. We have found that 300 scans of duration 0.5 sec. would result in data corresponding to 300 x 0.5 = 150 sec. of actual performance. This data is sufficient and the duration is adequate in unfolding the specifics of a Raga. There are exceptional cases when an artiste takes more than 2.5 minutes to reveal the raga he renders. This is due to the individual's style of elaborating a Raga which is permissible in Classical Music. We have also conducted analysis of Ragas using the program by taking different number of scans and durations.

Raga Kamavardhani, sung by M. S. Subhalakshmy was used for the study with different scan durations and 300 scans. Time durations 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 sec. were considered for the study. It was found that for 0.1 and 0.2 sec. durations the detection was not consistent and for all other durations, the Raga was identified.

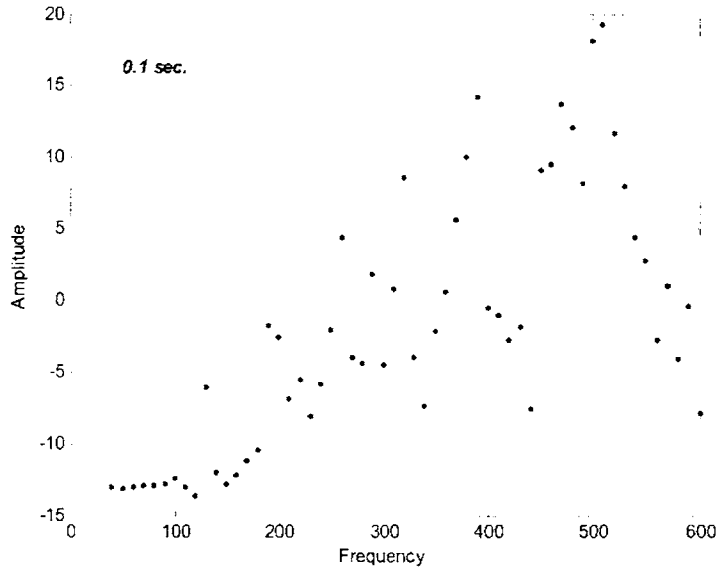


Fig 4.3 No. of sample frequencies obtained in the range 0 to 600 Hz for a scan duration of **0.1** sec.

The sensitivity of the scan is dependant on the scan duration and is the inverse of the scan duration. The unit of sensitivity is Hertz. For 1.0 sec. scan duration, the sensitivity is 1/1.0sec.= 1Hz. and for 0.1 sec. the sensitivity is 1/0.1sec.= 10 Hz. This means that the frequencies detected will be 10, 20, 30, 40, 50, etc. But if the sensitivity is 1, the frequencies detected will be 1, 2, 3 .... etc. If the scan duration is 0.5 sec., the sensitivity will be 2 Hz. For 300 scans the time taken for detection is 150 sec. If sensitivity is 1 Hz, total time for scan will be 300 sec. If we want more accuracy in the detection, scan duration must be increased. As a compromise, we have taken 0.5 sec. as the scan time for our study. This means

that a singer has to sing a Raga for at least 1.5 minutes in order for the program to identify the Raga.

The graphs showing amplitude and frequency for scan duration of 0.1 sec., 1.0 sec. and 0.5 sec. are given in Fig 4.3, Fig 4.4 and Fig 4.5.

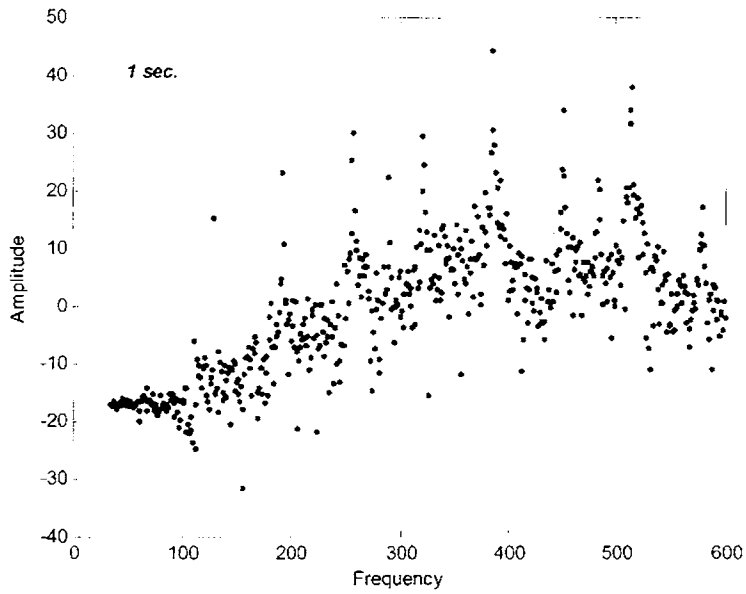


Fig 4.4 Sample frequencies obtained for duration of **1.0** sec.

Figure 4.3 corresponding to 0.1seconds duration contain very less no of scan points and is found to be inadequate to arrive at a meaning full conclusion. The identification of Ragas with 0.1 seconds is not advisable.

Figure 4.4 corresponding to 1.0 sec. duration have a very large number of scan points and is very good for Raga analysis. The Raga identification in this case will be very accurate. However the total time for the scan is 300 sec. which is very high and is not recommended for the analysis.

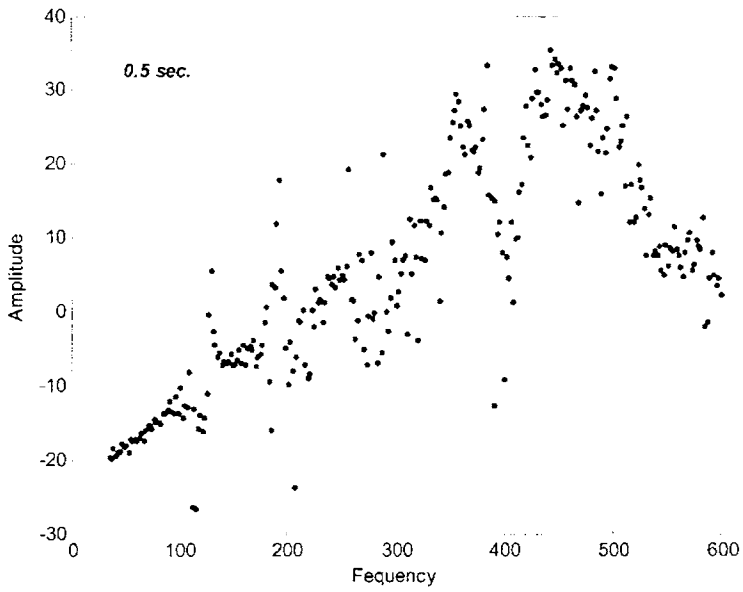
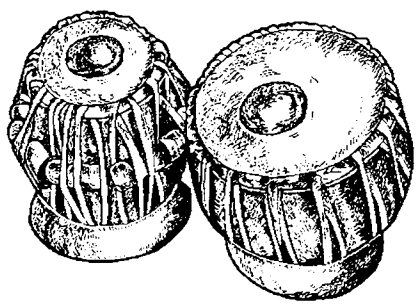


Fig 4.5 Sample frequencies obtained for duration of 0.5 sec.

Figure 4.5 contains scan points corresponding to 0.5 sec. scan duration. The number of points is adequate to arrive at a consistently good result. Therefore for practical purposes 0.5 sec. of scan duration is ideal for the Raga identification programs.

A research paper **on Identification of ragas played on Musical Instruments** was presented in the National Seminar held at Sree Saraswathi Thyagaraja College, Pollachi.

Chapter 5



Identification of Ragas – Case Study

Veena recital in all the72 Melakartha Ragas is analysed as part of this study. Interestingly, the popular performance of the Hanumathodi Raga is found to be different from the theoretical prescriptions

In this chapter, recorded renderings, both vocal and instrumental are analysed using the programs **mrag** and **frag**, and the findings are accounted. Veena recitals in all the72 Melakartha Ragas is analysed as part of this study. Interestingly, the popular performance of the Hanumathodi Raga is found to be different from the theoretical prescriptions. It is a strong case of the difference in the tradition and the theory of Classical Music. It is also pertinent to note that though some experts and well known artists have noticed this deviation many times, this dissertation is arguably the first authentic record in this respect. The recitals of the Hanumathodi Raga by 10 experts have been subjected for analysis and the results obtained.

5.1 Veena recital by S. Balachander

Here, an account of the results of the evaluation of the veena recital by the eminent Veena artist S.Balachander in all the 72 Melakartha Ragas is given [23]. The recital is commercially available in the form of an audio CD, titled "Marvellous Melakarta Melodies" (Balachandar). On evaluation with our software, it is found that 52 Ragas are correctly rendered in accordance with the theory. However there are deviations from the theory in 20 out of the 72 Ragas as evident from the details given below. We have found correct performances in 8 of the 20 Ragas by artistes and the details are given in table 5.2.

Raga **Hanumathodi,** which is commonly sung in the traditional way by artistes, will not be identified by this software as it differs from the theory. So Hanumathodi Raga sung by ten eminent musicians were tested and the results

tabulated at table 5.4. Theoretically correct renderings of the remaining 11 Ragas could not be found, as performances in these Ragas were not available to us.

5.2 Testing and case studies

The results of the analysis of rendering of 72 Melakartha Ragas in Veena by S.Balachander is given below. Here Sruti is basic Sruti in which the Raga is played. No. of scans is the number of times the signal is received for Swara identification.

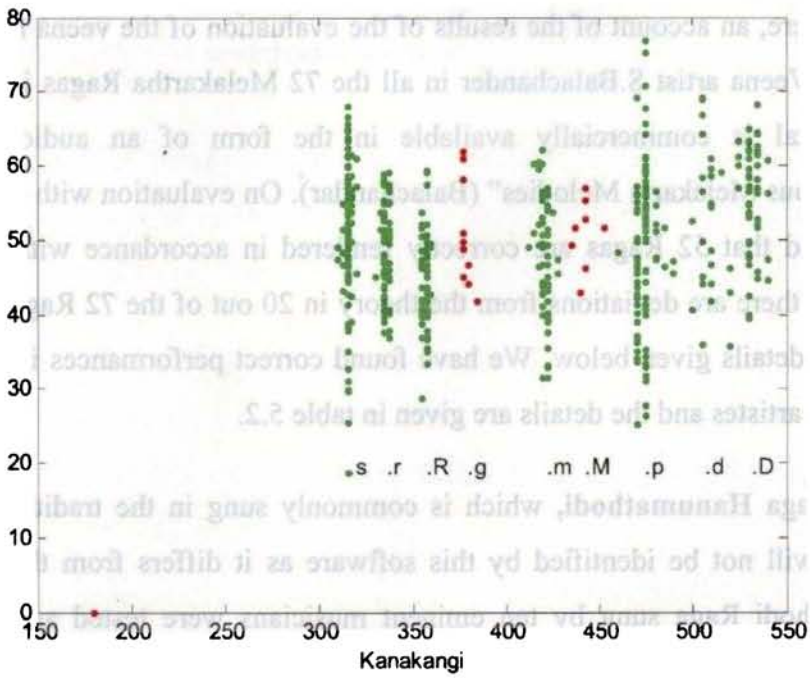
5.2.1 Raga, Kanakangi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **1 Kanakangi**

The Swaras of the Raga are > S r R m P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	315	335	356.5	378.8	0.0	421	441.9	473.7	505.8	531.3	0.0	0.0
Amplitude>	51.2	48.6	44.6	50.8	0.0	47	50.8	49.3	53.1	54.9	0.0	0.0
Swara count>	100	73	62.0	10.0	0.0	60	8.0	102	25.0	57.0	0.0	0.0



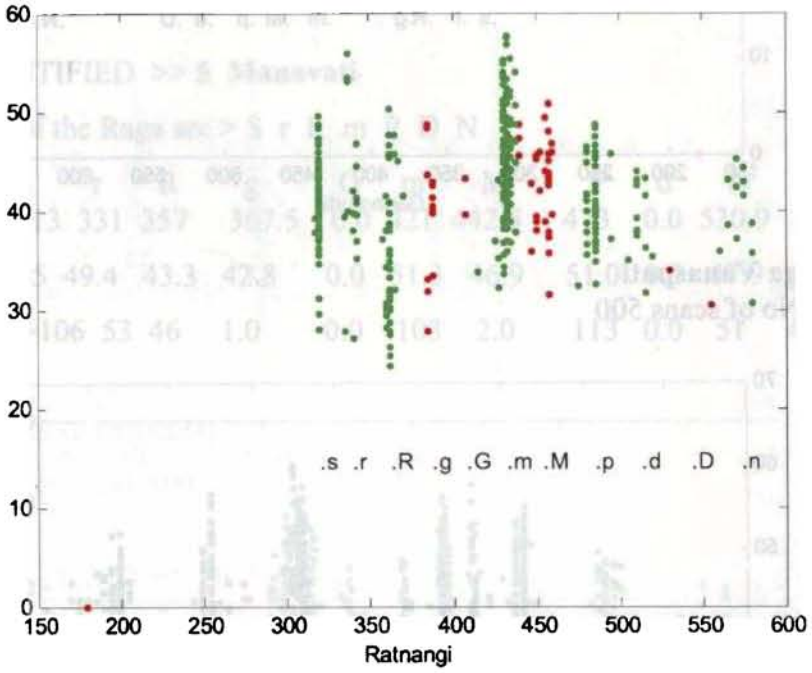
5.2.2 Raga Ratnangi

Sruti D#, No of scans 500 (Begin after 1/3)

RAGA IDENTIFIED >> **2 Ratnangi**

The Swaras of the Raga are > S r R m P d n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	319	339	362.4	386.4	407.5	431	453.7	484.1	511.9	542.5	572	0.0
Amplitude>	41	41.2	36.3	39.1	41.3	45.4	42.8	40.8	38.9	32.1	39	0.0
Swara count >	81	18	49	14.0	2.0	129.0	33	53	13	2.0	12.0	0.0



5.2.3 Raga Ganamurti

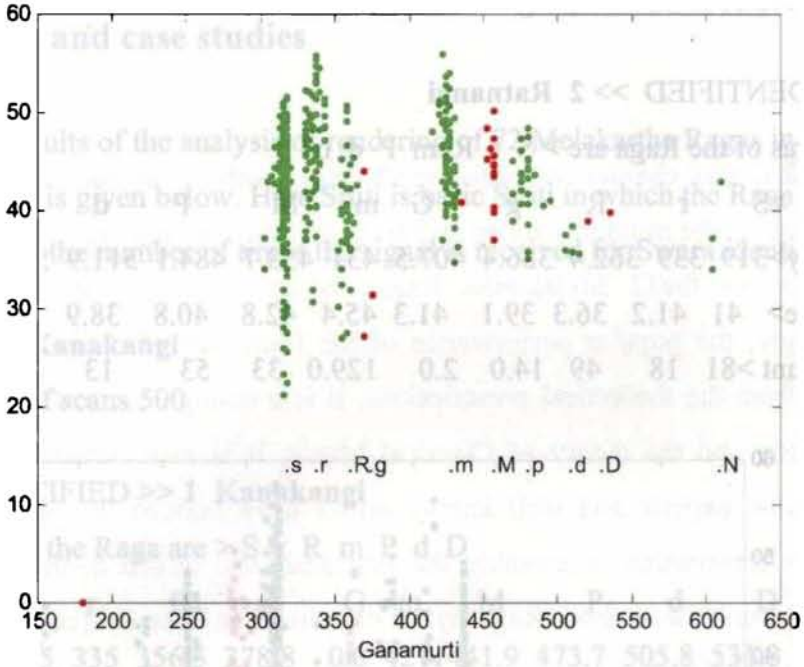
Sruti D#, No of scans 500

RAGA IDENTIFIED >> **3 Ganamurti**

The Swaras of the Raga are > S r R m P d N

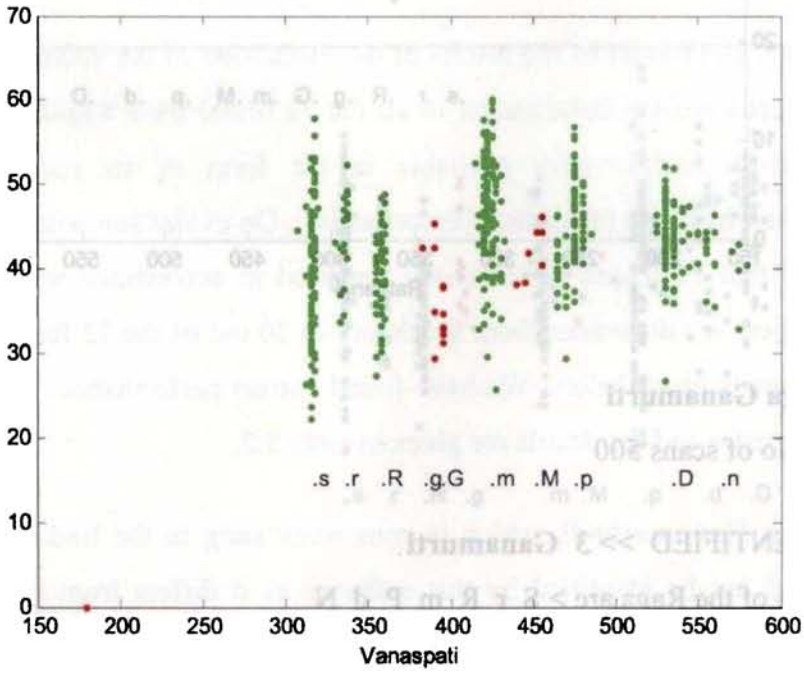
Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	315	335	357.6	371.7	0.0	426	454.8	477.8	506.7	527.5	0.0	606

Amplitude	>42	46	39.2	34.1	0.0	45.4	44.1	42.8	37.3	39.3	0.0	38
Swara count	>226	71	37	3.0	0.0	77	15.0	30.0	6.0	2.0	0.0	3



5.2.4 Raga Vanaspati

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **4 Vanaspati**

The Swaras of the Raga are > S r R m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	315	335	357.4	382	393.3	423.2	450.0	474.1	0.0	533.3	562.8	0.0
Amplitude >	39	43.8	39.9	42.5	35.4	47.2	42.0	44.9	0.0	43.8	41.0	0.0
Swara count >	95	19	57	1.0	12.0	123.0	7.0	81.0	0.0	78.0	16.0	0.0

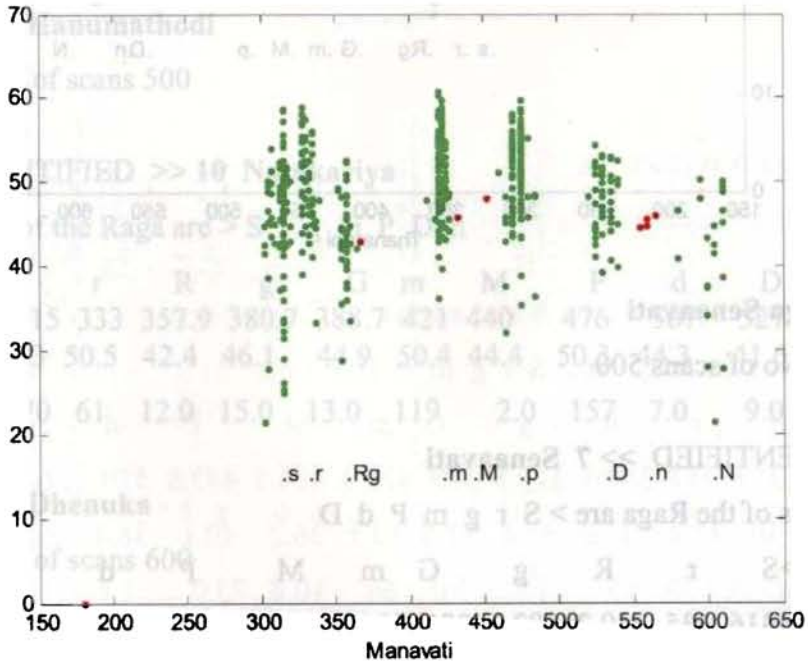
5.2.5 Raga Manavati

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **5 Manavati**

The Swaras of the Raga are > S r R m P D N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	313	331	357	367.5	0.0	421	442.5	473	0.0	530.9	560	602
Amplitude>	45	49.4	43.3	42.8	0.0	51.3	46.9	51.0	0.0	47.9	45.2	41.1
Swara count>	106	53	46	1.0	0.0	103	2.0	113	0.0	51	4.0	20



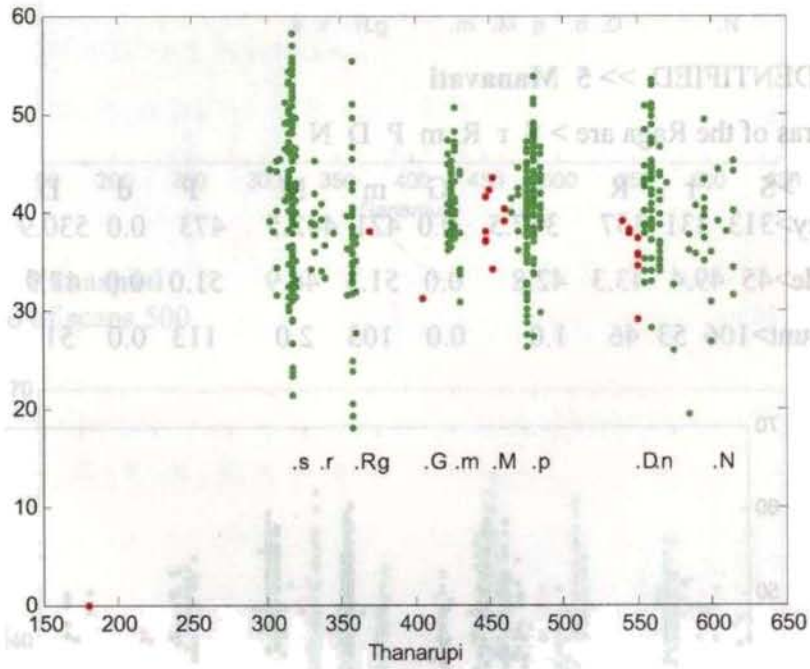
5.2.6 Raga Thanarupi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **6 Thanarupi**

The Swaras of the Raga are > S r R m P n N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	316	335	357.6	370	405	425	451.7	477	0.0	547.5	560	599
Amplitude>	41.7	38	36	38	31.1	41.1	39.2	40.7	0.0	35.9	41	37.7
Swara count>	137	14	44	1.0	1.0	55.0	9.0	140	0.0	8.0	72.0	24



5.2.7 Raga Senaavati

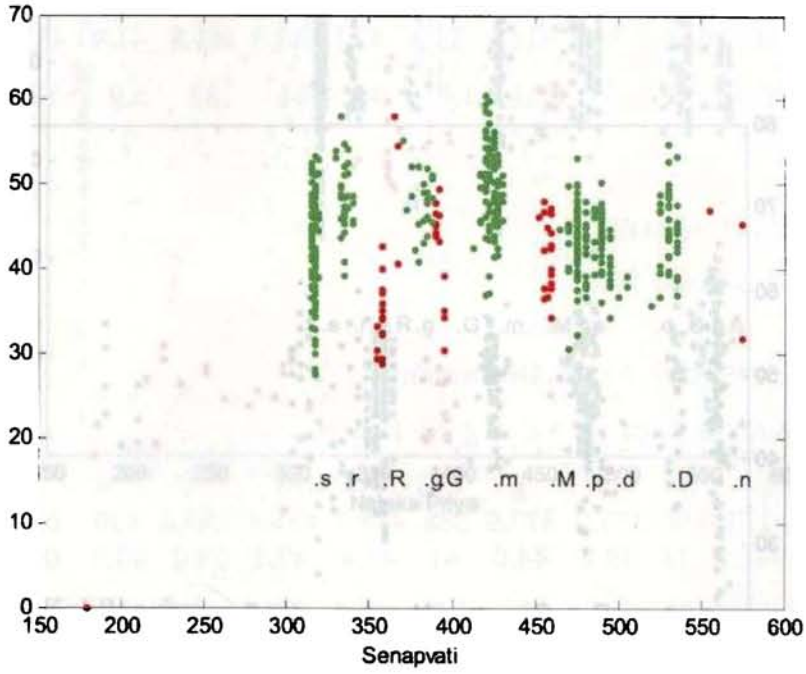
Sruti D#, No of scans 500

RAGA IDENTIFIED >> **7 Senaavati**

The Swaras of the Raga are > S r g m P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	316	335	359.2	382.1	391	424.3	457.8	478.6	497	530	565	0.0

Amplitude>40	45.3	34.4	44.5	40.9	48	38.3	44.9	40.4	44.3	39.7	0.0
Swara count>67	27	9.0	32.0	11.0	89	24.0	160	20.0	53.0	2.0	0.0



5.2.8 Raga Hanumathodi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **10 Natakariya**

The Swaras of the Raga are > S r g m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>315	333	357.9	380.7	388.7	421	440	476	507	527	561	597	
Amplitude>43	50.5	42.4	46.1	44.9	50.4	44.4	50.3	44.3	41.6	46.7	44	
Swara count70	61	12.0	15.0	13.0	119	2.0	157	7.0	9.0	9.0	2.0	

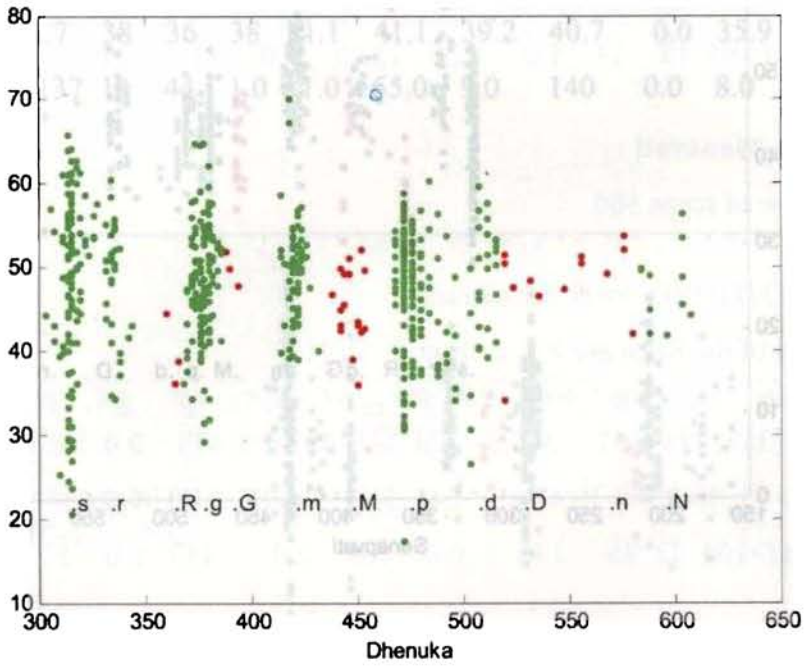
5.2.9 Raga Dhenuka

Sruti D#, No of scans 600

RAGA IDENTIFIED >> **9 Dhenuka**

The Swaras of the Raga are > S r g m P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	315	333	363	377	390	420	446	474.5	507	528.6	568	595
Amplitude>	47	49.8	39.8	48.1	49.9	49.5	45.3	47.1	46.3	46.5	49	47
Swara count>	102	40	3.0	136	3.0	69.0	17.0	165	39.0	7.0	6	11



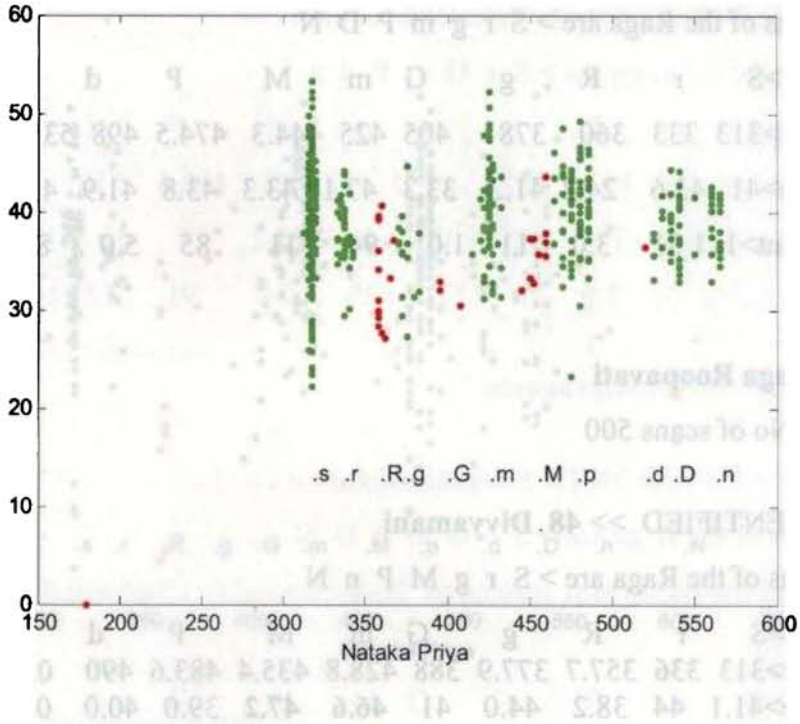
5.2.10 Raga Natakapriya

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **10 Natakapriya**

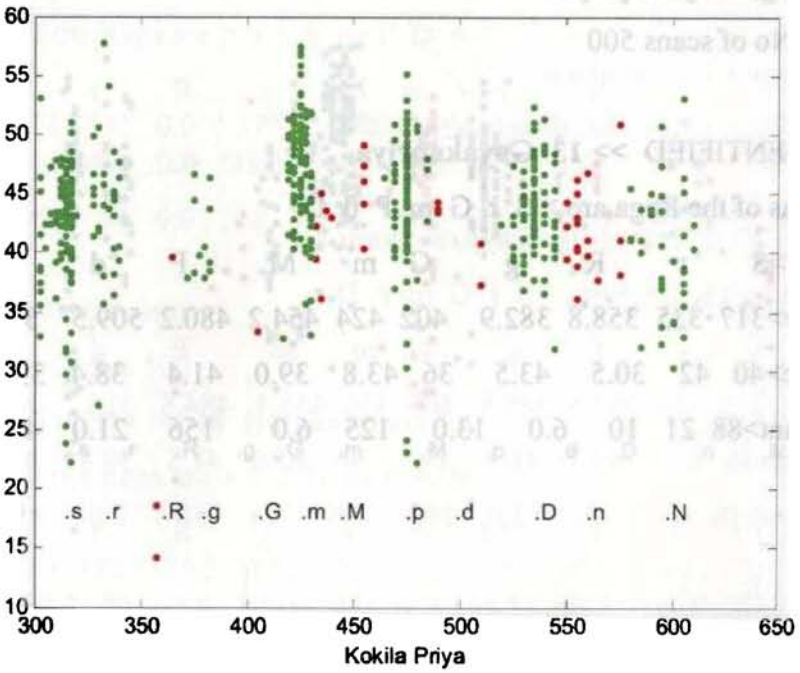
The Swaras of the Raga are > S r g m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	317	337	359.3	374.3	399	425.3	454.5	477.8	520	536.4	562.5	0.0
Amplitude>	40	37.9	32.9	35.4	31.8	40.7	36.2	40.1	36.4	38.3	39	0.0
Swara count >	201	39	15	17	3.0	66	10.0	73.0	1.0	37.0	24.0	0.0



5.2.11 Raga Kokilapriya

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **11 Kokilapriya**

The Swaras of the Raga are > S r g m P D N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	313	333	360	378	405	425	444.3	474.5	498	535.2	558.9	596
Amplitude>	41	43.6	24.2	41.2	33.3	47.1	43.3	43.8	41.9	43.7	41.9	40
Swara count>	111	31	3.0	11	1.0	94	11	85	5.0	83	18.0	38

5.2.12 Raga Roopavati

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **48 Divyamani**

The Swaras of the Raga are > S r g M P n N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	313	336	357.7	377.9	388	428.8	435.4	483.6	490	0.0	567.3	593.6
Amplitude>	41.1	44	38.2	44.0	41	**46.6**	**47.2**	39.0	40.0	0.0	40.0	42.1
Swara count >	61	83	24	28	17	**41.0**	**94**	49.0	3.0	0.0	24.0	11.0

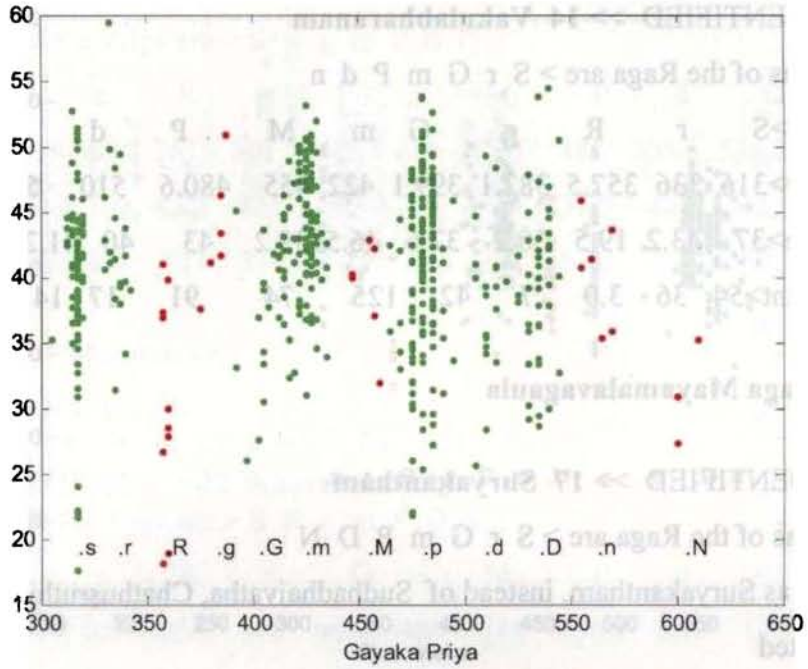
5.2.13 Raga Gayakapriya

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **13 Gayakapriya**

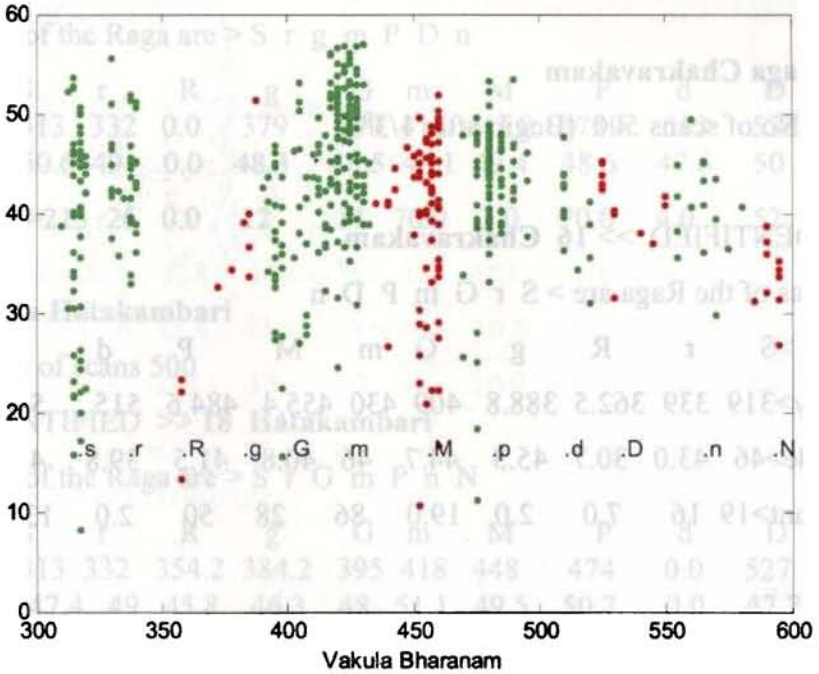
The Swaras of the Raga are > S r G m P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	317	335	358.8	382.9	402	424	454.2	480.2	509.5	535	562	603
Amplitude>	40	42	30.5	43.5	36	43.8	39.0	41.4	38.4	39.8	40	31
Swara count>	88	21	10	6.0	13.0	125	6.0	156	21.0	42	6.0	3.0



5.2.14 Raga Vakulabharanam

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **14 Vakulabharanam**

The Swaras of the Raga are > S r G m P d n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	316	336	357.5	382.1	399.1	422	455	480.6	510	532	564	592
Amplitude>	37	43.2	19.5	38.2	37.6	46.5	39.2	43	40	41.2	40.6	33.6
Swara count>	54	36	3.0	7	42	125	74	91	17	14	17	10

5.2.15 Raga Mayamalavagaula

RAGA IDENTIFIED >> **17 Suryakantham**

The Swaras of the Raga are > S r G m P D N

Identified as Suryakantham, instead of Sudhadhaivatha, Chathusruthi dhaivatha was detected

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	315	335	0.0	370	397.4	420	446	476.9	503.3	526.7	0.0	603
Amplitude>	42	44.7	0.0	46.4	41.7	46.8	42	40.7	**35.5**	**41.1**	0.0	40
Swara count>	125	35	0.0	1.0	17.0	176	15	110	**3.0**	**3.0**	0.0	8.0

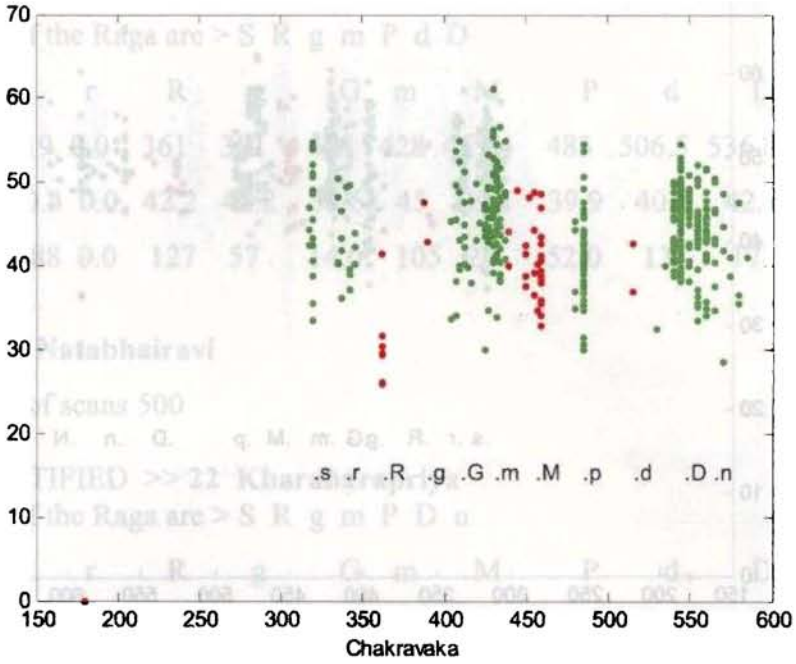
5.2.16 Raga Chakravakam

Sruti D#, No of scans 500 (Begin after 1/3rd)

RAGA IDENTIFIED >> **16 Chakravakam**

The Swaras of the Raga are > S r G m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	319	339	362.5	388.8	409	430	455.4	484.6	515	546	564	0.0
Amplitude>	46	43.0	30.7	45.3	44.7	46	40.8	41.5	39.8	45	43	0.0
Swara count>	19	16	7.0	2.0	19.0	86	28	50	2.0	135	53	0.0



5.2.17 Raga Suryakantham

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **10 Natakapriya**

The Swaras of the Raga are > S r g m P D n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>313	332	0.0	379	390	418	443.8	473.6	513	532	561	593
Amplitude>50.6	49	0.0	**48.3**	**46.5**	46.1	49.4	48.6	47.6	50	**49**	**46**
Swara count>213	26	0.0	**12**	**11**	70.0	2.0	70.0	4.0	52	**20**	**21**

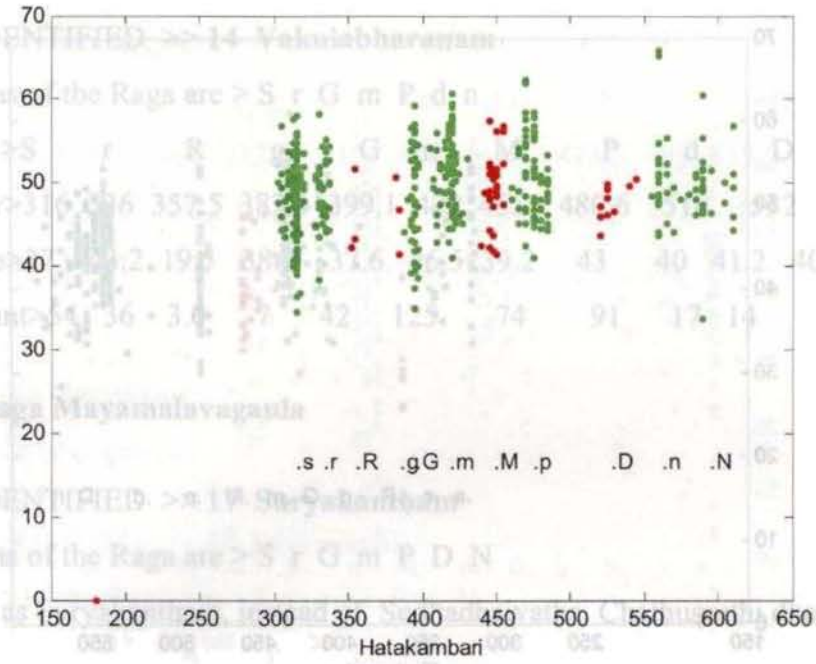
5.2.18 Raga Hatakambari

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **18 Hatakambari**

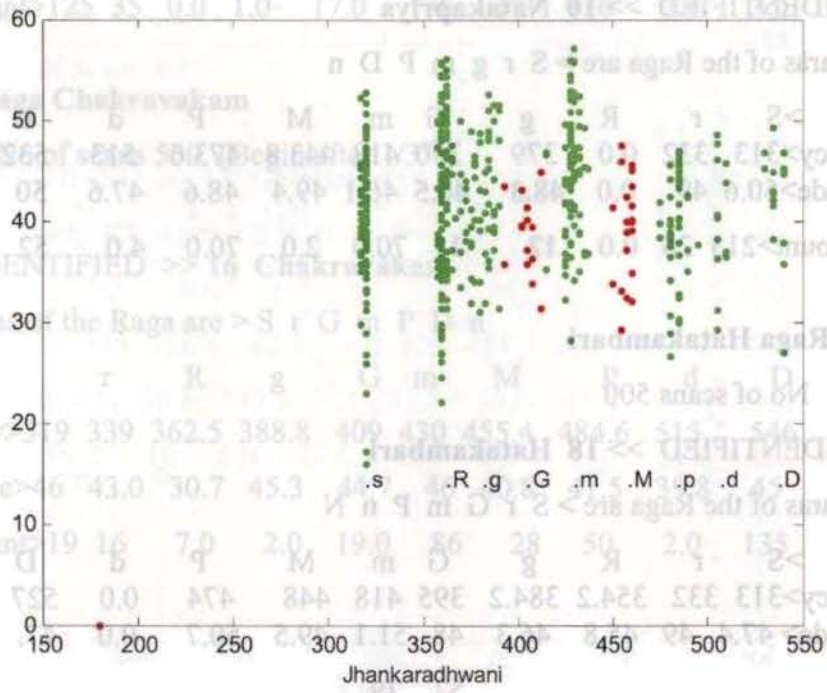
The Swaras of the Raga are > S r G m P n N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>313	332	354.2	384.2	395	418	448	474	0.0	527	562	593
Amplitude> 47.4	49	45.8	46.3	48	51.1	49.5	50.7	0.0	47.7	50	49
Swara count>142	44	3.0	3	52	79	34	80	0.0	10	25	29



5.2.19 Raga Jhankaradhwani

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **19 Jhankaradhwani**

The Swaras of the Raga are > S R g m P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>319	0.0	361	381	404	428	457.4	483	506.5	536.8	0.0	0.0	
Amplitude>40.4	0.0	42.2	42.2	38.6	45	39.1	39.9	40.1	42.5	0.0	0.0	
Swara count>88	0.0	127	57	14.0	105	20	52.0	13	17	0.0	0.0	

5.2.20 Raga Natabhairavi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **22 Kharaharapriya**

The Swaras of the Raga are > S R g m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>314	0.0	356	379	390	420	444	476.1	513	540	561	0.0	
Amplitude>46	0.0	46.8	47.8	43.4	47	46.9	47.8	**45.7**	**49.1**	50.8	0.0	
Swara count >86	0.0	92.0	83.0	1.0	71	14.0	107	**5.0**	**17.0**	20.0	0.0	

5.2.21 Raga Keeravaani

Sruti D#, No of scans 500

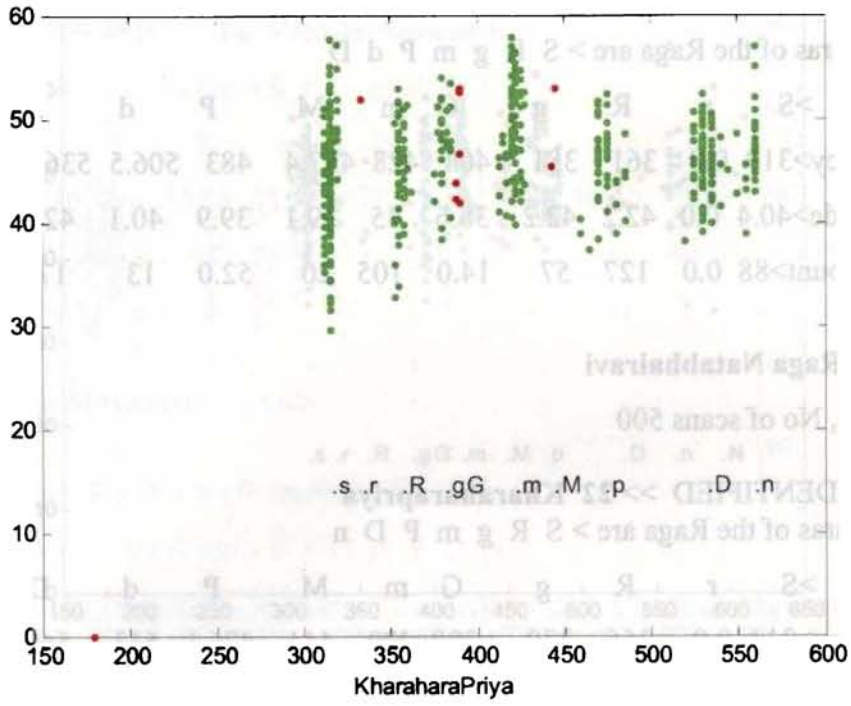
RAGA IDENTIFIED >> **3 Ganamurti**

The Swaras of the Raga are > S r R m P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	332	358	373	397	422	454	479	510	540	0.0	590	
Amplitude>37	41.6	43.8	42.4	33.6	41.	40.6	38.2	39.6	43.5	0.0	44	
Swara count>87	**23**	**227**	**15**	2.0	58	20.0	42	21.0	1.0	0.0	1.0	

5.2.22 Raga Kharaharapriya

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **22 Kharaharapriya**
The Swaras of the Raga are > S R g m P D n

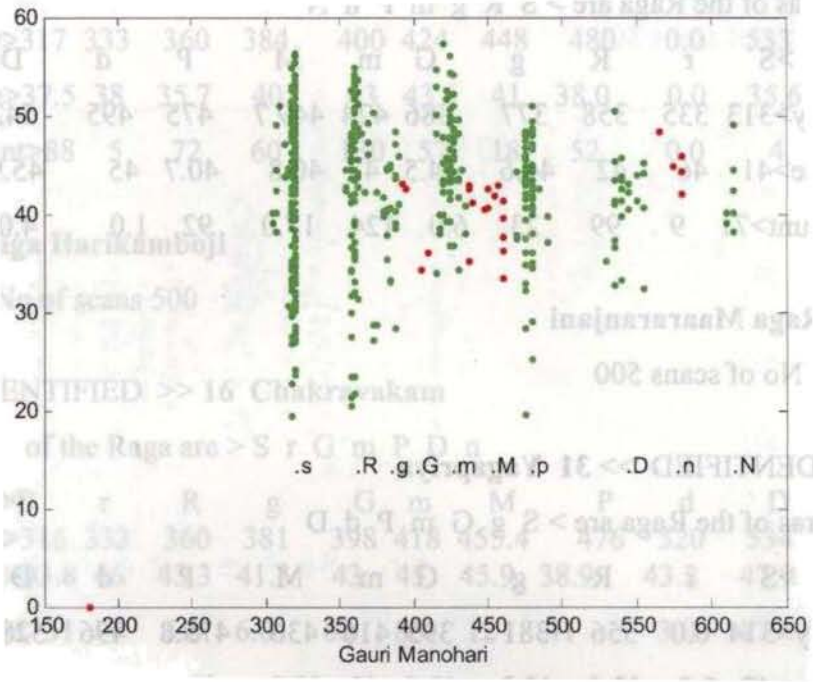
Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>314	332	355	380.9	389.3	421.2	443.8	473.2	0.0	531.7	559	0.0
Amplitude>44	51.9	44.7	47	46.0	49.3	49.1	45.8	0.0	45.8	47.1	0.0
Swara count>148	1.0	49	27	7.0	85	2.0	55	0.0	84	27.0	0.0

5.2.23 Raga Gaurimanohari

Sruti D#, No of scans 500

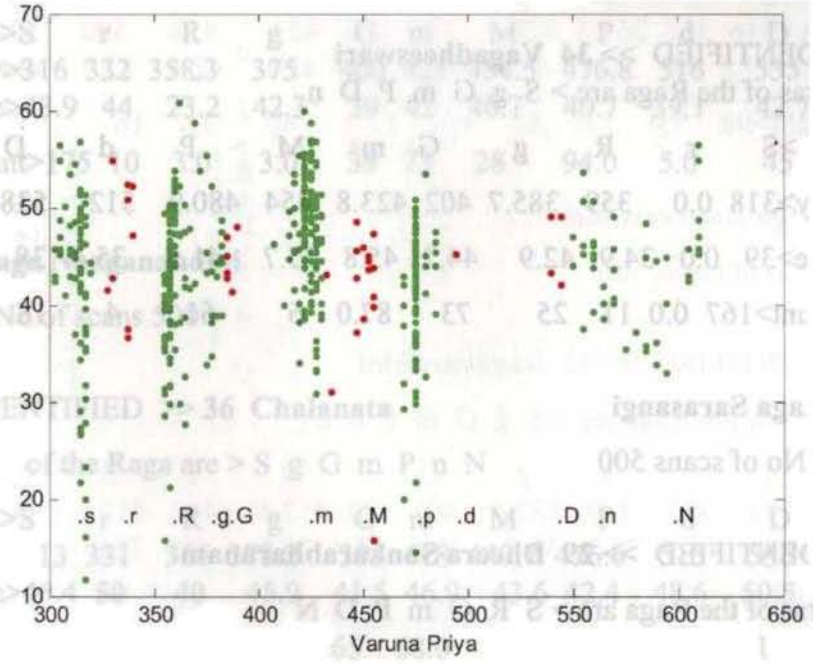
RAGA IDENTIFIED >> **23 Gaurimanohari**
The Swaras of the Raga are > S R g m P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>318	0.0	359	383	400	424	450.9	477	0.0	541	576	613
Amplitude>41	0.0	42.3	39.8	39.0	45	39.9	41.8	0.0	41.1	45	41
Swara count>166	0.0	80	30	4.0	70	14.0	71.0	0.0	26	5.0	7.0



5.2.24 Raga Varunapriya

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **24 Varunapriya**
The Swaras of the Raga are > S R g m P n N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>313	335	358	377	386	424	449.7	475	495	542	561	597
Amplitude>41	46	42	44.6	44.5	47	40.8	40.7	45	45.9	44	43
Swara count>71	9	99	23	6.0	124	17.0	92	1.0	4.0	24	20

5.2.25 Raga Maararanjani

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **31 Yagapriya**
The Swaras of the Raga are > S g G m P d D

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>314	0.0	356	381	395	416	436	475.8	496	528	0.0	0.0
Amplitude>47	0.0	42.6	45.2	48.6	48	50.3	47	46.9	48.4	0.0	0.0
Swara count>104	0.0	7	14	146	95	5.0	83	8.0	37.0	0.0	0.0

5.2.26 Raga Charukesi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **34 Vagadheeswari**
The Swaras of the Raga are > S g G m P D n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>318	0.0	359	385.7	402	423.8	454	480.9	512	538.9	576	615
Amplitude>39	0.0	34.9	42.9	44.2	45.8	35.7	41.5	35.4	38	37.3	39
Swara count>167	0.0	11	25	73	87.0	6	61	4	18	21	7.0

5.2.27 Raga Sarasangi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **29 Dheera Sankarabharanam**
The Swaras of the Raga are > S R G m P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	333	360	384	400	424	448	480	0.0	533	571	608
Amplitude>37.5	38	35.7	40	43	43.6	41	38.0	0.0	35.6	37.4	35
Swara count>88	5	72	60	130	57	18	52	0.0	4	3.0	8.0

5.2.28 Raga Harikamboji

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **16 Chakravakam**

The Swaras of the Raga are > S r G m P D n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	333	360	381	398	418	455.4	476	520	534	557	0.0
Amplitude>33.8	46	43.3	41.3	43	45	45.9	38.9	43.2	47.9	46	0.0
Swara count>31	19	5.0	6.0	68	86	12	41	3.0	179	22	0.0

5.2.29 Raga Dheera Sankarabharanam

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **17 Suryakantham**

The Swaras of the Raga are > S r G m P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	332	358.3	375	400	421	454.5	476.8	516	535	558	603
Amplitude>43.9	44	23.2	42.3	39	42	40.7	40.7	39.1	42.7	42	41
Swara count>175	10	3.0	3.0	39	73	28	94.0	5.0	45	15	19

5.2.30 Raga Naaganandini

Sruti D#, No of scans 500

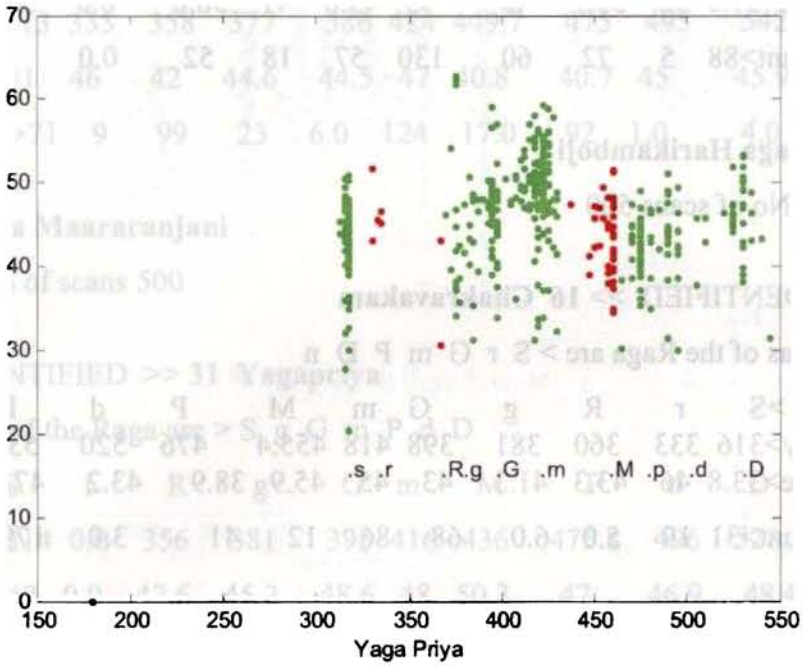
RAGA IDENTIFIED >> **36 Chalanata**

The Swaras of the Raga are > S g G m P n N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>313	331	356	378.2	395	418	449.7	476.6	515	536	563	600
Amplitude>45.4	**50**	**40**	45.9	41.5	46.9	43.6	42.4	48.6	50.5	47	47
Swara count >165	**2**	**13**	17.0	65	68.0	9.0	76.0	3.0	11.0	52	38

5.2.31 Raga Yagapriya

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **31 Yagapriya**
The Swaras of the Raga arc > S g G m P d D

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	332	367.5	379.2	396	420	457	478	500	529	0.0	0.0
Amplitude>43.2	46	36.9	44.5	46.7	49	43.1	42.6	42.7	46.4	0.0	0.0
Swara count>98	5.0	2.0	32	60	137	40	71	16	37	0.0	0.0

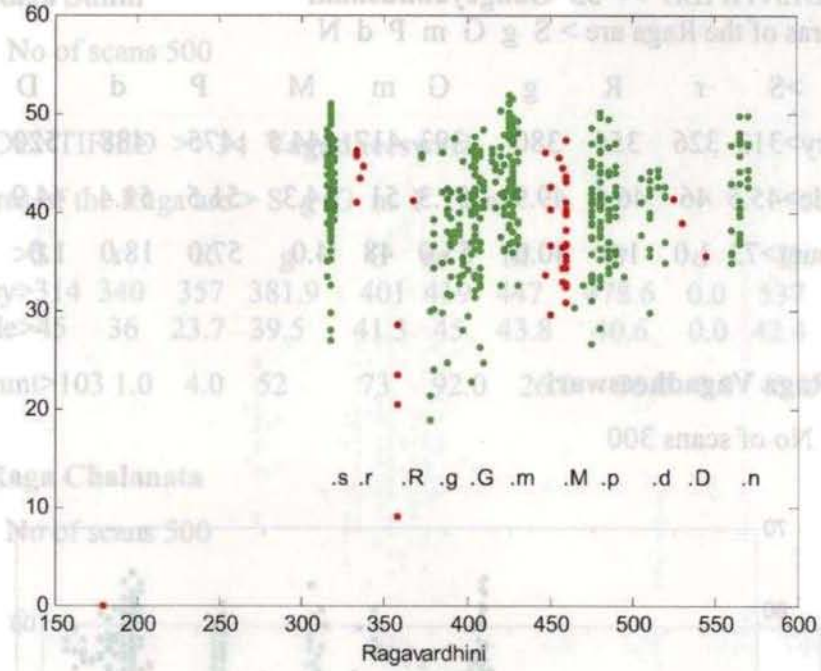
5.2.32 Raga Ragavardhini

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **32 Ragavardhini**

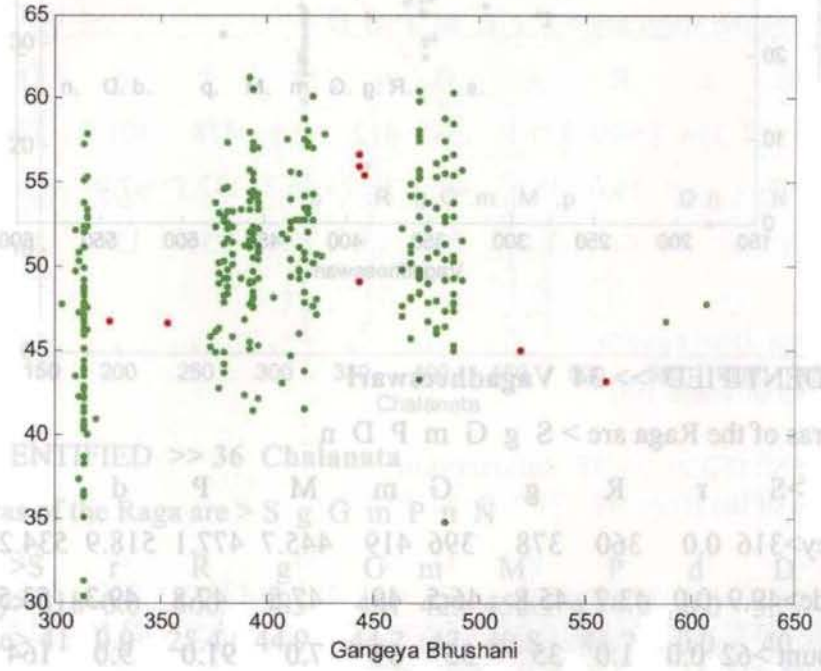
The Swaras of the Raga are > S g G m P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	333	359	382.4	401	425	457.4	480	511.6	533.3	565	0.0
Amplitude>41	44.5	24.5	35.5	38.6	43.4	37.8	40	39.9	38.5	42.5	0.0
Swara count>117	6	5.0	24.0	86	86.0	31.0	88	22	3.0	29	0.0



5.2.33 Raga Gangeyabhushani

Sruti D#, No of scans 500

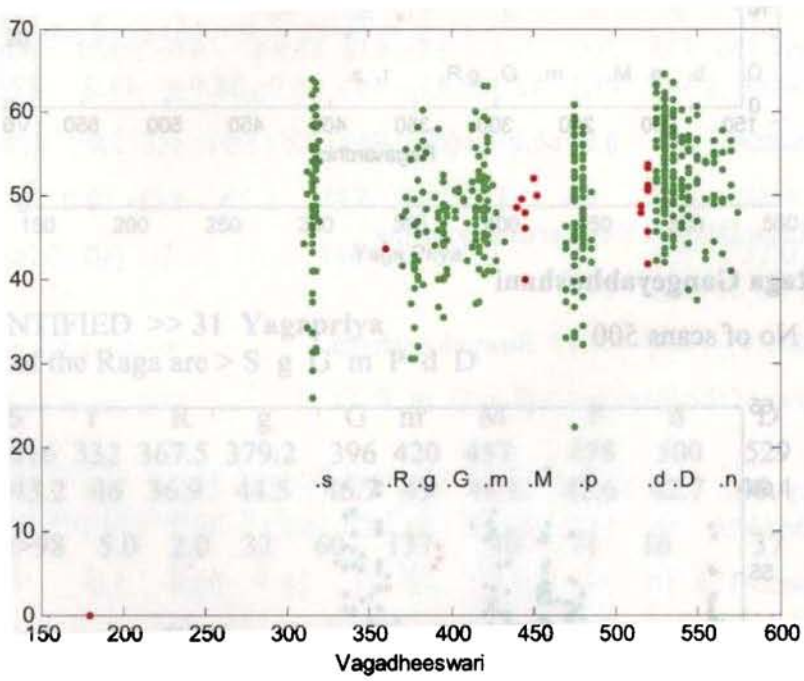


RAGA IDENTIFIED >> **33 Gangeyabhushani**
The Swaras of the Raga are > S g G m P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>313	326	354	380	393	417	444.5	475	488	520	560	598	
Amplitude>45.5	46	46.6	49.9	51.3	51	54.3	51.5	51.4	44.9	43	47.3	
Swara count>73	1.0	1.0	40.0	55.0	48	4.0	57.0	18.0	1.0	1.0	2.0	

5.2.34 Raga Vagadheeswari

Sruti D#, No of scans 300



RAGA IDENTIFIED >> **34 Vagadheeswari**

The Swaras of the Raga are > S g G m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	0.0	360	378	396	419	445.7	477.1	518.9	534.2	562	0.0	
Amplitude>49.9	0.0	43.7	45.8	46.5	49	47.8	47.8	49.3	53.5	50	0.0	
Swara count >62	0.0	1.0	35	35	67	7.0	91.0	9.0	164	28	0.0	

5.2.35 Raga Sulini

Sruti D#, No of scans 500

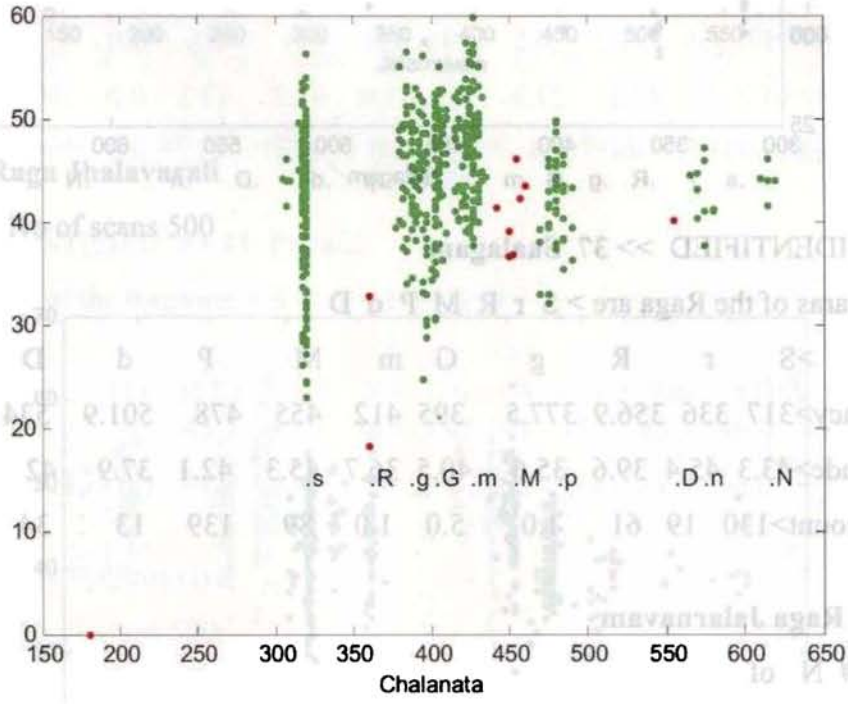
RAGA IDENTIFIED >> **34 Vagadheeswari**

The Swaras of the Raga are > S g G m P D n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>314	340	357	381.9	401	419	447	478.6	0.0	537	560	609
Amplitude>45	36	23.7	39.5	41.3	45	43.8	40.6	0.0	42.4	40.8	46
Swara count>103	1.0	4.0	52	73	92.0	26.0	76.0	0.0	43.0	17	13

5.2.36 Raga Chalanata

Sruti D#, No of scans 500



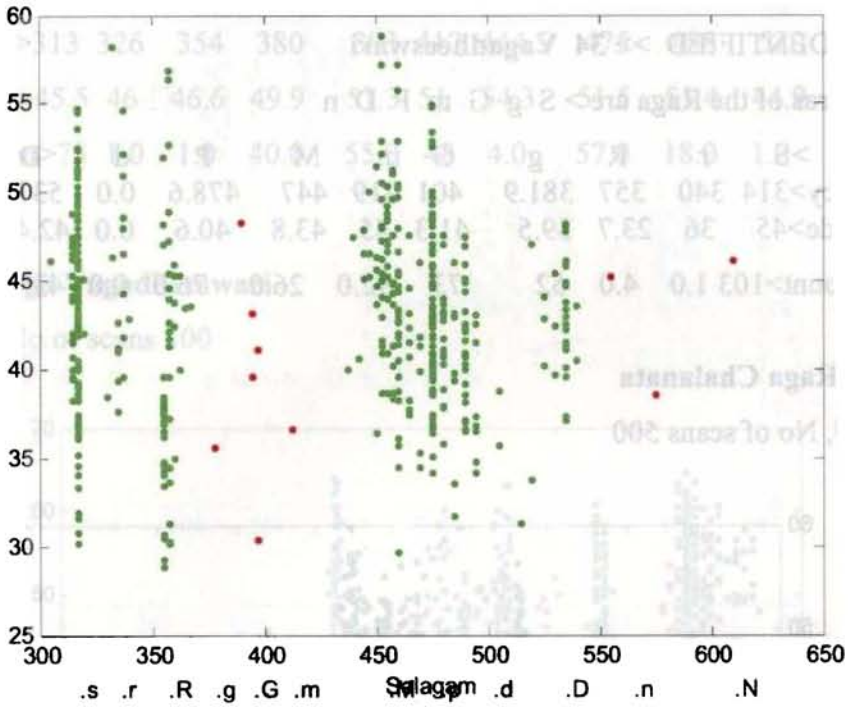
RAGA IDENTIFIED >> **36 Chalanata**

The Swaras of the Raga are > S g G m P n N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency> 318	0.0	360	385	401	425	452.5	4 79.9	0.0	555	573	615
Amplitude> 41	0.0	25.4	44.9	44.2	47	40.8	41.7	0.0	40	42.5	43
Swara count>126	0.0	2.0	54.0	115	126	7	44.0	0.0	1.0	11.0	5.0

5.2.37 Raga Saalagam

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **37 Saalagam**

The Swaras of the Raga are > S r R M P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>317	336	356.9	377.5	395	412	455	478	501.9	534	565	610
Amplitude	>43.3	45.4	39.6	35.6	40.5	36.7	45.3	42.1	37.9	42.9	41.9	46
Swara count	>130	19	61	1.0	5.0	1.0	89	139	13	34	2.0	1.0

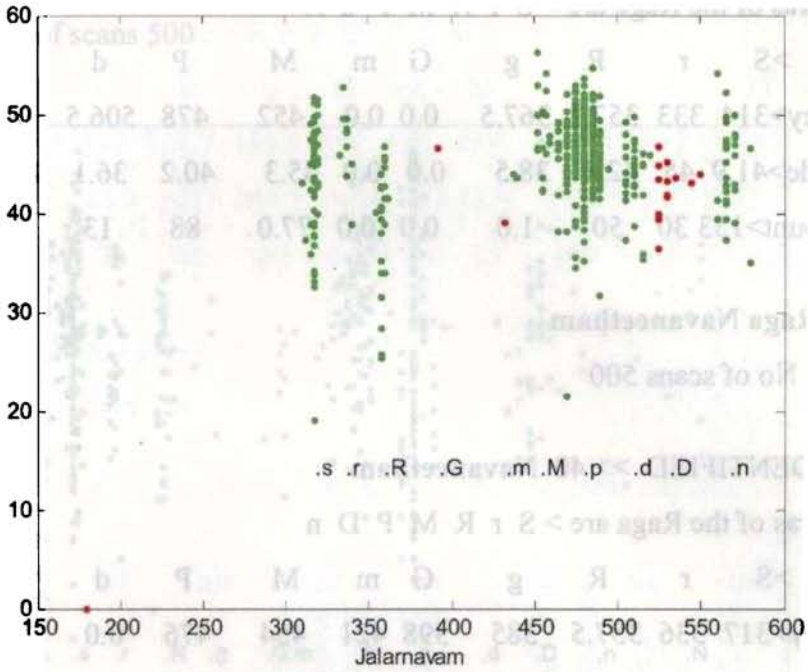
5.2.38 Raga Jalarnavam

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **38 Jalarnavam**

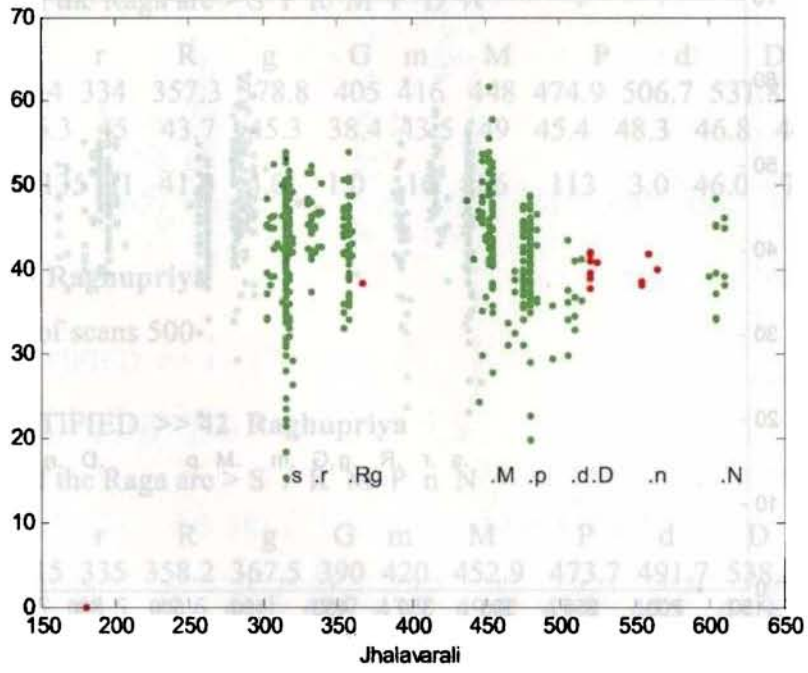
The Swaras of the Raga are > S r R M P d n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>317	336	358.5	0.0	392	432	453.6	479.7	509	530.8	567	0.0
Amplitude	>43.8	46	38.6	0.0	46.6	39	48.0	46.5	43.9	42.5	44	0.0
Swara count	>67	11	23.0	0.0	1.0	1.0	20.0	259	32.0	13.0	33	0.0



5.2.39 Raga Jhalavarali

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **39 Jhalavarali**

The Swaras of the Raga are > S r R M P d N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>314	333	357.1	367.5	0.0	0.0	452	478	506.5	520.7	558	606
Amplitude>41.9	45	42.4	38.5	0.0	0.0	45.3	40.2	36.1	40.3	39.6	41
Swara count>153	30	50	1.0	0.0	0.0	77.0	88	13	7.0	4	12

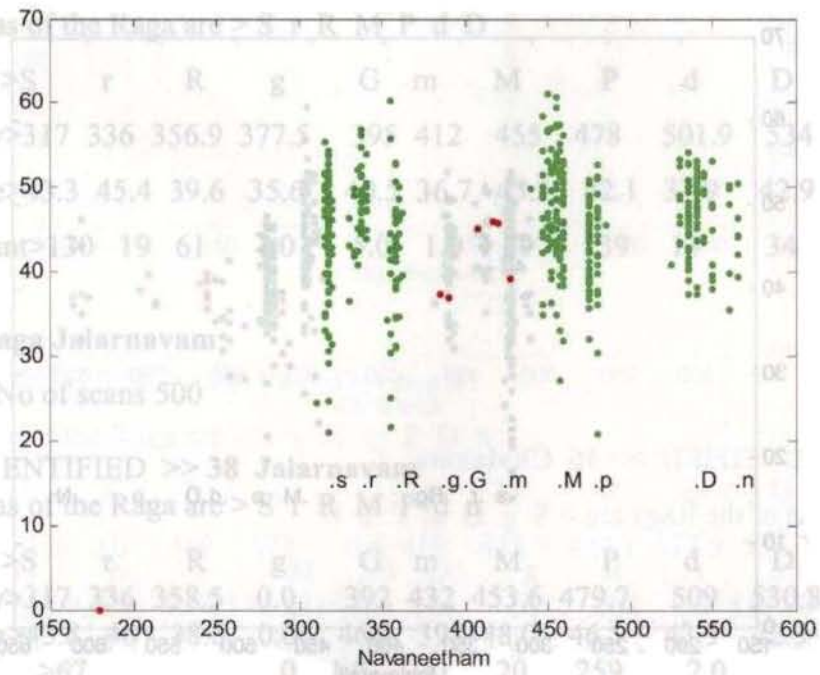
5.2.40 Raga Navaneetham

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **40 Navaneetham**

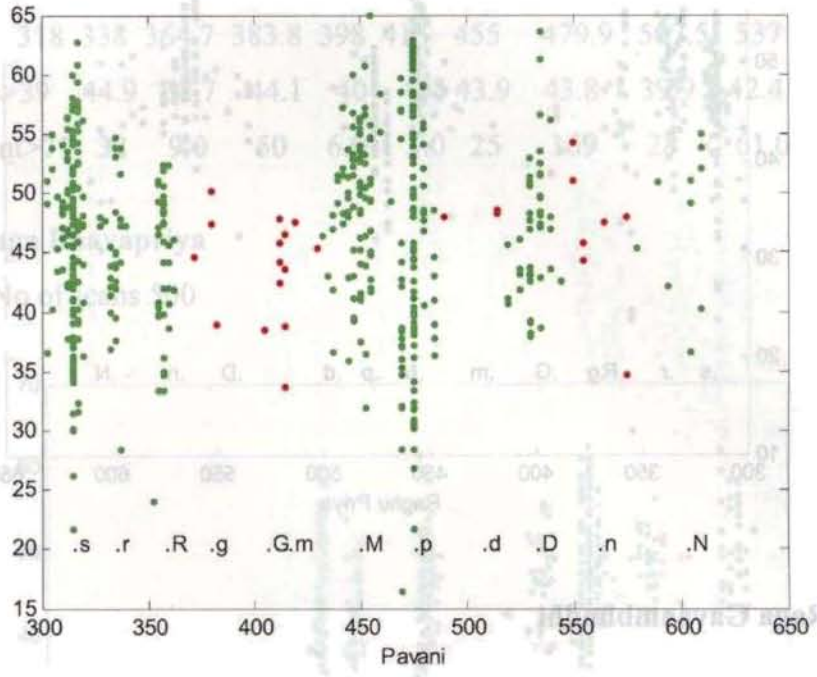
The Swaras of the Raga are > S r R M P D n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	336	357.5	385	398	421	454	476	0.0	538	562	0.0
Amplitude>44.7	47	42.2	37.3	41	43.6	47.2	43.3	0.0	46.5	44	0.0
Swara count>103	41	49	1.0	2.0	3.0	112	73	0.0	85	11	0.0



5.2.41 Raga Pavani

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **41 Pavani**

The Swaras of the Raga are > S r R M P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>314	334	357.3	378.8	405	416	448	474.9	506.7	531.8	560.7	602
Amplitude>46.3	45	43.7	45.3	38.4	43.5	49	45.4	48.3	46.8	46.5	47.6
Swara count>135	31	41.0	4.0	1.0	10	86	113	3.0	46.0	7.0	10.0

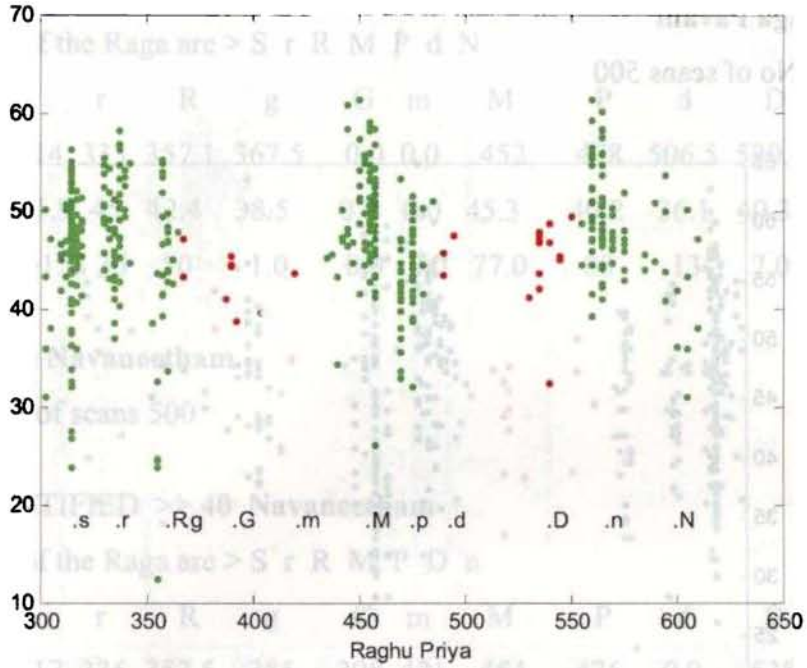
5.2.42 Raga Raghupriya

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **42 Raghupriya**

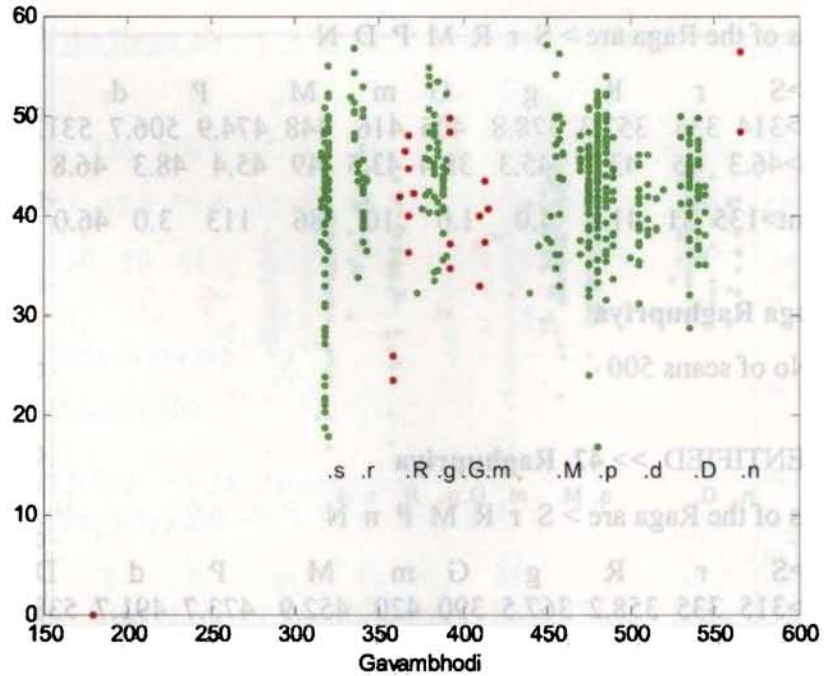
The Swaras of the Raga are > S r R M P n N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>315	335	358.2	367.5	390	420	452.9	473.7	491.7	538.5	565	598
Amplitude>45	48.5	42.6	45.1	42.7	43.7	49.6	43.9	45.5	44.9	49	43.5
Swara count>115	54	31	2.0	5.0	1.0	83	54	3.0	13	70	16



5.2.43 Raga Gavaambhodhi

Sruti D#, No of scans 500



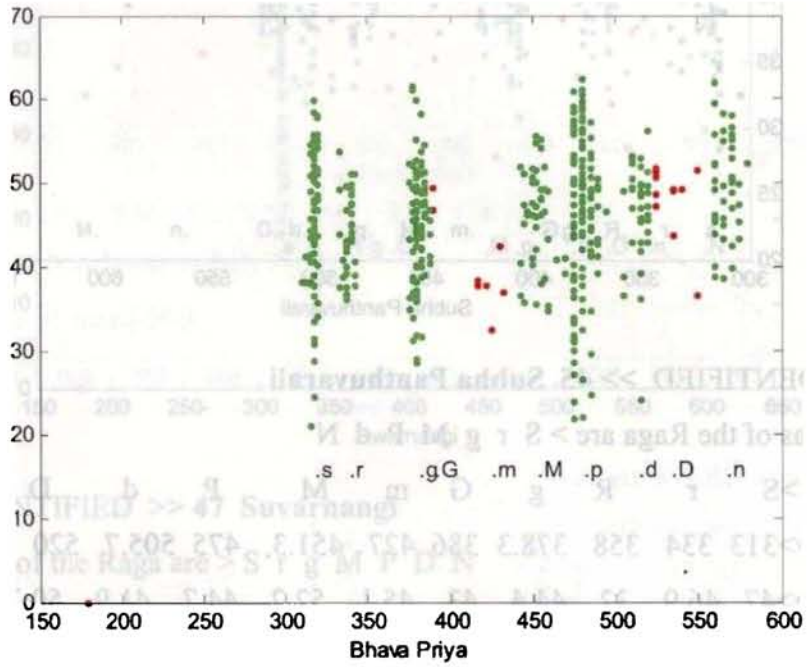
RAGA IDENTIFIED >> **43 Gavaambhodhi**

The Swaras of the Raga are > S r g M P d D

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>318	338	364.7	383.8	398	413	455	479.9	507.5	537	565	0.0
Amplitude>39	44.9	38.7	44.1	40	40	43.9	43.8	39.9	42.4	52.4	0.0
Swara count>71	32	9.0	50	6.0	3.0	25	169	28	61.0	2.0	0.0

5.2.44 Raga Bhavapriya

Sruti D#, No of scans 500



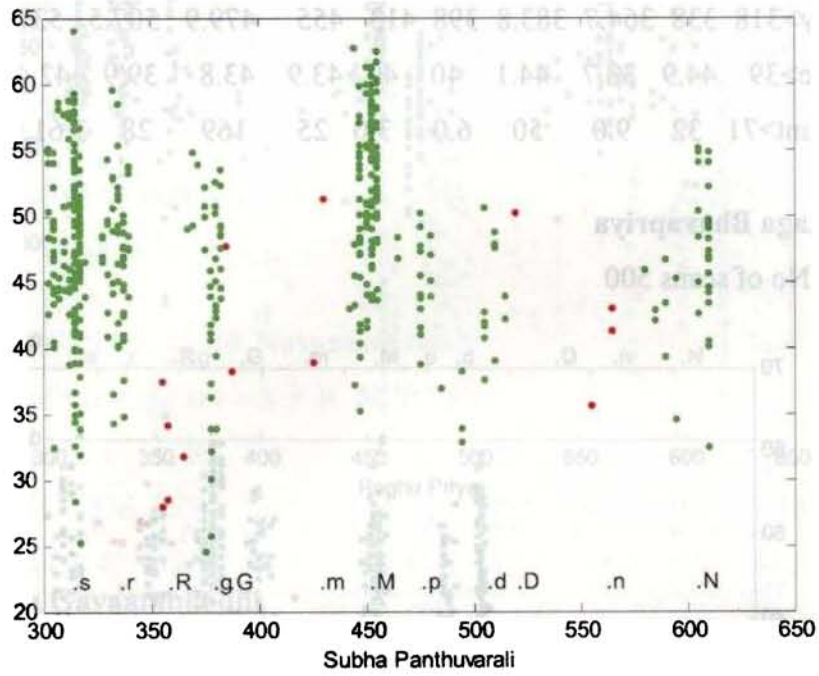
RAGA IDENTIFIED >> **44 Bhavapriya**

The Swaras of the Raga are > S r g M P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	338	0.0	381.1	390	424.2	452.0	479.9	513	533.6	566.2	0.0
Amplitude>46.2	43	0.0	45	48.2	37.6	46.1	46.0	46.5	48.0	49	0.0
Swara count>78	38	0.0	89	2.0	6.0	42.0	135	37.0	11	42	0.0

5.2.45 Raga Subha Panthuvarali

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **45 Subha Panthuvarali**

The Swaras of the Raga are > S r g M P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>313	334	358	378.3	386	427	451.3.	475	505.7	520	561.7	603	
Amplitude>47	46.9	32	44.4	43	45.1	52.2	44.7	41.9	50.2	39.9	46.3	
Swara count>165	58	5.0	42.0	2.0	2.0	127	19.0	15.0	1.0	3.0	33	

5.2.46 Raga Shadvidha Margini

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **70 Nasika Bhushani**

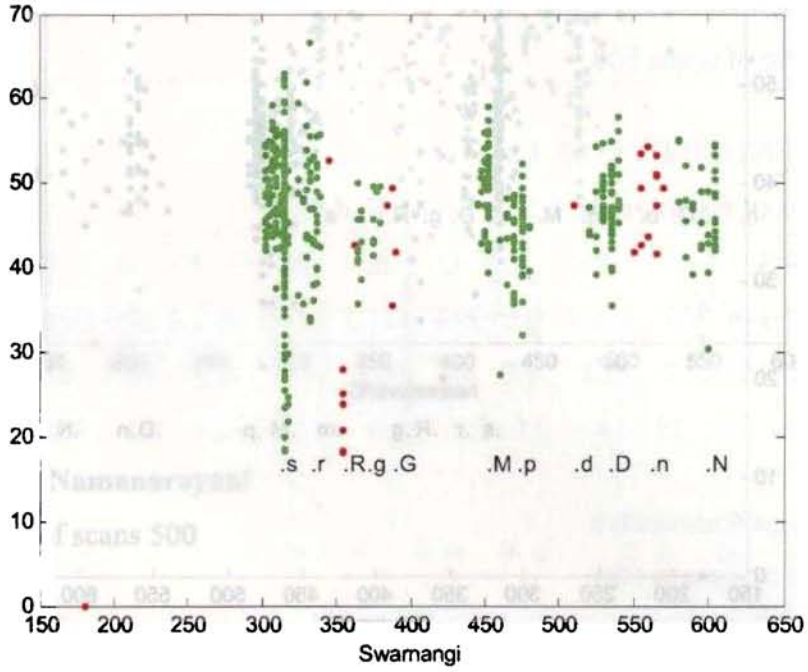
The Swaras of the Raga are > S g G M P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	338	359.3	378.8	391.5	423	456	476	520	537	570	585	

Amplitude>45	43.4	37.1	43.5	42.2	43.1	44.9	43.3	34.8	43.6	42.3	39
Swara count >253	13	11	14.0	15.0	4.0	61.0	43	1.0	64	18	1.0

5.2.47 Raga Suvarnangi

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **47 Suvarnangi**

The Swaras of the Raga are > S r g M P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>312	333	354	370.4	387	0.0	451	472	510	533.1	560.8	597.2
Amplitude> 46	47.3	28.7	44.1	43.6	0.0	50	43.4	47.3	47.5	48.3	46.7
Swara count>191	47	8.0	19	4	0.0	43	51	1.0	59.0	12.0	37.0

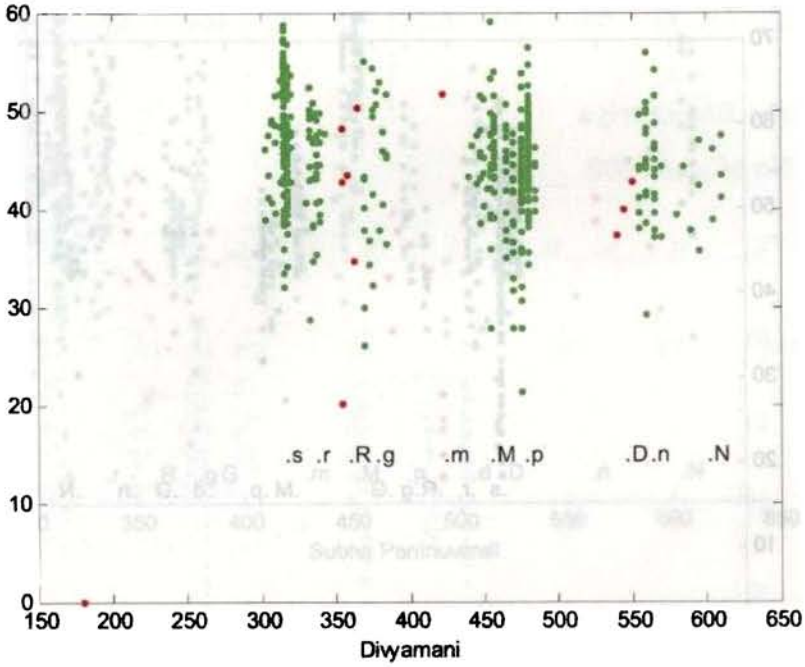
5.2.48 Raga Divyamani

Sruti D#, No of scans 500

RAGA IDENTIFIED >> 48 Divyamani

The Swaras of the Raga are > S r g M P n N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>315	336	358.3	376.5	0.0	422	453.8	476.6	0.0	545	561.8	600	
Amplitude>47	44.6	39.9	43.2	0.0	51.7	45.5	43.9	0.0	39.9	44.4	42.4	
Swara count>143	38	6.0	25	0.0	1.0	52	161	0.0	3.0	40	10	



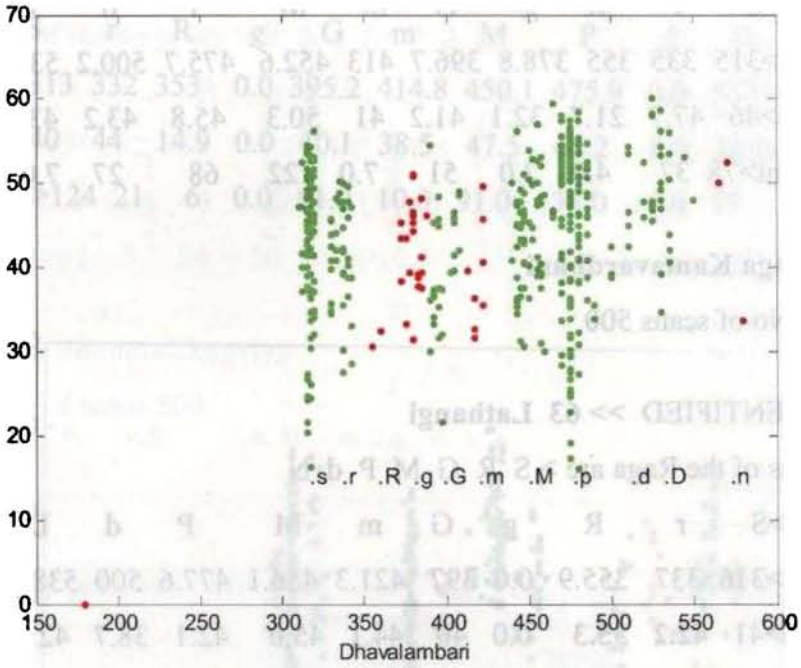
5.2.49 Raga Dhavalambari

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **49 Dhavalambari**

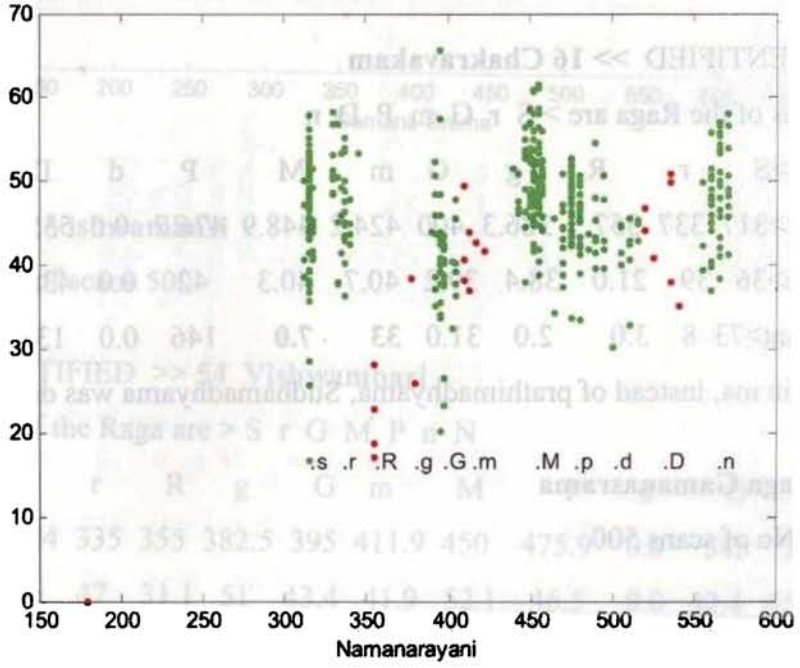
The Swaras of the Raga are > S r G M P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	335	357.5	379	397.6	419	449	475.7	511.5	530.9	571.7	0.0	
Amplitude>43	41.5	31.5	42.5	39.7	38.9	44	45.7	46.5	49.7	45.4	0.0	
Swara count >99	39	2.0	22	28.0	8.0	66	161	13.0	27.0	3.0	0.0	



5.2.50 Raga Namanarayani

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **50 Namanarayani**

The Swaras of the Raga are > S r G M P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>315	335	355	378.8	396.7	413	452.6	475.7	500.2	530	563.6	0.0
Amplitude>46	47.7	21.7	32.1	41.2	41	50.3	45.8	43.2	43.6	48.5	0.0
Swara count>78	37	4.0	2.0	51	7.0	122	68	27	7.0	49.0	0.0

5.2.51 Raga Kamavardhani

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **63 Lathangi**

The Swaras of the Raga are > S R G M P d N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	337	355.9	0.0	397	421.3	456.1	477.6	500	538	576.7	612.5
Amplitude>41	**42.2**	**35.3**	0.0	40	44.1	45.0	42.1	38.7	42.2	40.2	46.9
Swara count>162	**25**	**34**	0.0	28	38.0	91.0	96.0	9.0	3.0	3.0	4.0

5.2.52 Raga Ramapriya

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **16 Chakravakam**

The Swaras of the Raga are > S r G m P D n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	337	357.5	386.3	400	424.2	448.9	476.7	0.0	535.7	565.7	0.0
Amplitude>36	39	21.0	38.4	39.2	40.7	40.3	42	0.0	43.0	41.6	0.0
Swara count>73	8	3.0	2.0	31.0	**33**	**7.0**	146	0.0	133	22	0.0

A change in ma, instead of prathimadhyama, Sudhamadhyama was detected.

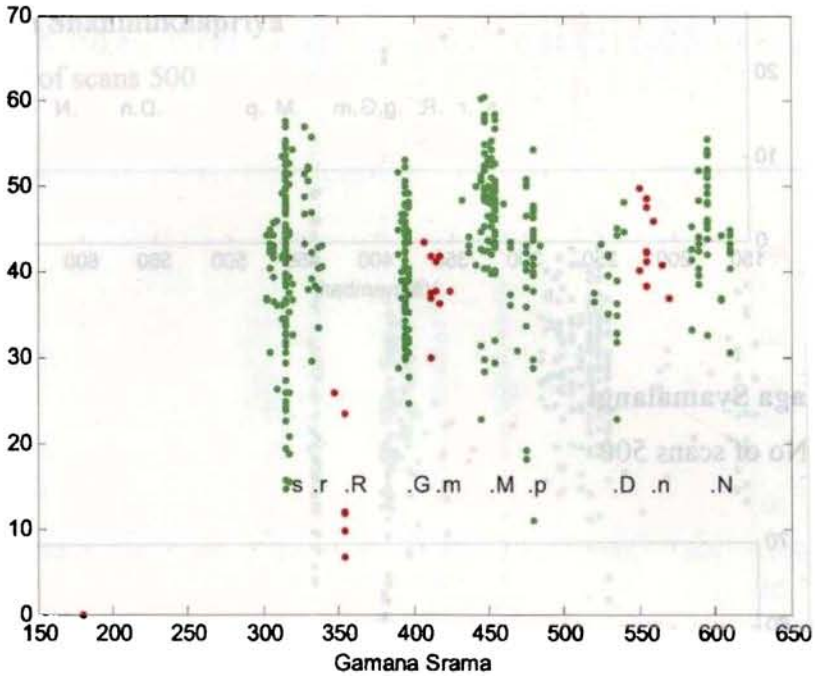
5.2.53 Raga Gamanasrama

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **53 Gamanasrama**

The Swaras of the Raga are > S r G M P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>313	332	353	0.0	395.2	414.8	450.1	475.9	0.0	532	556.8	596
Amplitude>40	44	14.9	0.0	40.1	38.5	47.5	40.2	0.0	38.6	43.1	45.2
Swara count>124	21	6	0.0	81.0	10.0	91.0	38.0	0.0	17	11	46



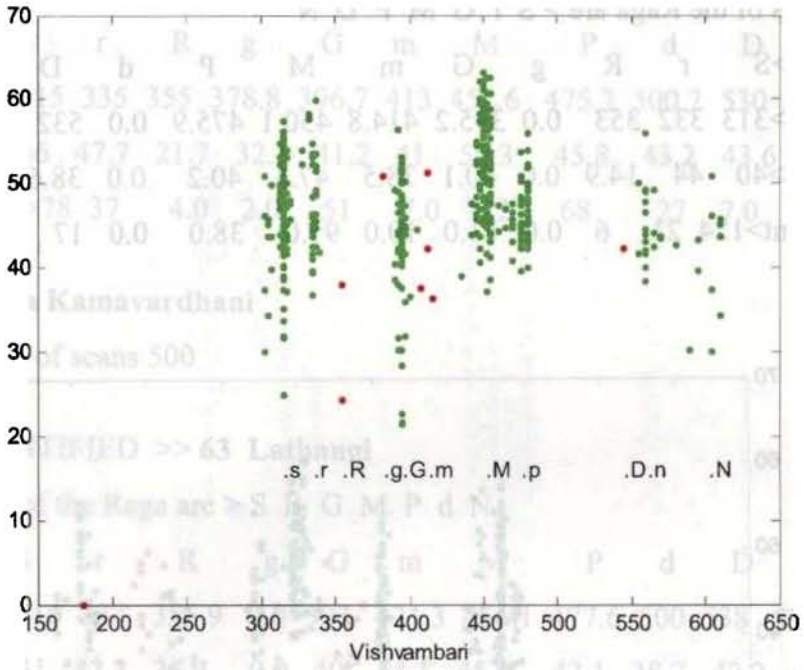
5.2.54 Raga Vishwambari

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **54 Vishwambari**

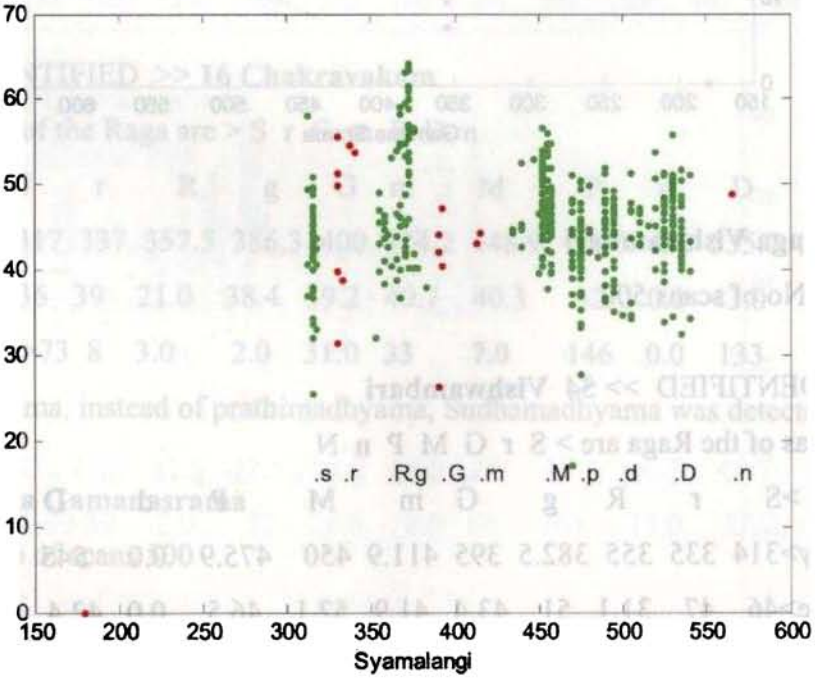
The Swaras of the Raga are > S r G M P n N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>314	335	355	382.5	395	411.9	450	475.9	0.0	545	561	601.7
Amplitude>46	47	31.1	51	43.4	41.9	52.1	46.5	0.0	42.4	45.2	40.8
Swara count >129	40	2	1.0	75.0	4.0	120	57.0	0.0	1.0	20.0	12.0



5.2.55 Raga Syamalangi

Sruti D#, No of scans 500



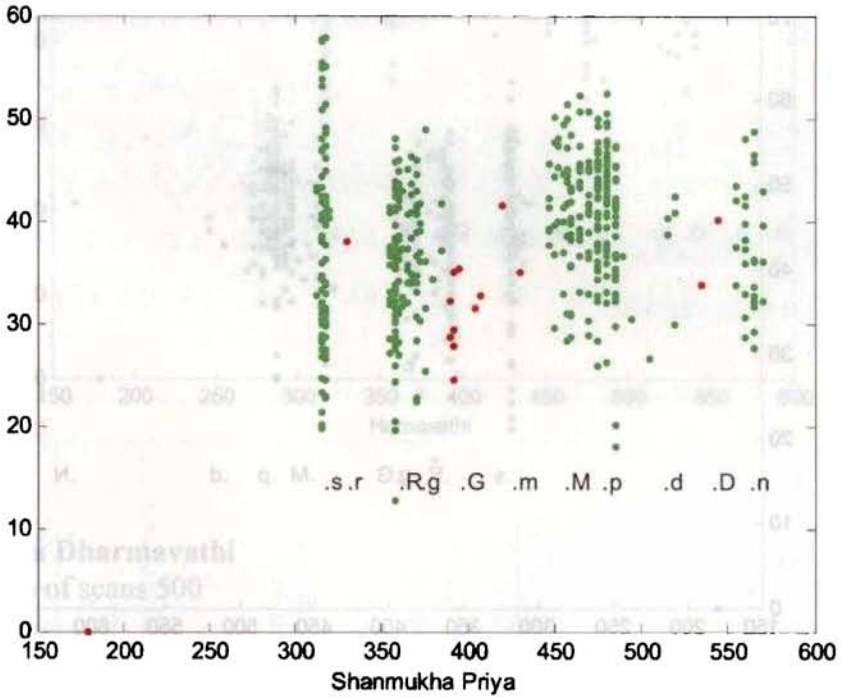
RAGA IDENTIFIED >> **55 Syamalangi**

The Swaras of the Raga are > S R g M P d D

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>315	332	359	371.6	391	413.8	453.6	474.1	497	529	565	0.0
Amplitude>42.6	46.8	43	52.2	40.1	43.7	47.5	42.0	44.0	45.5	48.9	0.0
Swara count >52	8	24	50	5.0	2.0	92	60	59	80	1.0	0.0

5.2.56 Raga Shanmukhapriya

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **56 Shanmukhapriya**

The Swaras of the Raga are > S R g M P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	330	359.5	372.4	395	425	455.2	477	512.9	540	562.7	0.0
Amplitude>37	38	35.8	36.3	30	38.2	41	41	35.6	36.9	37.3	0.0
Swara count>88	1.0	100	31.0	9.0	2.0	48	173	7.0	2.0	30	0.0

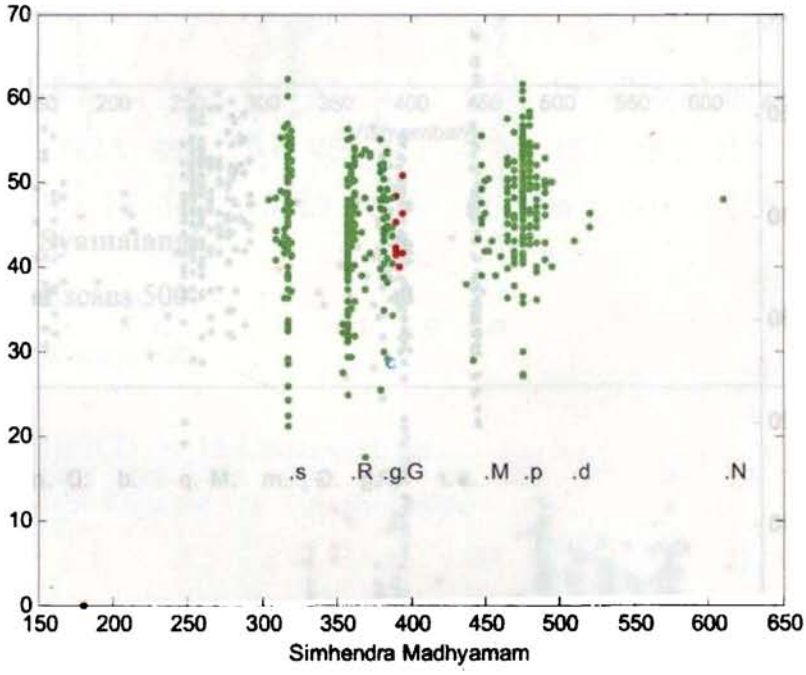
5.2.57 Raga Simhendramadhyamam

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **57 Simhendramadhyamam**

The Swaras of the Raga are > S R g M P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	317	0.0	359.1	381.0	391	0.0	449.1	475.8	508	0.0	0.0	610
Amplitude>	45.4	0.0	43.5	44.3	44.3	0.0	44.5	48.7	44.9	0.0	0.0	48
Swara count>	84	0.0	111	48.0	9.0	0.0	19.0	187.0	5.0	0.0	0.0	1.0



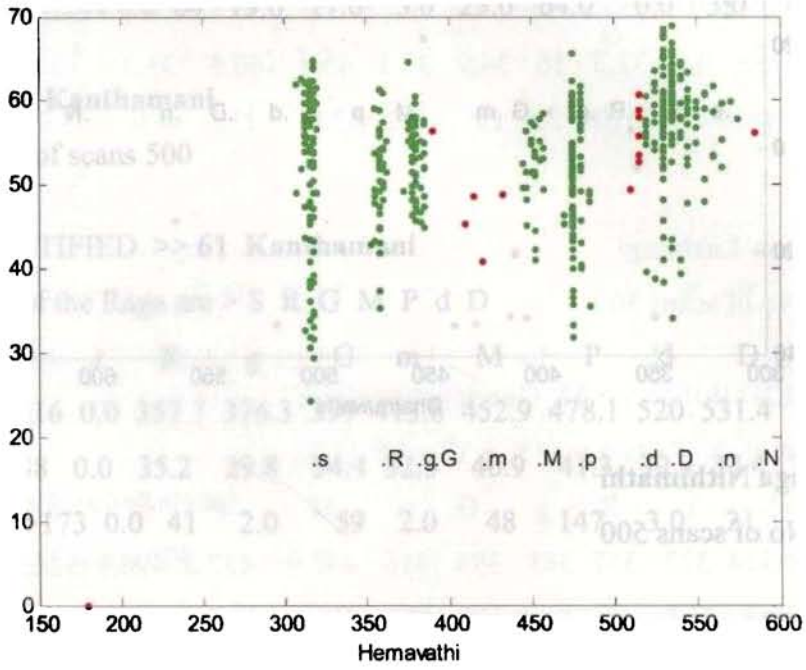
5.2.58 Raga Hemavathi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **58 Hemavathi**

The Swaras of the Raga are > S R g M P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>315	0.0	357.8	380.1	390	419.4	451.8	476.7	514.3	533	561.1	585
Amplitude	>51.1	0.0	51.0	52.9	56.4	45.9	52.0	50.6	55.5	58.3	56	56
Swara count	>94	0.0	46.0	55.0	1.0	4.0	30.0	92.0	7.0	153	14	1.0



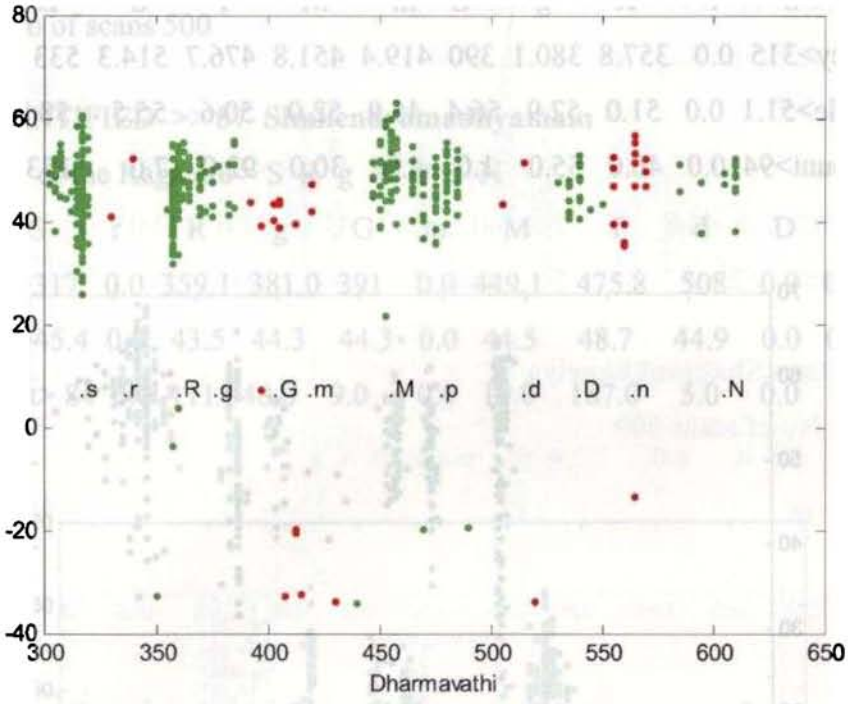
5.2.59 Raga Dharmavathi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **59 Dharmavathi**

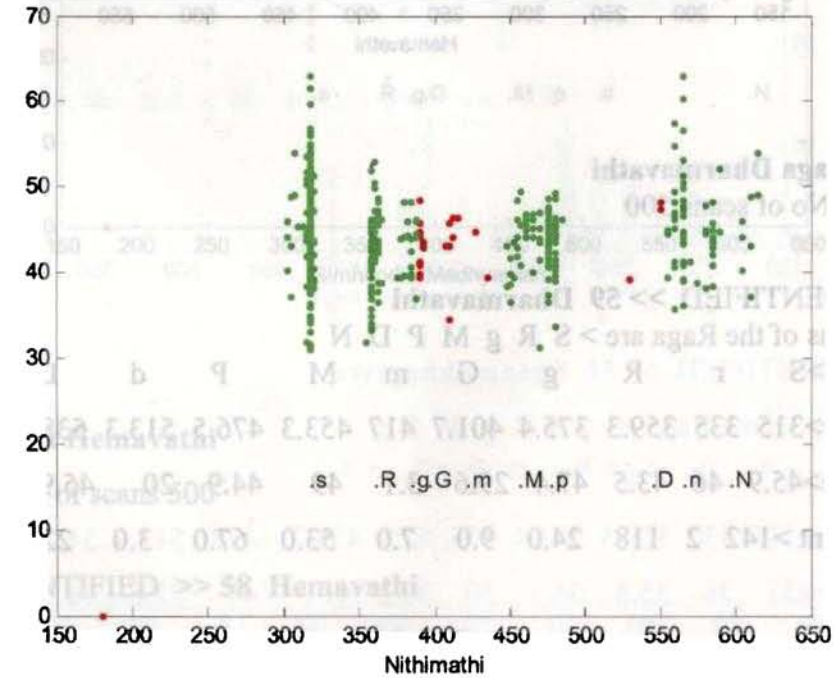
The Swaras of the Raga are > S R g M P D N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>315	335	359.3	375.4	401.7	417	453.3	476.5	513.3	538.2	562	604
Amplitude	>45.9	46	43.5	47.4	29.6	3.1	49	44.9	20	45.9	43.6	47
Swara count	>142	2	118	24.0	9.0	7.0	53.0	67.0	3.0	22.0	1 6	15



5.2.60 Raga Nithimathi

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **60 Nithimathi**

The Swaras of the Raga are > S R g M P n N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	317	0.0	359.3	383.3	395	420.5	455	475	0.0	543.3	564.7	595.3
Amplitude>	44	0.0	42.3	43.0	42.7	44.2	43.3	43.4	0.0	44.9	45.8	44.6
Swara count >	244	0.0	64	19.0	17.0	5.0	23.0	64.0	0.0	3.0	46.0	20

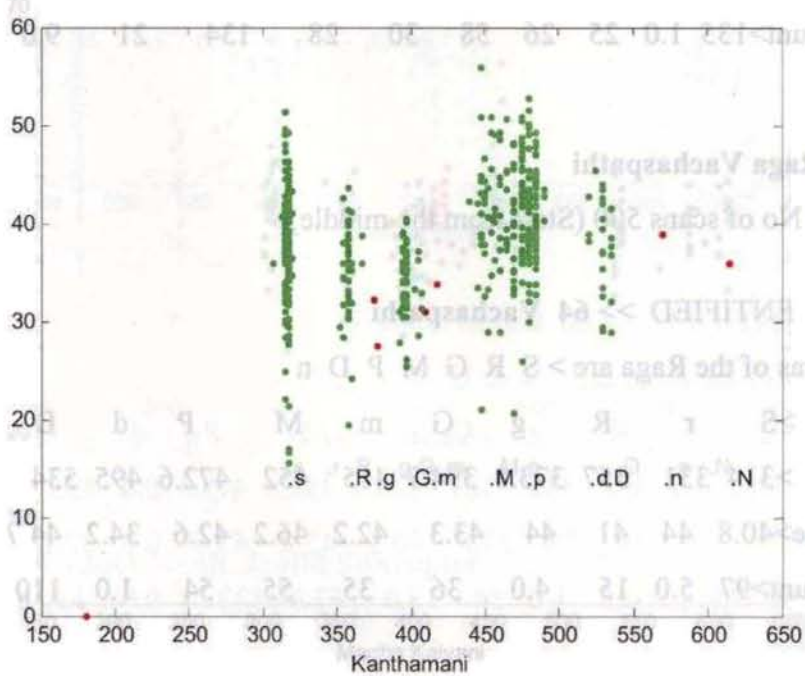
5.2.61 Raga Kanthamani

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **61 Kanthamani**

The Swaras of the Raga are > S R G M P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	316	0.0	357.7	376.3	397	413.8	452.9	478.1	520	531.4	570	615
Amplitude>	38	0.0	35.2	29.8	34.4	32.3	40.9	41.3	39.9	37.4	38.8	35.9
Swara count>	173	0.0	41	2.0	59	2.0	48	147	3.0	21	1.0	1.0



5.2.62 Raga Rishabhapriya

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **64 Vachaspathi**
The Swaras of the Raga are > S R G M P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	317	0.0	357.7	380	403	423.8	455.2	478.2	516.3	533.8	563.5	0.0
Amplitude>	38	0.0	32.3	36	34.9	38.1	43.1	40.5	33.2	33.6	37.1	0.0
Swara count>	123	0.0	106	3.0	19	4.0	65.0	132	4.0	8.0	24.0	0.0

5.2.63 Raga Lathangi

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **33 Gangeyabhushani**

The Swaras of the Raga a re > S g G m P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	314	327	357	381	394	416	447.9	477.2	496.9	526.7	563.3	594
Amplitude>	48	51.9	46	51.2	49	49.7	49.1	45.7	45.0	44.3	50	53.9
Swara count>	135	1.0	25	26	58	30	28	134	21	9.0	6.0	23

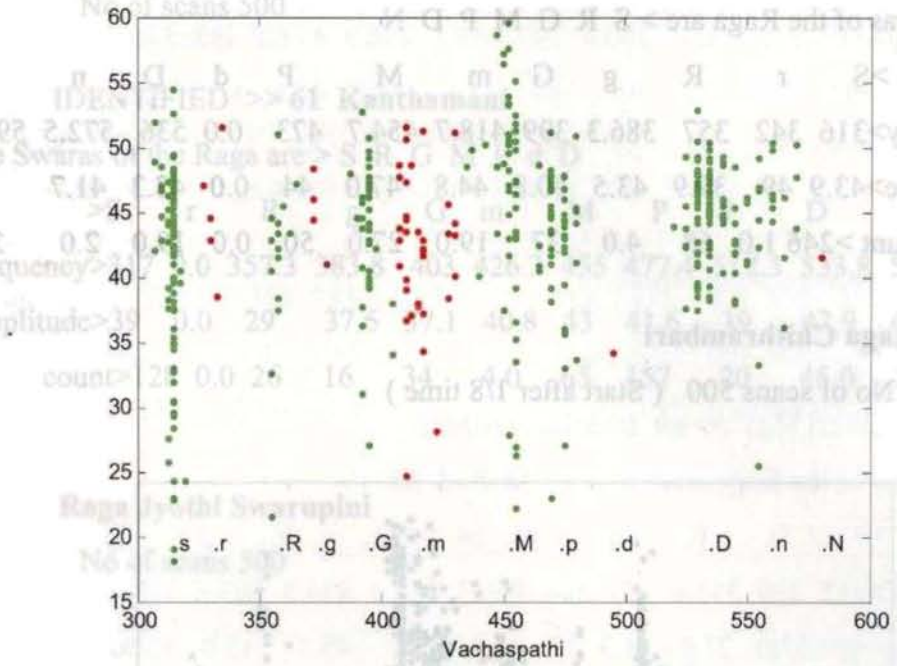
5.2.64 Raga Vachaspathi

Sruti D#, No of scans 500 (Start from the middle)

RAGA IDENTIFIED >> **64 Vachaspathi**

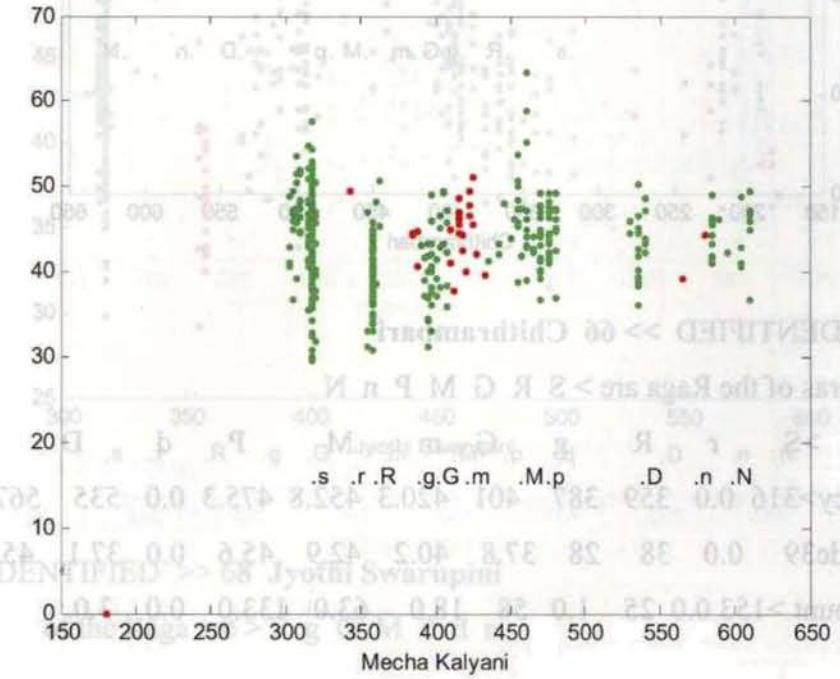
The Swaras of the Raga are > S R G M P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	314	331	357	373.8	394.7	415	452	472.6	495	534	558.8	580
Amplitude>	40.8	44	41	44	43.3	42.2	46.2	42.6	34.2	44.7	44	41.6
Swara count>	97	5.0	15	4.0	36	35	55	54	1.0	110	24.0	1.0



5.2.65 Raga Mechakalyani

Sruti D#, No of scans 500



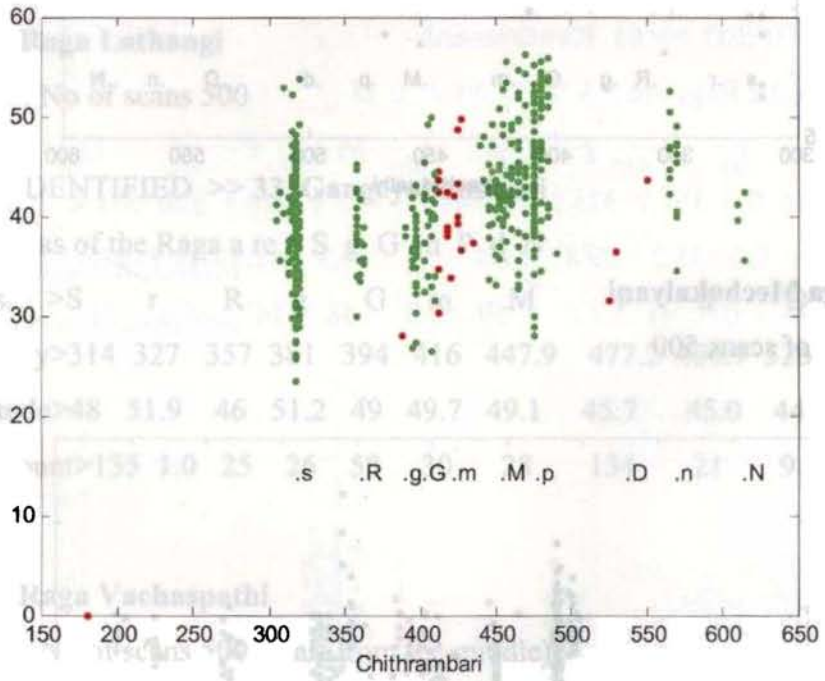
RAGA IDENTIFIED >> **65 Mechakalyani**

The Swaras of the Raga are > S R G M P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	342	357	386.3	399	418.7	454.7	473	0.0	536	572.5	596.7
Amplitude>43.9	49	39.9	43.5	40.8	44.8	47.0	44	0.0	43.3	41.7	44.6
Swara count >246	1.0	68	4.0	37	19.0	27.0	50	0.0	19.0	2.0	23

5.2.66 Raga Chithrambari

Sruti D#, No of scans 500 (Start after 1/8 time)



RAGA IDENTIFIED >> **66 Chithrambari**

The Swaras of the Raga are > S R G M P n N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>316	0.0	359	387	401	420.3	452.8	475.3	0.0	535	567.8	612.5
Amplitude39	0.0	38	28	37.8	40.2	42.9	45.6	0.0	37.1	45.4	39.6
Swara count >153	0.0	25	1.0	58	18.0	63.0	133.0	0.0	3.0	16.0	4.0

5.2.67 Raga Sucharitra

Sruti D#, No of scans 500

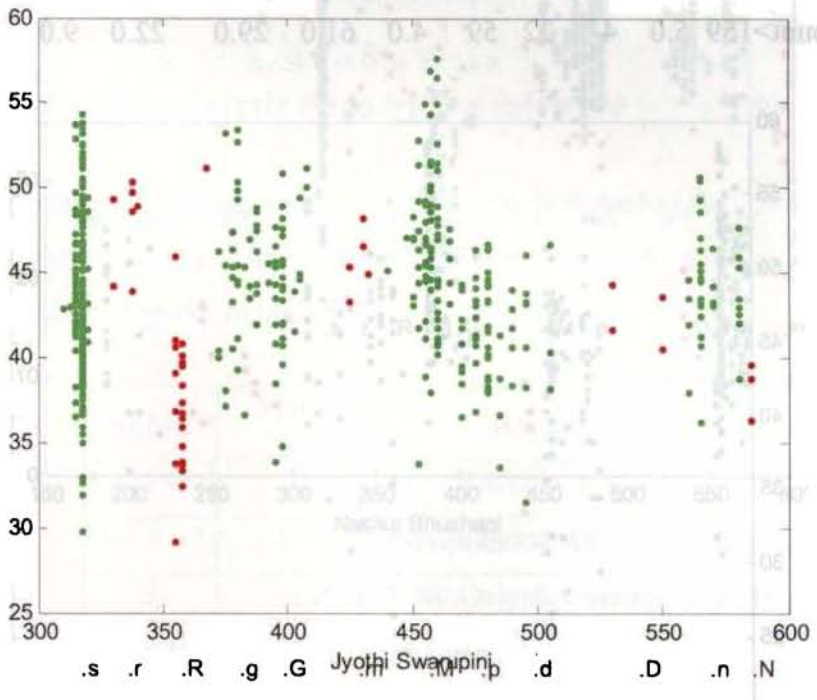
RAGA IDENTIFIED >> **61 Kanthamani**

The Swaras of the Raga are > S R G M P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	0.0	357.3	383.8	403	426.3	455	477.4	512.3	533.8	561.7	615	
Amplitude>39	0.0	29	37.6	37.1	40.8	43	41.6	39	42.9	45.9	42.5	
Swara count>128	0.0	26	16	34	4.0	65	157	20	45.0	3.0	1.0	

5.2.68 Raga Jyothi Swarupini

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **68 Jyothi Swarupini**

The Swaras of the Raga are > S g G M P d n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	335	357	380.4	397	428.5	456.3	477.2	498	540.0	568.7	585	
Amplitude >43	47.9	37	45	44	45.6	46.8	41.8	41.2	42.5	44.1	38	
Swara count>93	7.0	23	37	38	5.0	72	54	10.0	4.0	35.0	3.0	

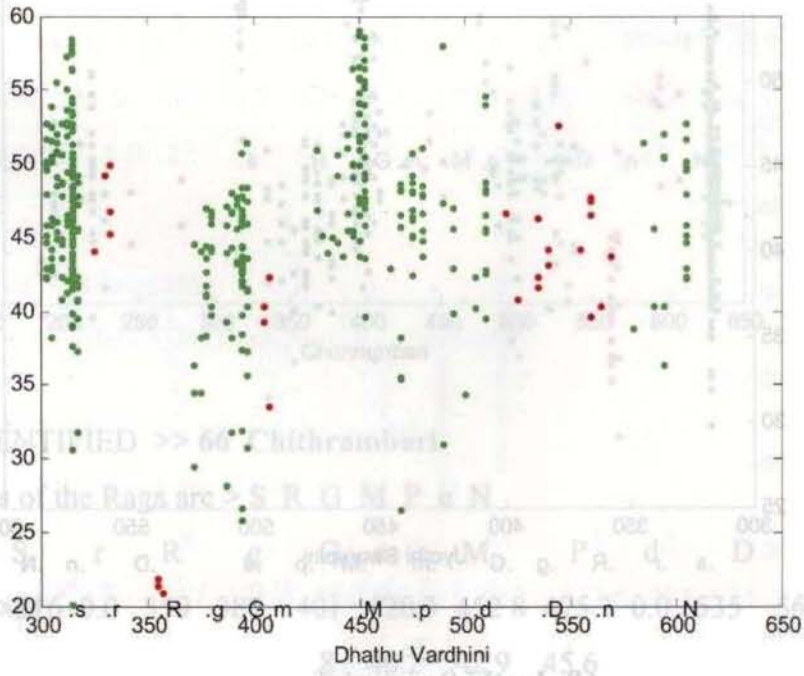
5.2.69 Raga Dhathuvardhini

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **69 Dhathuvardhini**

The Swaras of the Raga are > S g G M P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>312	330	355.6	377	394	406.3	448.4	474.5	503.6	535.6	561.4	599	
Amplitude>46	47.0	21.3	41.3	42	38.8	50.4	45.1	45.0	45.5	44.2	46.3	
Swara count>159	5.0	4	22	59	4.0	61.0	29.0	22.0	9.0	7.0	22.0	



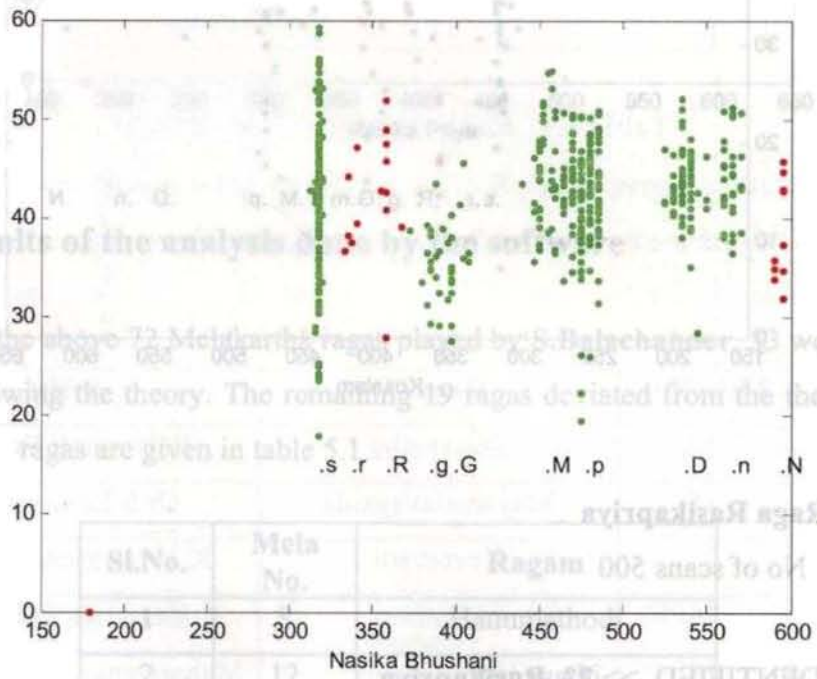
5.2.70 Raga Nasikabhushani

Sruti D#, No of scans 500

RAGA IDENTIFIED >> 70 Nasikabhushani

The Swaras of the Raga are > S g G M P D n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>317	336	358	383.8	397	0.0	453	477	0.0	536	563.8	593.5
Amplitude>42	40.5	43	36	35	0.0	44.6	42.3	0.0	43.1	43.6	38.4
Swara count>151	6	9.0	14	22	0.0	42.0	131	0.0	68.0	33.0	10



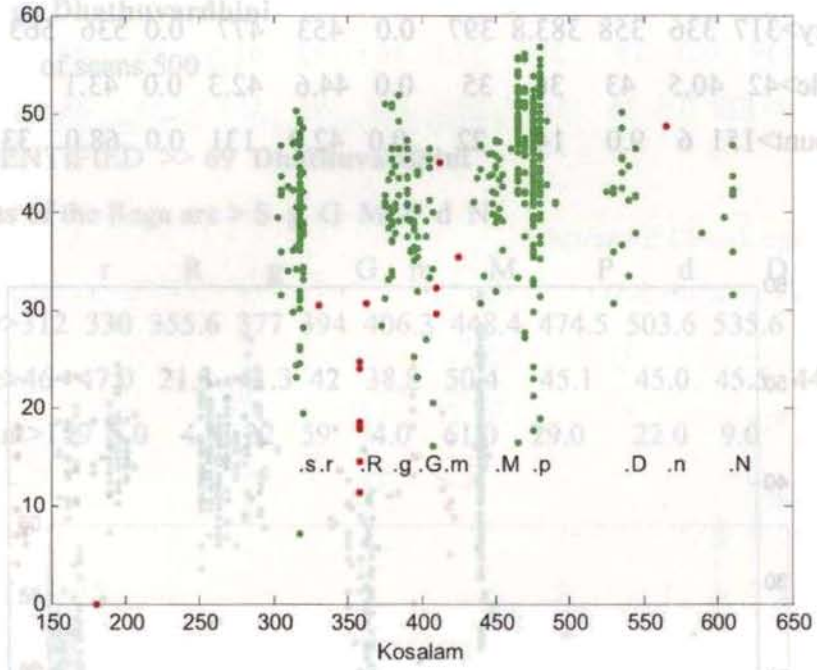
5.2.71 Raga Kosalam

Sruti D#, No of scans 500

RAGA IDENTIFIED >> 71 Kosalam

The Swaras of the Raga are > S g G M P D N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>316	330	358	379.8	396.9	414	448.8	474	0.0	536.3	565	607
Amplitude	>38	30.4	19.9	41	37.8	35.5	42.4	45.3	0.0	41.7	48	40
Swara count	>89	1.0	8.0	33	44	4.0	34.0	198	0.0	19	1.0	9.0



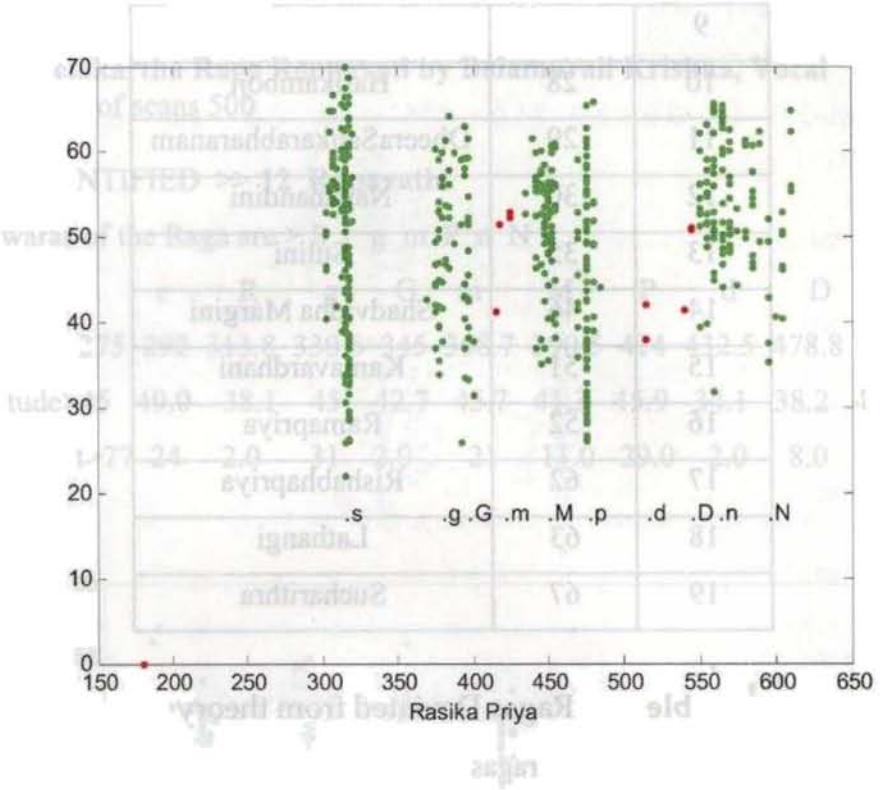
5.2.72 Raga Rasikapriya

Sruti D#, No of scans 500

RAGA IDENTIFIED >> **72 Rasikapriya**

The Swaras of the Raga are > S g G M P n N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>314	0.0	0.0	378	395	420	448.7	475	515	543.3	561.9	593.6
Amplitude	> 49	0.0	0.0	48.9	47	49.5	51.6	44	40	47.8	54	51.9
Swara count	>153	0.0	0.0	40	30.0	4.0	76	89	2.0	3.0	73	32



5.3 Results of the analysis done by the software

In the above 72 Melakartha ragas played by **S.Balachander**, 53 were found to be following the theory. The remaining 19 ragas deviated from the theory. The 19 deviated ragas are given in table 5.1

Sl.No.	Mela No.	Ragam
1	8	Hanumathodi
2	12	Rupavathi
3	15	Mayamalavagaula
4	17	Suryakantham
5	20	Natabhairavi
6	21	Keeravani
7	25	Mararanjani
8	26	Charukesi

9	27	Sarasangi
10	28	Harikamboji
11	29	DheeraSankarabharanam
12	30	Naganandini
13	35	Sulini
14	46	Shadvidha Margini
15	51	Kamavardhani
16	52	Ramapriya
17	62	Rishabhapriya
18	63	Lathangi
19	67	Sucharithra

Table 5.1 Ragas Deviated from theory

But in the above ragas, 8 ragas played by other artists were found to be matching with the theory as identified by the program. These ragas are given in the table 5.2 below.

Sl No.	Mela No.	Ragam	Artist
1	12	Rupavathy	Balamurali Krishna
2	15	Mayamalavagaula	Dr S Ramanathan
3	21	Keeravani	K.V.Narayana Swamy
4	26	Charukesi	Kudamaloor Janardanan
5	28	Harikamboji	Maharajapuram Santhanam
6	29	Dheerasankarabharanam	Indira Menon
7	51	Kamavardhani	M.S.Subhalakshmy
8	62	Rishabhapriya	Dr.K.J.Yesudas

Table 5.2 Other Eight identified Ragas

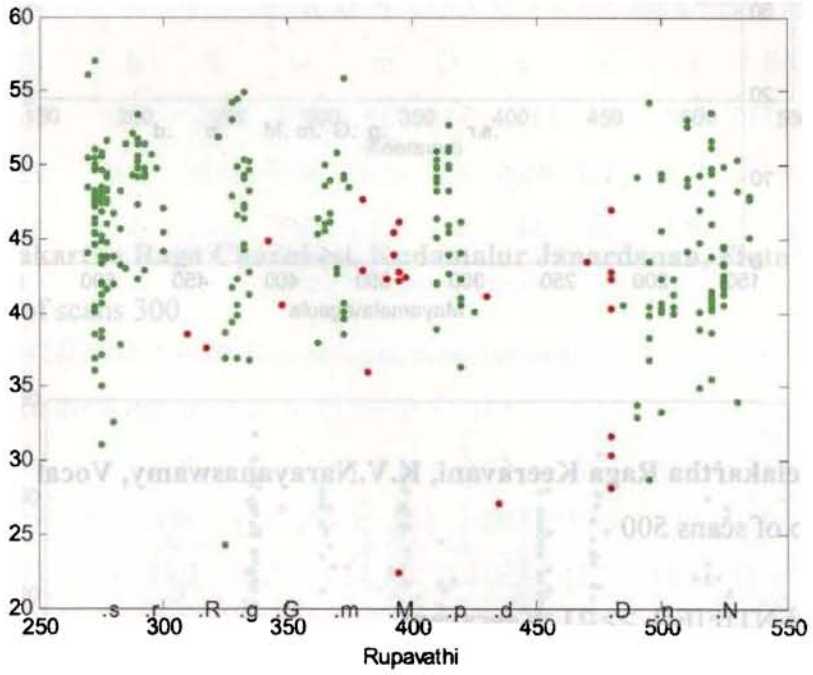
The details of above eight correctly detected ragas are given below:

1. 12th Melakartha Raga Roopavati by Balamurali Krishna, Vocal
Sruti D#, No of scans 500

RAGA IDENTIFIED >> **12 Rupavathi**

The Swaras of the Raga are > S r g m P n N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>275	292	313.8	330.6	345	368.7	390.5	414	432.5	478.8	497.4	521
Amplitude	>45	49.0	38.1	45	42.7	45.7	41.3	45.9	34.1	38.2	41.0	44.6
Swara count	>77	24	2.0	31	2.0	21	11.0	29.0	2.0	8.0	23.0	46.0



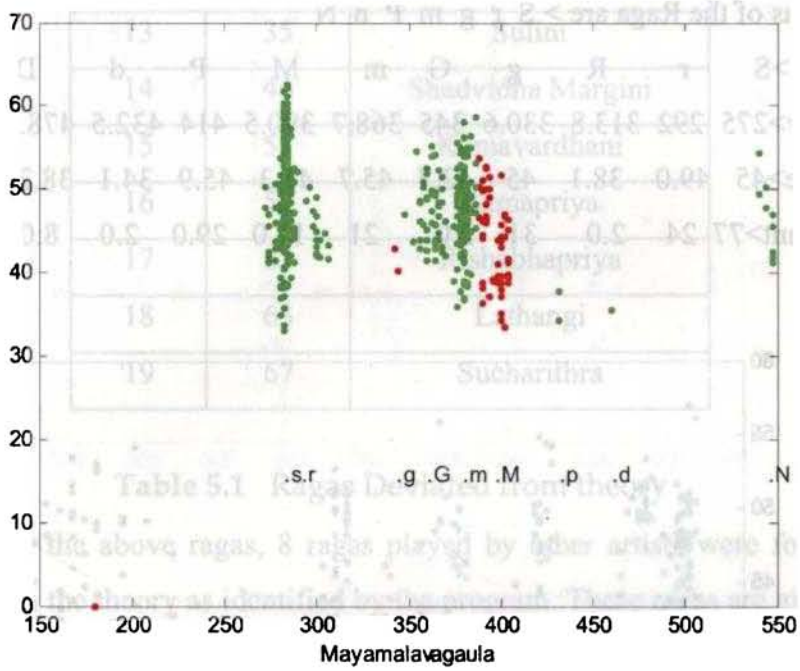
2. 15th Melakartha Raga Mayamalavagaula, Dr. S. Ramanathan, Vocal
Sruti C#, No of scans 500

RAGA IDENTIFIED >> **15 Mayamalavagaula**

The Swaras of the Raga are > S r G m P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N

Frequency>282	291	0.0	343	359.9	378	396	432	460	0.0	0.0	545.3
Amplitude>49	46.9	0.0	41.5	47.6	47.3	43.6	36.1	35.5	0.0	0.0	46.7
Swara count>231	49	0.0	2.0	34.0	126	53	2.0	1.0	0.0	0.0	9.0



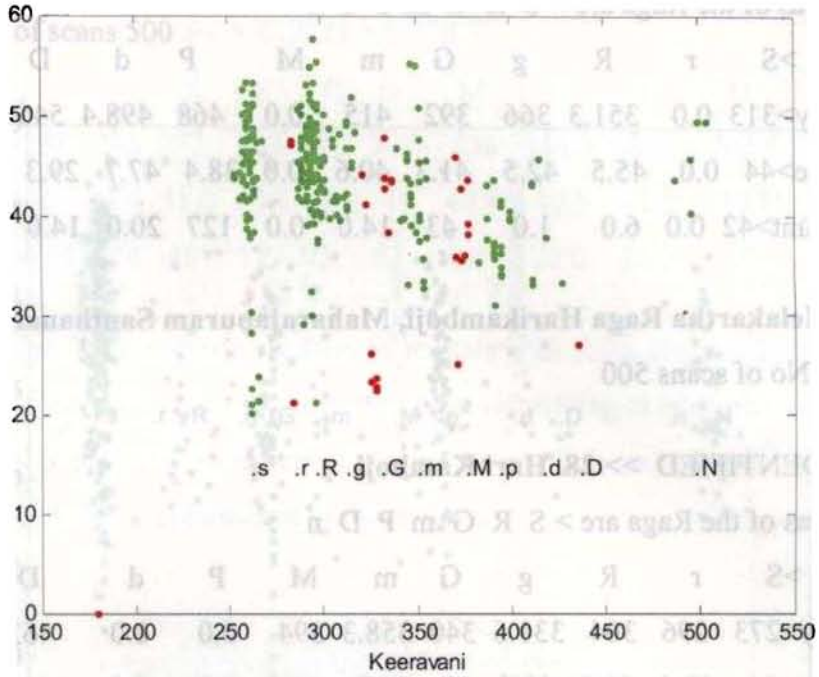
3. 21th Melakartha Raga Keeravani, K.V.Narayanaswamy, Vocal

Sruti c, No of scans 500

RAGA IDENTIFIED >> **21 Keeravani**

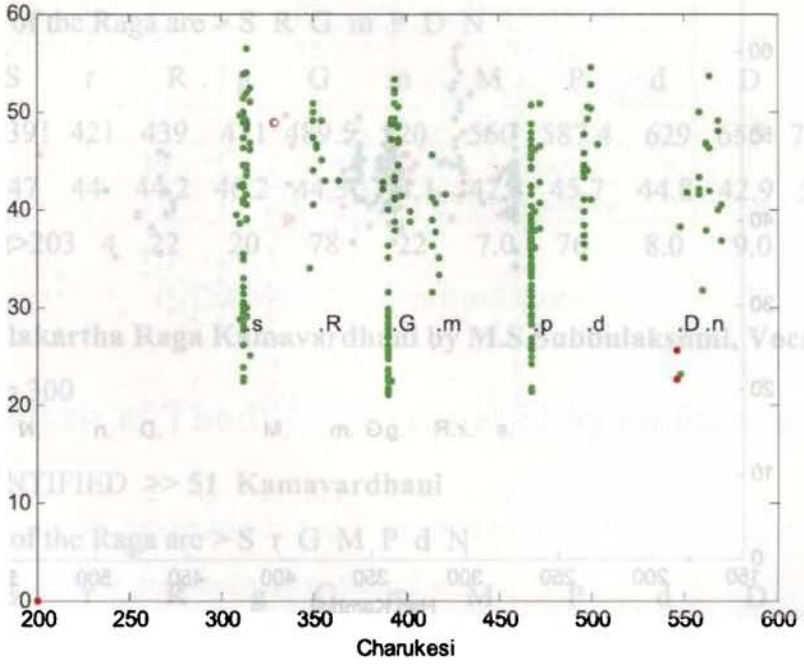
The Swaras of the Raga are > S R g m P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>261	284	294	311	330	349.6	374.9	393	416	436	0.0	496	
Amplitude >44	38.6	45	44.6	35.6	42.4	38	37.7	38.5	26.9	0.0	45.7	
Swara count >80	3.0	110	21.0	13	29	9.0	22	7.0	1.0	0.0	5.0	



4. 26th Melakartha Raga Charukesi, Kudamalur Janardanan, Flute

Sruti D, No of scans 300



RAGA IDENTIFIED >> **26 Charukesi**

The Swaras of the Raga are > S R G m P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>313	0.0	351.3	366	392	415	0.0	468	498.4	546	559	597
Amplitude>44	0.0	45.5	42.5	41.3	40.6	0.0	38.4	47.7	29.3	43.8	31.1
Swara count>42	0.0	6.0	1.0	43	14.0	0.0	127	20.0	14.0	27.0	6.0

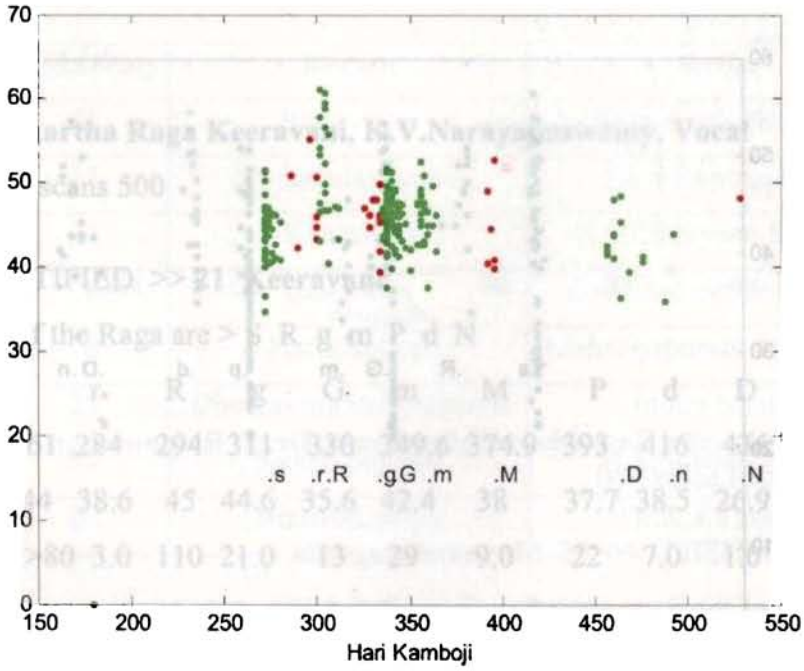
5. 28th Melakartha Raga Harikamboji, Maharajapuram Santhanam, Vocal

Sruti C#, No of scans 500

RAGA IDENTIFIED >> **28 Hari Kamboji**

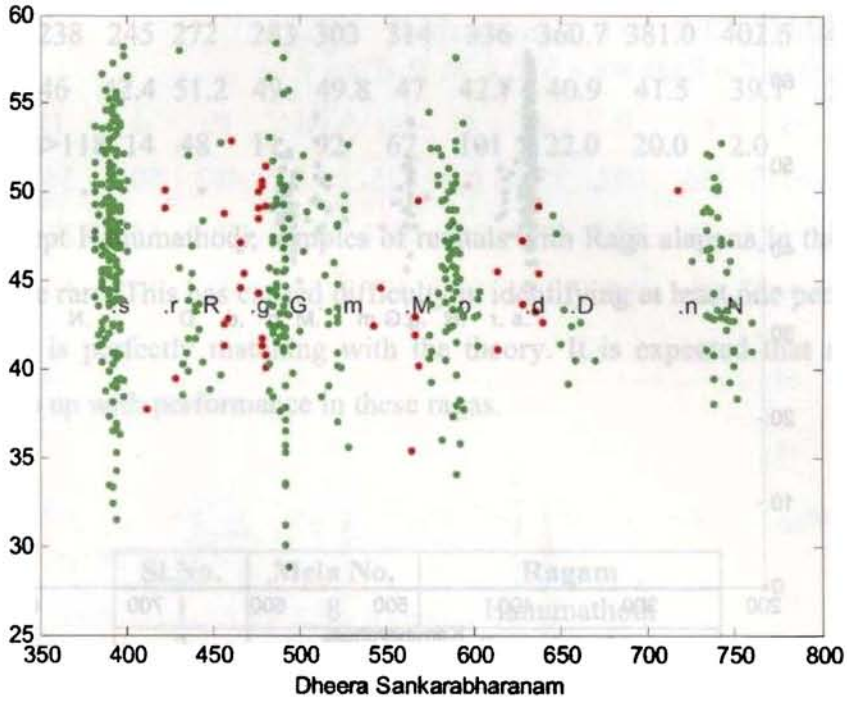
The Swaras of the Raga are > S R G m P D n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>273	296	304	331.6	340	358.3	394	0.0	0.0	463	490	528
Amplitude>44	47.6	51.5	45.6	45	46.2	44.5	0.0	0.0	42.6	39	48
Swara count >54	7.0	22	11	80	24	6.0	0.0	0.0	13	2.0	1.0



6. 29th Melakartha Raga Dheerasankarabharanam, Indira Menon, Vocal

Sruti g, No of scans 500



RAGA IDENTIFIED >> **29 Dheerasankarabharanam**

The Swaras of the Raga are > S R G m P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>391	421	439	471	489.5	520	560	587.4	629	655	718	741.6
Amplitude>47	44	44.2	46.2	44.3	44.1	42.4	45.7	44.8	42.9	50	45.1
Swara count>203	4	22	20	78	22	7.0	76	8.0	9.0	1.0	45

7. 51st Melakartha Raga Kamavardhani by M.S.Subbulakshmi, Vocal

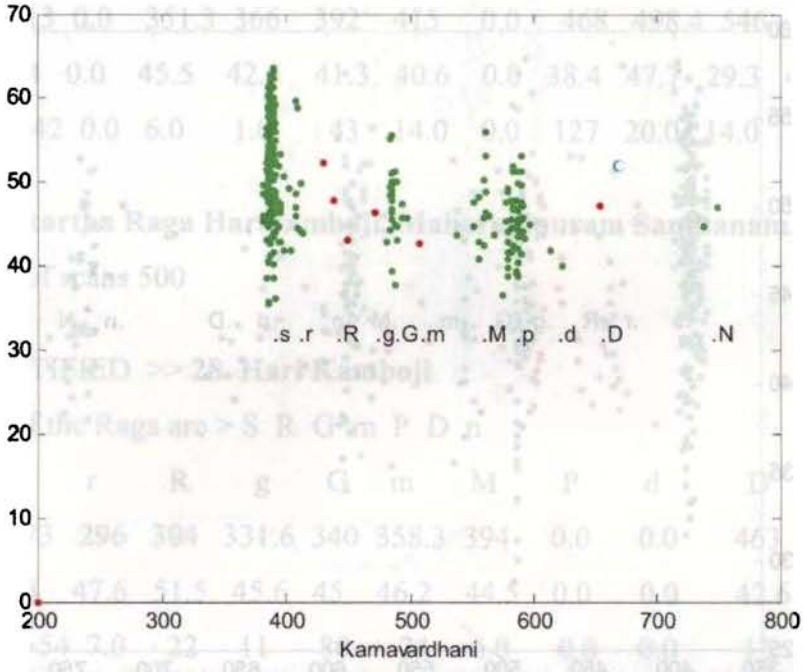
Sruti G, scan 300

RAGA IDENTIFIED >> **51 Kamavardhani**

The Swaras of the Raga are > S r G M P d N

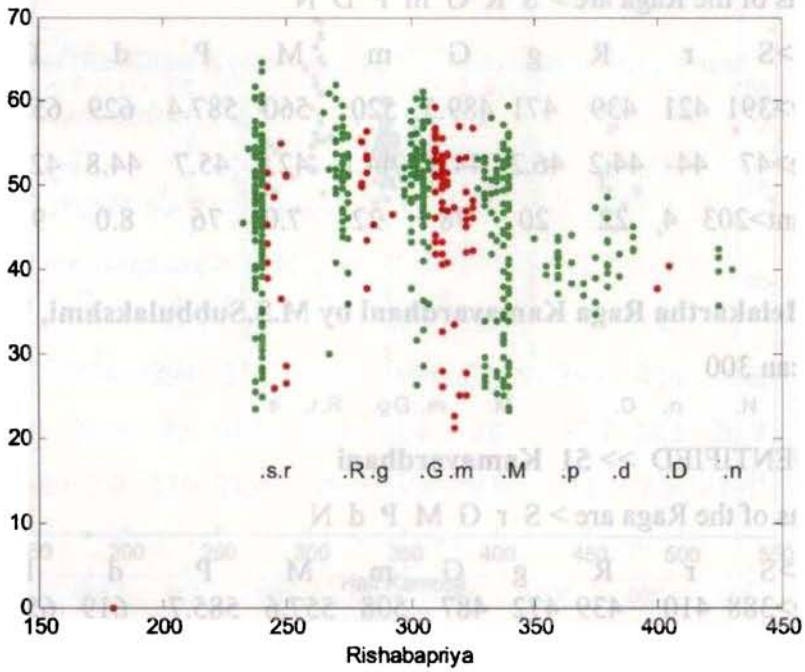
Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>388	410	439	472	487	508	557.6	585.7	619	654	0.0	744
Amplitude>52	49.2	47.7	46	47.3	42	46.9	45.2	40.9	47.1	0.0	45.9

Swara count>183	9	3.0	1.0	26	1.0	15.0	53.0	2.0	1.0	0.0	2.0



8. 62nd Melakartha Raga Rishabhapriya by Dr K.J.Yesudas, Vocal

Sruti A#, No of scans 500



RAGA IDENTIFIED >> **62 Rishabapriya**

The Swaras of the Raga are > S R G M P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>238	245	272	283	303	314	336	360.7	381.0	402.5	426	0.0
Amplitude>46	42.4	51.2	49	49.8	47	42.7	40.9	41.5	39.1	39	0.0
Swara count>118	14	48	11	92	67	101	22.0	20.0	2.0	5.0	0.0

Except Hanumathodi, samples of recitals with Raga alapana in the ragas in table 5.3 are rare. This has caused difficulty in identifying at least one performance each which is perfectly matching with the theory. It is expected that musicians would come up with performance in these ragas.

Sl.No.	Mela No.	Ragam
1	8	Hanumathodi
2	17	Suryakantham
3	20	Natabhairavi
4	25	Mararanjani
5	27	Sarasangi
6	30	Naganandini
7	35	Sulini
8	46	Shadvidha Margini
9	52	Ramapriya
10	63	Lathangi
11	67	Sucharithra

Table 5.3 Unidentified Ragas

5.4 Analysis of Thodi Raga rendered by eminent artists

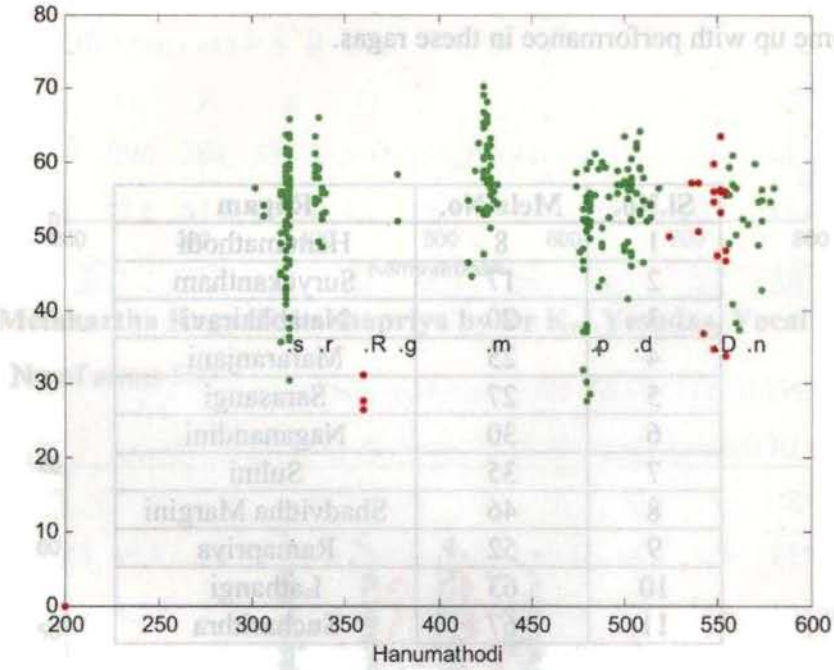
Analysis of Hanumathodi Raga rendered by 10 eminent musicians is given below and the results are tabulated in table 5.4

5.4.1 Raga Hanumathodi by T.N.Krishnan Violin

Sruti D# scan 300

RAGA IDENTIFIED >> **8 Hanumathodi**
The Swaras of the Raga are > S r g m P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>318	336	360	378	0.0	425	0.0	482	504	547	565	0.0
Amplitude>52.8	56	28.5	55	0.0	58.4	0.0	49.4	55.0	51.2	51	0.0
Swara count>87	20	3.0	2.0	0.0	52	0.0	47	44.0	19.0	21.0	0.0



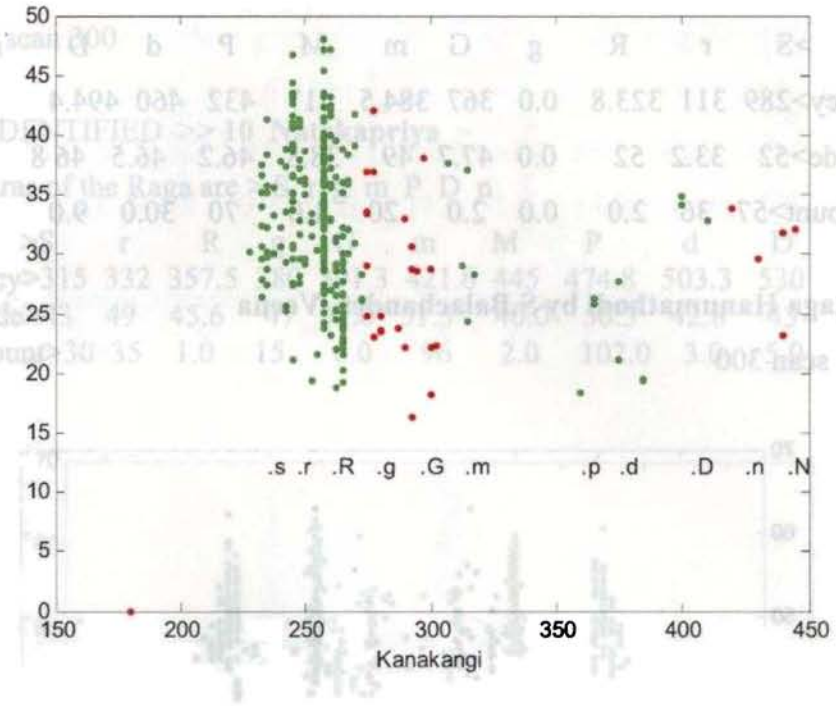
5.4.2. Raga Hanumathodi by M.D. Ramanathan vocal

Sruti A# scan 300

RAGA IDENTIFIED >> **1 Kanakangi**

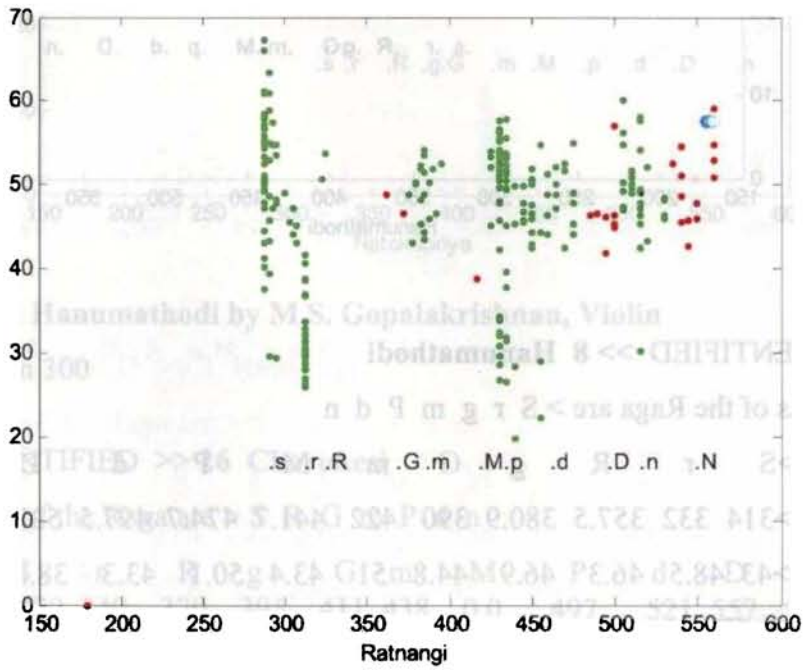
The Swaras of the Raga are > S r R m P d D

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>234	246	260	277	295.7	313	0.0	360	375	403	425	441.7
Amplitude>32	35.2	32.2	29.6	26.3	31	0.0	18.4	23.3	33.9	31.7	29
Swara count>25	61	171	12	11	5.0	0.0	1.0	6.0	3.0	2.0	3.0



5.4.3 Raga Hanumathodi by T.M. Krishna, vocal

Sruti D, scan 300



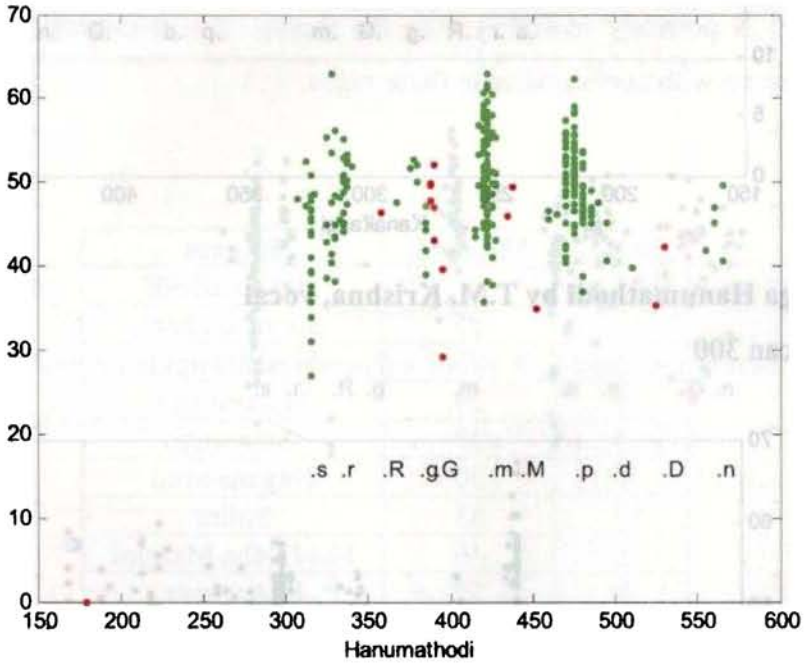
RAGA IDENTIFIED >> **2 Ratnangi**

The Swaras of the Raga are > S r R m P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>289	311	323.8	0.0	367	384.5	417	432	460	494.4	514.4	548.1
Amplitude>52	33.2	52	0.0	47.7	49	38.8	46.2	46.5	46.8	49	50.1
Swara count>57	36	2.0	0.0	2.0	20	1.0	70	30.0	9.0	34.0	13.0

5.4.4 Raga Hanumathodi by S.Balachander, Veena

Sruti D# scan 300



RAGA IDENTIFIED >> **8 Hanumathodi**

The Swaras of the Raga are > S r g m P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>314	332	357.5	380.9	390	422	441.7	474.7	497.5	527.5	560	0.0
Amplitude>43	48.5	46.3	46.9	44.8	51	43.4	50.1	43.3	38.8	45.3	0.0
Swara count>27	36	1.0	11	8.0	94	3.0	108	4.0	2.0	6.0	0.0

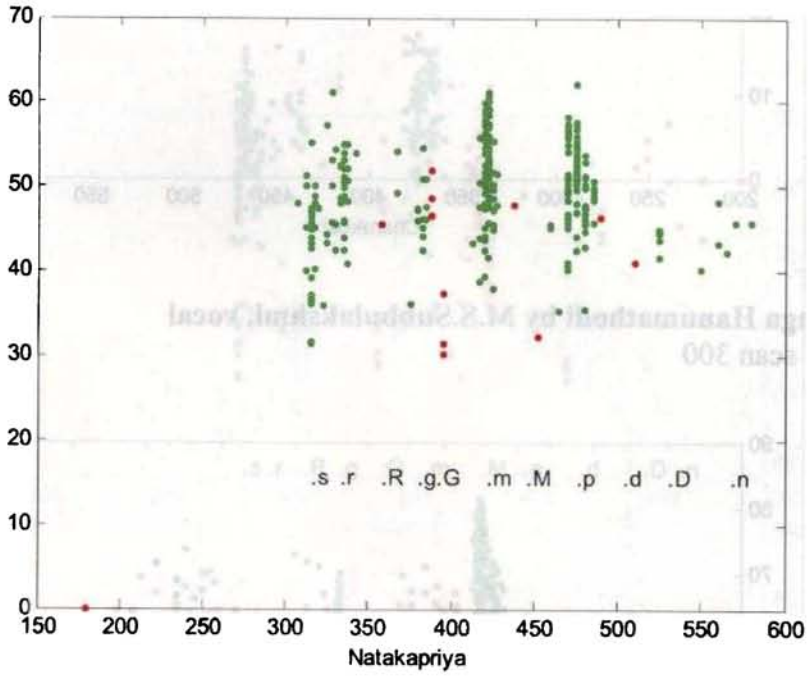
5.4.5 Raga Hanumathodi by S.Balachander Veena (repeated)

Sruti D# scan 300

RAGA IDENTIFIED >> **10 Natakapriya**

The Swaras of the Raga are > S r g m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>315	332	357.5	380	391.3	421.6	445	474.8	503.3	530	567	0.0	
Amplitude>43	49	45.6	47	41.0	51.3	40.0	50.3	42.8	43	45.0	0.0	
SwaraCount>30	35	1.0	15	6.0	96	2.0	102.0	3.0	5.0	5.0	0.0	



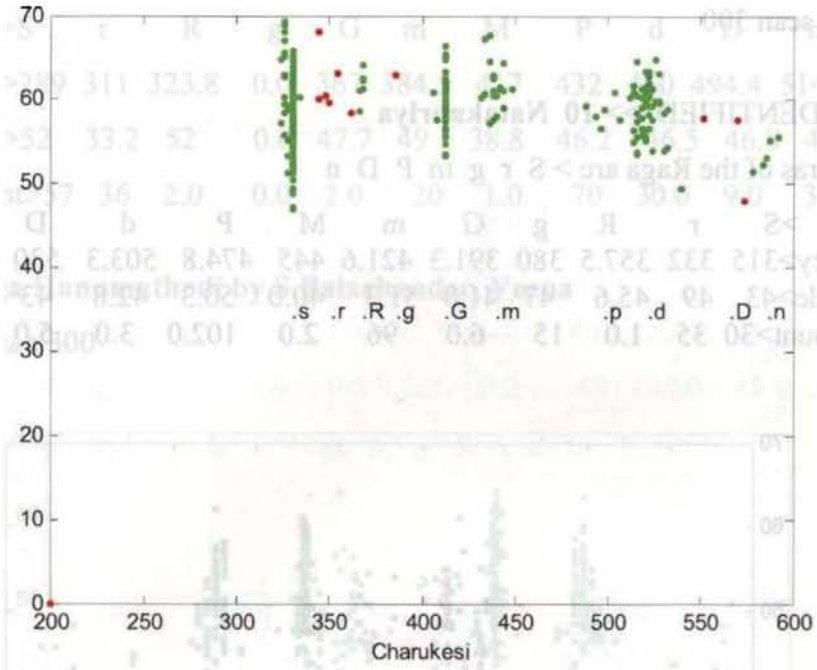
5.4.6 Raga Hanumathodi by M.S. Gopalakrishnan, Violin

Sruti E scan 300

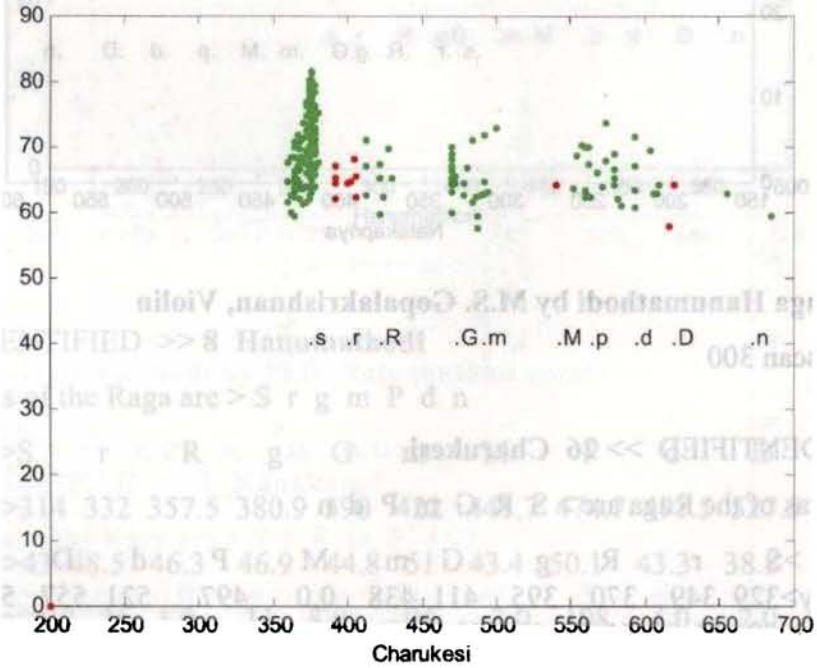
RAGA IDENTIFIED >> **26 Charukesi**

The Swaras of the Raga are > S R G m P d n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>329	349	370	395	411	438	0.0	497	521	557	585.5	0.0	
Amplitude>59	61.5	61.5	62	60.3	60	0.0	58.3	60	51	52.7	0.0	
Swara count>158	9	11	2.0	36	33	0.0	4.0	38	4.0	4.0	0.0	



5.4.7 Raga Hanumathodi by M.S.Subbulakshmi, vocal
Sruti F# scan 300



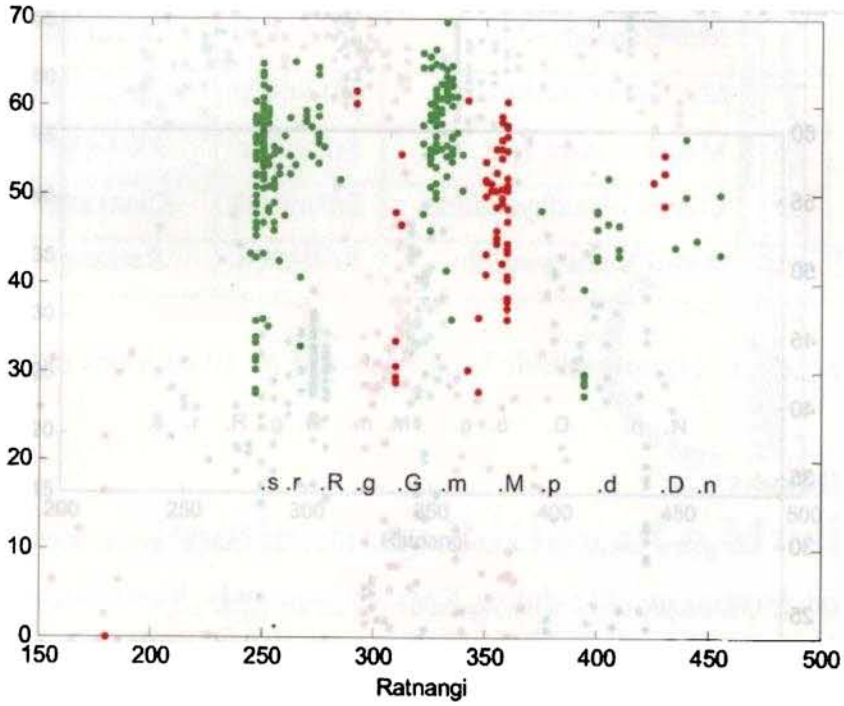
RAGA IDENTIFIED >> **26 Charukesi**

The Swaras of the Raga are > S R G m P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>373	398	420	0.0	471	490	540	562.9	592.1	618	671	0.0
Amplitude>71	64.8	65	0.0	65.5	64.4	64.2	66.5	64.9	60.9	61	0.0
Swara count>218	9	9	0.0	19.0	11.0	1.0	14.0	14.0	2.0	2.0	0.0

5.4.8 Raga Hanumathodi by Madurai Mani Iyer, Vocal

Sruti b, scan 300



RAGA IDENTIFIED >> **2 Ratnangi**

The Swaras of the Raga are > S r R m P d n

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>249	261	276	292	310	329	356	375	400	428.8	445	0.0
Amplitude>52	52.3	57.6	61	38.8	57	48	48	40.3	51.8	48.1	0.0
Swara count>103	28	10	2.0	7.0	74	49	1.0	16	4.0	6.0	0.0

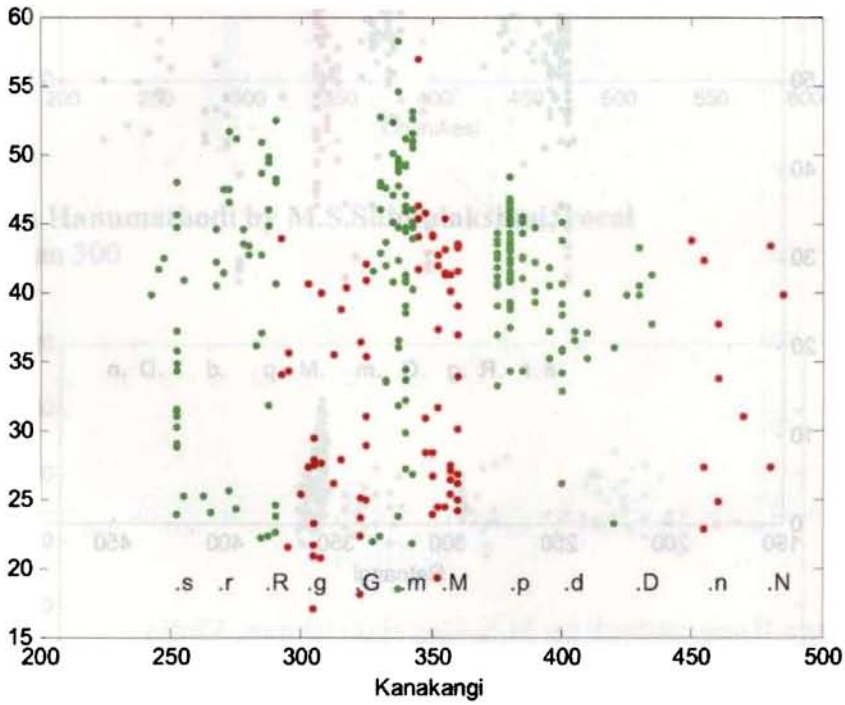
5.4.9 Raga Hanumathodi by Chembai Vaidhyanatha Bhagavathar, Vocal

Sruti b scan 300

RAGA IDENTIFIED >> **1 Kanakangi**

The Swaras of the Raga are > S r R m P d D

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>251	268	286	301	320	337	354	380	401	428	456	478	
Amplitude>35	38	39.8	28.8	31	42.5	35.7	42.5	37.5	37.7	33.2	35.4	
SwaraCount>17	15	23.0	18.0	16	66	42	66	19	8.0	7.0	4.0	



5.4.10 Raga Hanumathodi by Voliti Vekiteswarulu, vocal

Sruti A# scan 300

RAGA IDENTIFIED >> **2 Ratnangi**

The Swaras of the Raga are > S r R m P d n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>235	251	266.8	282.5	296	316	332	359.4	373	397	428	444
Amplitude	>46	51	51.3	51.6	52	52.9	43.9	51.2	50.1	48.0	52.6	48.5
Swara count	>16	14	22	5.0	10	66	61.0	39	27	6.0	24.0	11.0

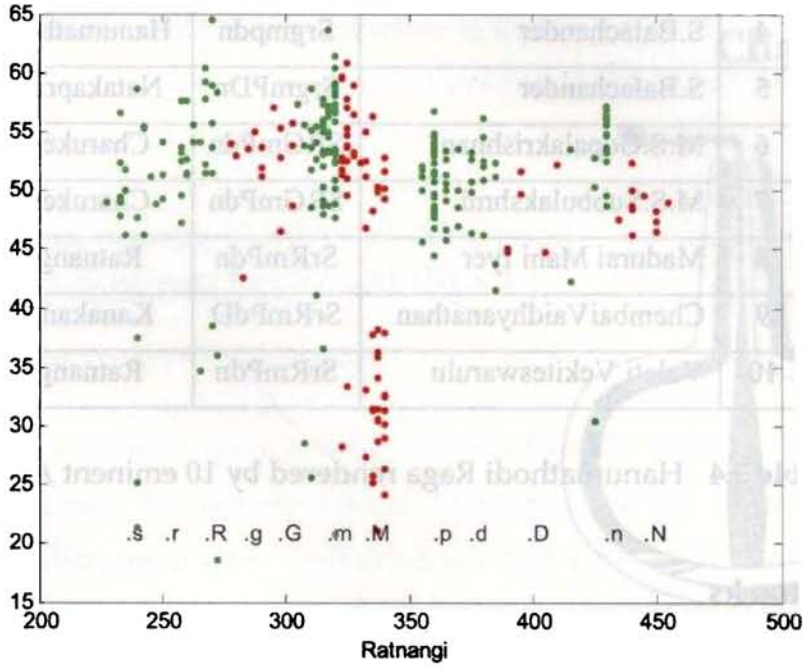


Table 5.4 given below shows the performance of Hanumathodi Raga rendered by 10 eminent musicians. The Swaras of Hanumathodi Raga are: S r g m p d n. It can be seen that the Hanumathodi Raga was detected correctly only in very few cases. It shows that the present day rendering of the Hanumathodi is not according to theory. The style of singing of the Thodi Raga of most of the artists is seen to deviate much from theory. It can also be noted that the changes have occurred in swaras Ga and Ni, which are having much Gamaka for Hanumathodi Raga.

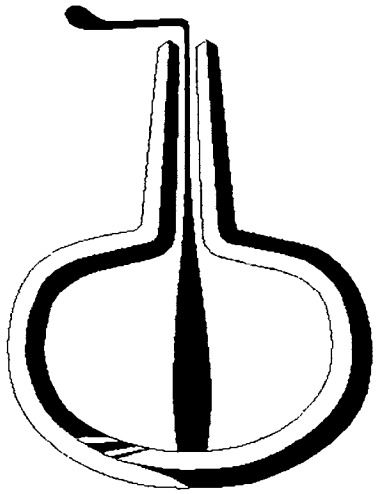
Sl. No	Name of Artist	Detected Swaras	Detected Raga
1	T.N.Krishnan	Srgmpdn	Hanumathodi
2	M.D.Ramanathan	SrRmPdD	Kanakangi
3	T.M.Krishna	SrRmPdn	Ratnangi
4	S.Balachander	Srgmpdn	Hanumathodi
5	S.Balachander	SrgmPDn	Natakapriya
6	M.S.Gopalakrishnan	SRGmPdn	Charukesi
7	M.S.Subbulakshmi	SRGmPdn	Charukesi
8	Madurai Mani Iyer	SrRmPdn	Ratnangi
9	ChembaiVaidhyanathan	SrRmPdD	Kanakangi
10	Voleti Vekiteswarulu	SrRmPdn	Ratnangi

Table 5.4 Hanumathodi Raga rendered by 10 eminent Artistes

5.5 Remarks

In the samples taken for experiment, all recordings were accompanied by Violin and Mridangam. But during Raga alapana, only Violin accompanies the vocalist. However, experiments were conducted during Raga alapana only.

Chapter 6



Proficiency Rating of a Musician

Here we are introducing two musical quantities, SCC (Sruti Consistency Coefficient) and RCC (Raga Consistency Coefficient) which will be used to measure the proficiency of an artiste in the field of vocal or instrumental recital of Ragas.

Here we are introducing two quantifiers SCC and RCC which will be used to measure the proficiency of an artiste in the field of vocal or instrumental recital of Ragas. Performances of ten well known musicians are analysed and the SCC and RCC were calculated.

6.1 Sruti Consistency Coefficient (SCC) and Raga Consistency Coefficient (RCC)

6.1.1 Sruti Consistency Coefficient (SCC)

When a musician sings, he often deviates from the theoretically specified frequencies. Lesser the deviation, more pleasing would be the performance. However, a difference of a few frequencies at a high pitch will be less noticeable than the same deviation at low pitch. This calls for standardization of the deviation. For this the frequency has been normalised to hundred. The observed frequency of a Swara is determined as the average observed value of the respective Swaras. The normalised standard deviation of the observed values of each Swara is independently calculated and the average of the standard deviations is taken as the consolidated deviation. **Sruti Consistency Coefficient (SCC)** is a measure of the consistency in the sruti, played by the artiste. The maximum value of SCC is 100. 100 minus the consolidated deviation is the SCC.

6.1.2 Raga Consistency Coefficient (RCC)

Raga Consistency Coefficient (RCC) is intended to measure the efficiency of the musician to play the Ragas consistently with theoretical precision. With

respect to the base Sruti the relative frequency of the Swaras in the Ragas are estimated and the deviations of the observed values are computed. The lesser the deviation, the more consistent is the musician in rendering the raga.

The average of the observed frequencies of Sa is considered as the base frequency and corresponding frequencies for the Swaras in the Raga are calculated. These are the theoretically expected frequencies. The deviation of the observed values of the Swaras from the expected values is calculated. Then the root of the mean of the squares of the deviation of frequencies of Swaras: ri, ga, ma, pa, dha, ni from the theoretical values are calculated. This way, the standard deviation of each note Sa, Ri, Ga, Ma, Pa, Dha and Ni of the Raga rendered is calculated. These standard deviations are then normalised to 100. The total of the standard deviations is a measure of the deviation from the Raga since Raga contains all the Swaras. If the total deviation is zero, Raga rendering is perfect. The maximum perfection is taken as 100 and 100 less the total deviation is taken as the RCC.

6.2 Analysis of Raga rendered by Eminent Artistes

The following analysis uses recordings of ten well known musicians. Two ragas sung by each musician are taken for the analysis. First it was tested, whether they have rendered the raga according to the theory. Then the Sruti Consistency Coefficient and the Raga Consistency Coefficient were calculated. By analyzing the SCC and RCC it is possible to find the perfection of the artist in **Sruti** as well as in **Raga**. The musician having the highest values for SCC and RCC will be the best. The details of this analysis is given below and the results are tabulated in table 6.1

6.2.1 Mela no 65, Mecha Kalyani by M.S. Subbulakshmi, Vocal

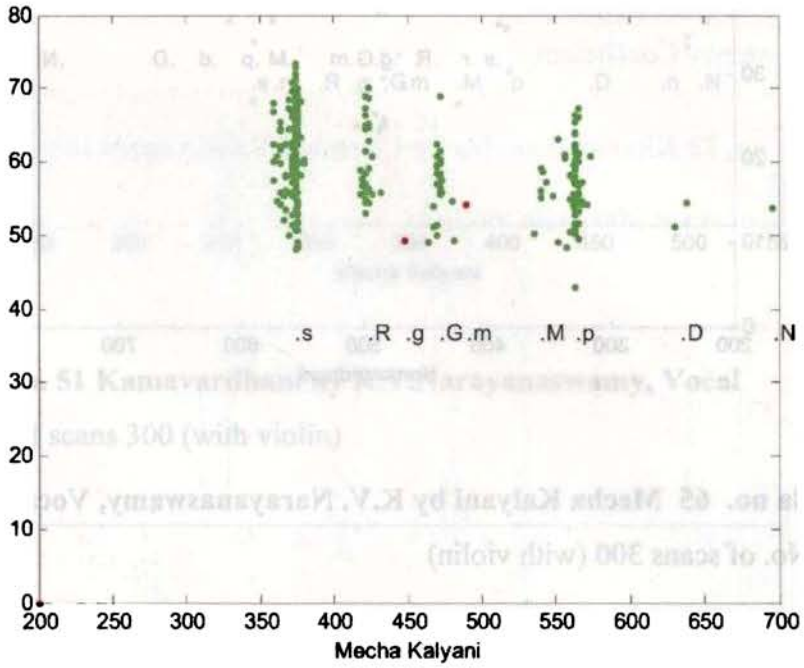
Sruti F#, No. of scans 300

RAGA IDENTIFIED >> **65 Mecha Kalyani**

The Swaras of the Raga are > S R G M P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>373	0.0	422.8	448	471	490	539.6	563.4	0.0	634	0.0	696
Amplitude>62	0.0	60	49.2	57	54	55.8	56.9	0.0	52.8	0.0	53
Swaracount>165	0.0	29	1.0	26	1.0	5.0	68	0.0	2.0	0.0	1.0

Sruti Consistency Coefficient is >> 99.32
Raga Consistency Coefficient is >> 90.24



6.2.2 Mela no. 51 Kamavardhani by M.S.Subbulakshmi, Vocal

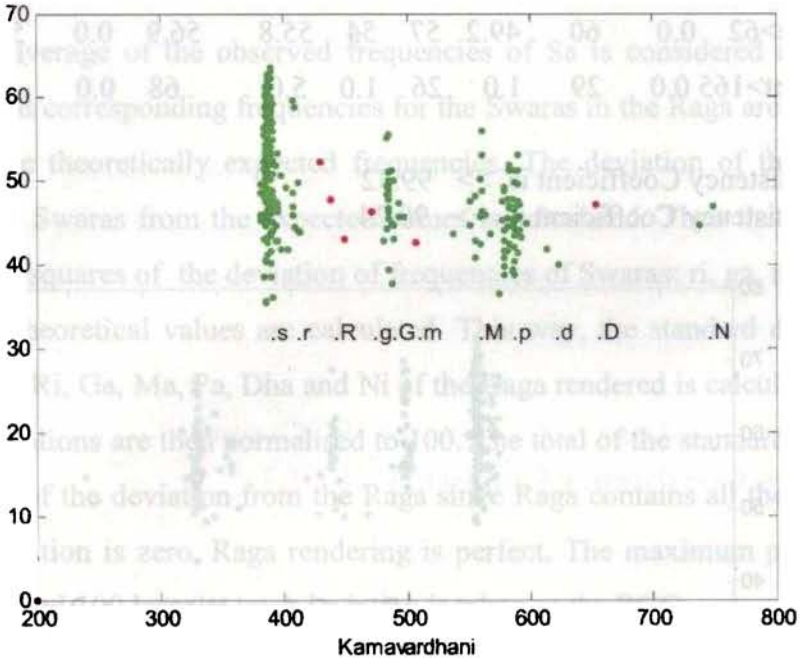
Sruti G, No. of scans 300

RAGA IDENTIFIED >> **51 Kamavardhani**

The Swaras of the Raga are > S r G M P d N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>388	410	439	472	487.4	508	557.6	585.7	619	654	0.0	744
Amplitude>52	49.2	47.7	46.5	47.3	42	46.9	45.2	40.9	47.1	0.0	45
Swaracount>183	9	3.0	1.0	26	1.0	15.0	53.0	2.0	1.0	0.0	2.0

Sruti Consistency Coefficient is >> 98.91
Raga Consistency Coefficient is >> 90.07



6.2.3 Mela no. 65 Mecha Kalyani by K.V. Narayanaswamy, Vocal

Sruti C, No. of scans 300 (with violin)

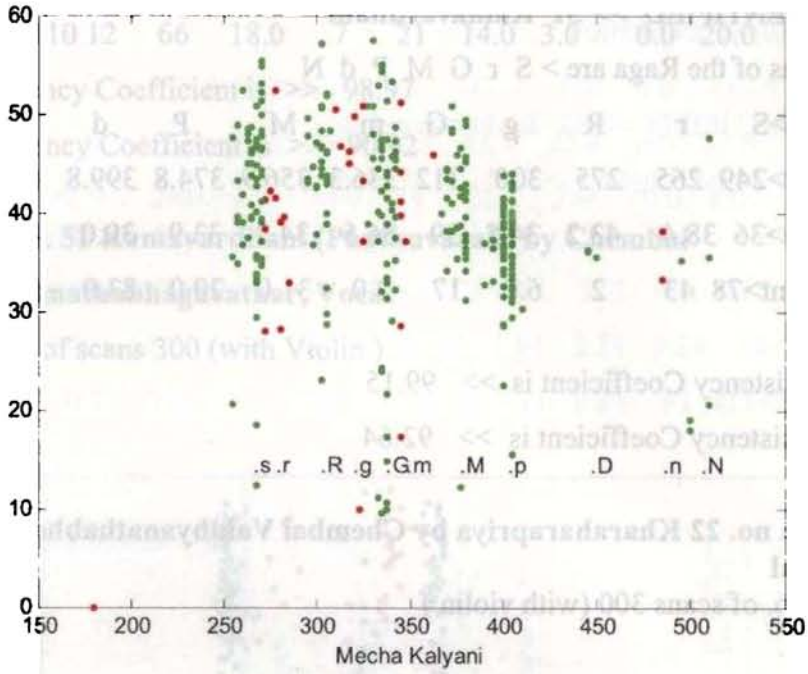
RAGA IDENTIFIED >> **65 Mecha Kalyani**

The Swaras of the Raga are > S R G M P D N

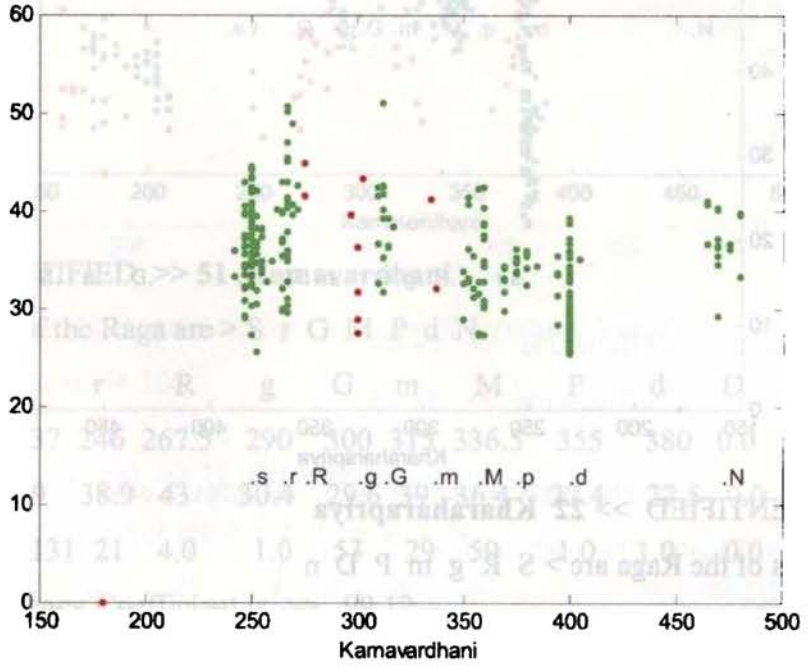
Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>265	277	302	319.4	337	347.5	376.4	402	0.0	446	485	505
Amplitude>41	38.3	43.5	42.1	39.4	38.1	40.6	36.2	0.0	35.9	35.7	30
Swara count>62	10	33	9.0	60.0	8.0	41.0	69.0	0.0	3.0	2.0	7.0

Sruti Consistency Coefficient is >> 98.83

Raga Consistency Coefficient is >> 89.77



6.2.4 Mela no. 51 Kamavardhani by K.V.Narayanaswamy, Vocal Sruti b, No. of scans 300 (with violin)



RAGA IDENTIFIED >> **51 Kamavardhani**

The Swaras of the Raga are > S r G M P d N

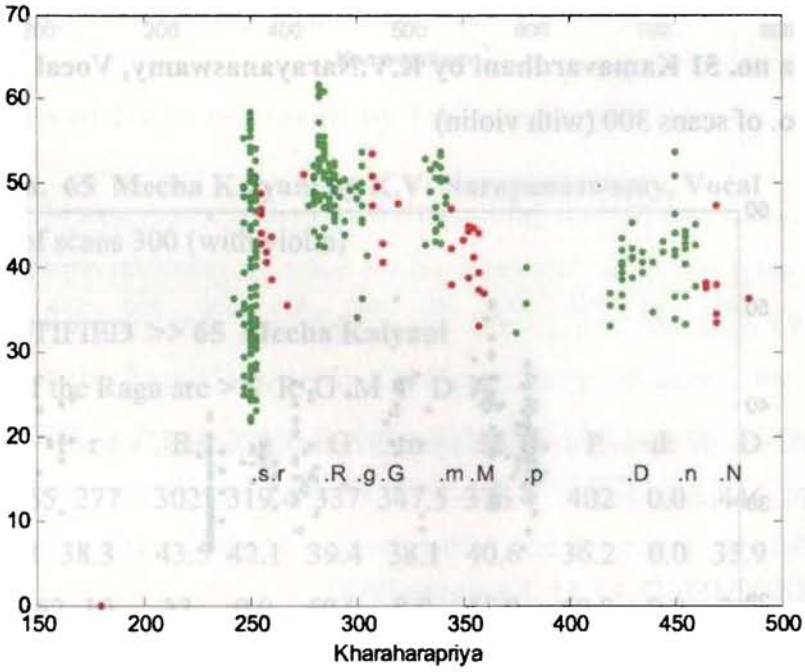
Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	249	265	275	300	312	336.3	356.9	374.8	399.8	0.0	0.0	471
Amplitude>	36	38.4	43.2	34.5	39	36.5	34.2	33.9	30.0	0.0	0.0	37
Swara count>	78	43	2	6.0	17	2.0	31.0	20.0	83.0	0.0	0.0	18

Sruti Consistency Coefficient is >> 99.15

Raga Consistency Coefficient is >> 92.64

6.2.5 Mela no. 22 Kharaharapriya by Chembai Vaidhyanathabhagavathar, Vocal

Sruti B, No. of scans 300 (with violin)



RAGA IDENTIFIED >> **22 Kharaharapriya**

The Swaras of the Raga are > S R g m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	250	259	284.7	299.6	311	338	353	378.3	0.0	427	451.3	470.7

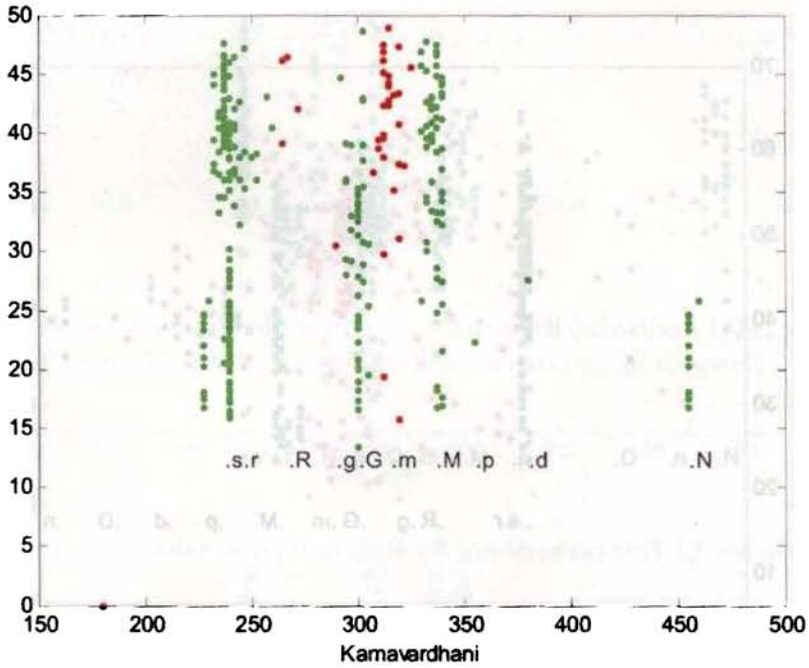
Amplitude>39	43.2	51.2	46.7	47.5	48.5	41	36	0.0	39.7	41.7	37.9
Swaracount>110	12	66	18.0	7	21	14.0	3.0	0.0	20.0	23.0	7.0

Sruti Consistency Coefficient is >> 98.97

Raga Consistency Coefficient is >> 90.92

6.2.6 Mela no. 51 Kamavardhani (Panthuvarali) by Chembai Vaidhyanathabhagavathar, Vocal

Sruti A#, No. of scans 300 (with Violin)



RAGA IDENTIFIED >> **51 Kamavardhani**

The Swaras of the Raga are > S r G M P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>237	246	267.5	290	300	315	336.5	355	380	0.0	0.0	455.4	
Amplitude>29	38.9	43	30.4	29.6	39	36.4	22.4	27.5	0.0	0.0	21.3	
Swaracount>131	21	4.0	1.0	53	29	59	1.0	1.0	0.0	0.0	12.0	

Sruti Consistency Coefficient is >> 99.12

Raga Consistency Coefficient is >> 90.54

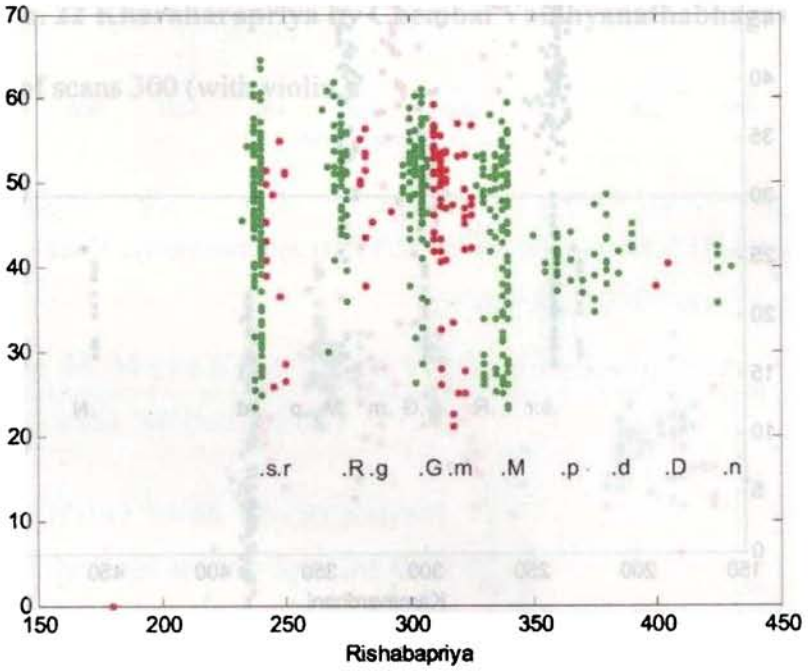
6.2.7 Mela no. 62 Rishabhapriya by Dr K.J.Yesudas.

Sruti A#, No. of scans 500

RAGA IDENTIFIED >> **62 Rishabhapriya**

The Swaras of the Raga are > S R G M P d n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>238	245	272	283	303.3	314	336	360	381.0	402.5	426.0	0.0	
Amplitude>46	42.4	51.2	49.4	49.8	47	42	40	41.5	39.1	39.9	0.0	
Swaracount>118	14	48.0	11.0	92.0	67	101	22	20.0	2.0	5.0	0.0	



Sruti Consistency Coefficient is >> 99.09

Raga Consistency Coefficient is >> 91.26

6.2.8 Mela no. 65 Mecha Kalyani by Dr K. J. Yesudas, Vocal

Sruti B, No. of scans 300 (with violin)

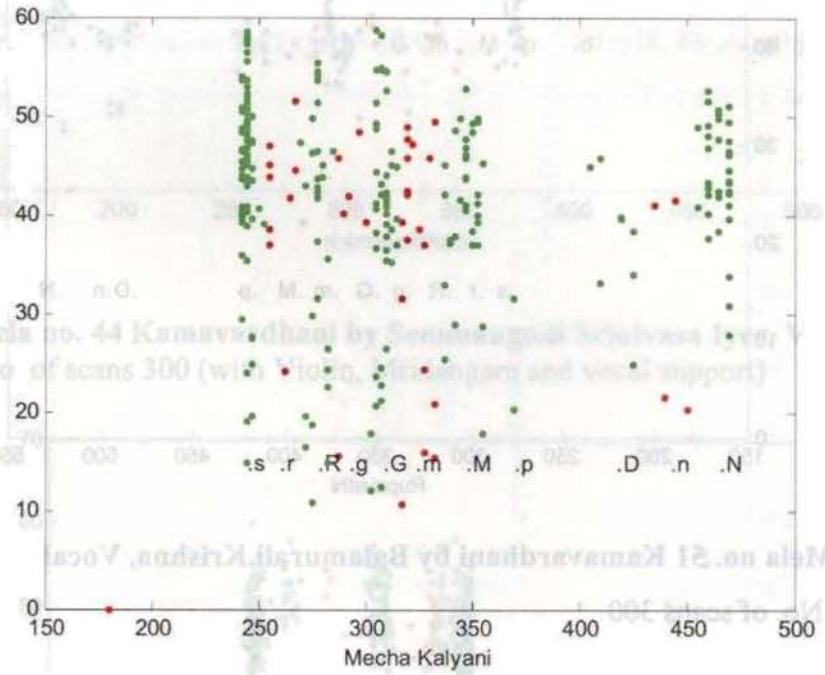
RAGA IDENTIFIED >> **65 Mecha Kalyani**

The Swaras of the Raga are > S R G M P D N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>244	259	277.6	292	308	323	347.3	370	0.0	417.5	442	465
Amplitude>44	41	37.7	38.5	39.9	35.9	41	25.8	0.0	37.5	31.1	43.8
Swara count>69	9	29.0	6.0	48.0	19	35	2.0	0.0	8.0	4.0	35

Sruti Consistency Coefficient is >> 98.95

Raga Consistency Coefficient is >> 90.00



6.2.9 Mela no. 12 Rupavathi by Balamurali Krishna, Vocal

Sruti C, No. of scans 300

RAGA IDENTIFIED >> **12 Rupavathi**

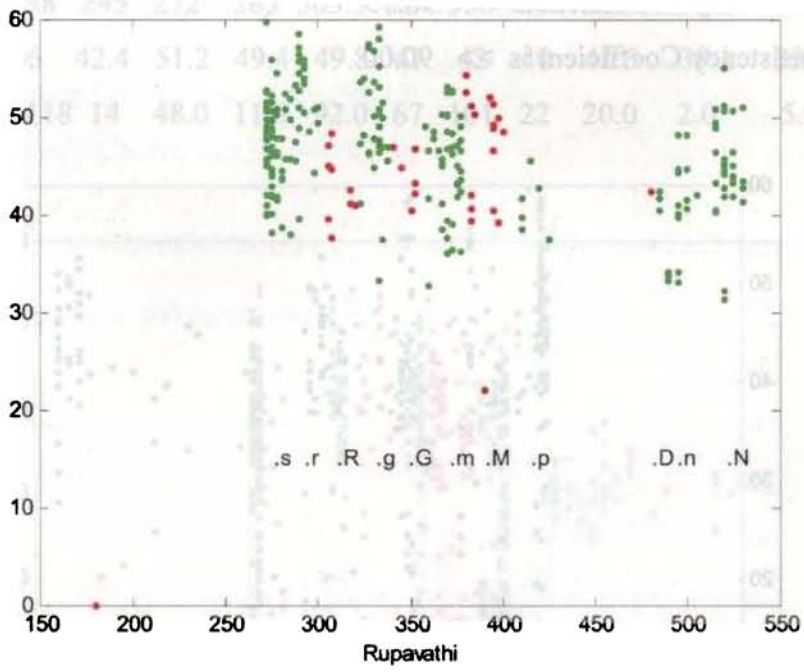
The Swaras of the Raga are > S r g m P n N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>275	292	310	330	348	370	389.9	415	0.0	480	494.2	521.3

Amplitude>47	51	43	49.5	44	45	45.8	40.9	0.0	42.4	40	44
Swaracount>71	23	9.0	33	7.0	43	17.0	6.0	0.0	1.0	19	30

Sruti Consistency Coefficient is >> 98.74

Raga Consistency Coefficient is >> 91.66



6.2.10 Mela no. 51 Kamavardhani by Balamurali Krishna, Vocal

Sruti B, No. of scans 300

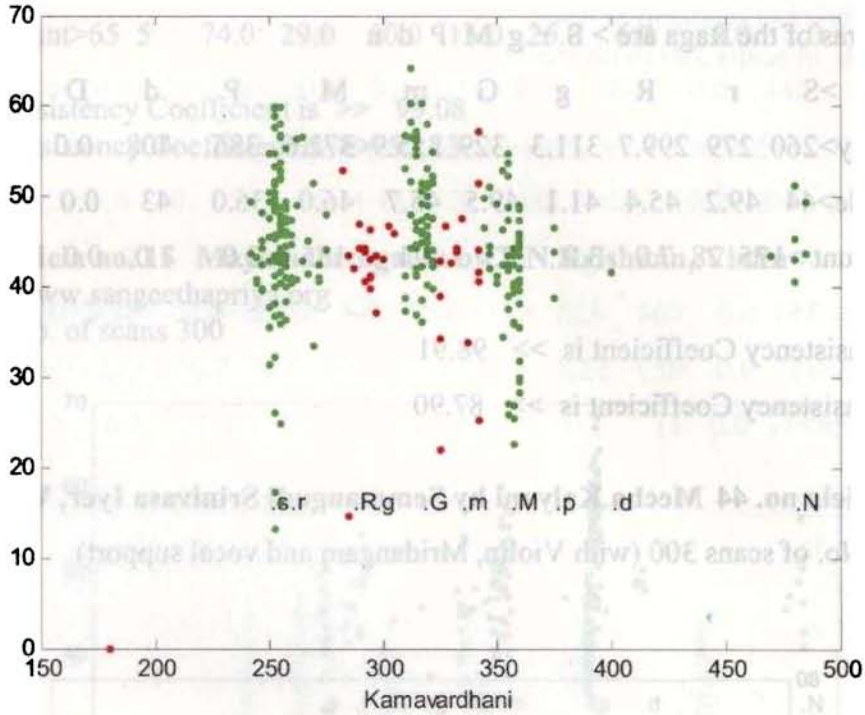
RAGA IDENTIFIED >> **51 Kamavardhani**

The Swaras of the Raga are > S r G M P d N

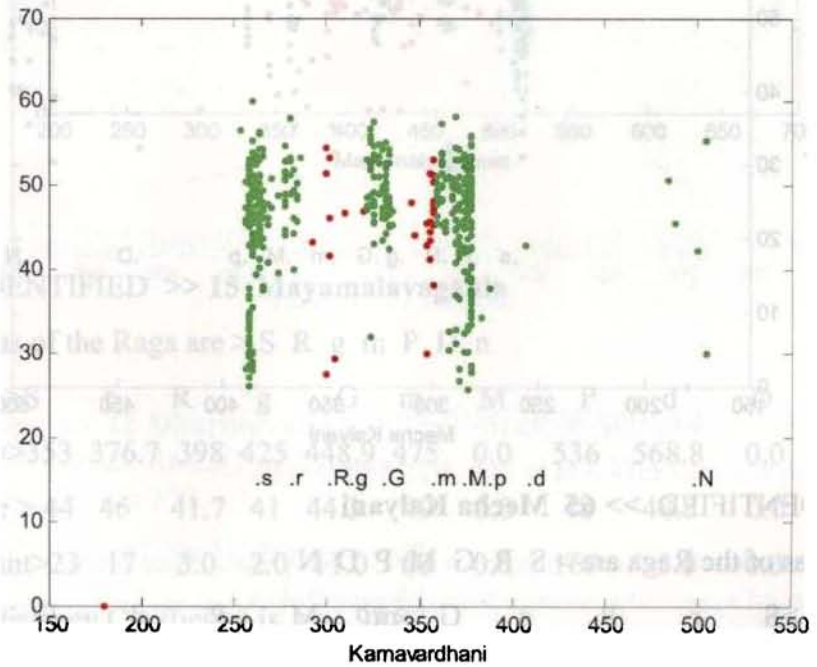
Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>250	259	286	296.5	317.1	334.4	356	375	400	0.0	0.0	480	
Amplitude>45	45.6	40.7	42	48.4	41.1	40	43.1	41.7	0.0	0.0	45	
Swara count>56	70	6.0	13	69	16	61	3.0	1.0	0.0	0.0	7.0	

Sruti Consistency Coefficient is >> 99.07

Raga Consistency Coefficient is >> 85.00



6.2.11 Mela no. 44 Kamavardhani by Semmangudi Srinivasa Iyer, Vocal Sruti B, No. of scans 300 (with Violin, Mridangam and vocal support)



RAGA IDENTIFIED >> **51 Kamavardhani**

The Swaras of the Raga are > S r g M P d n

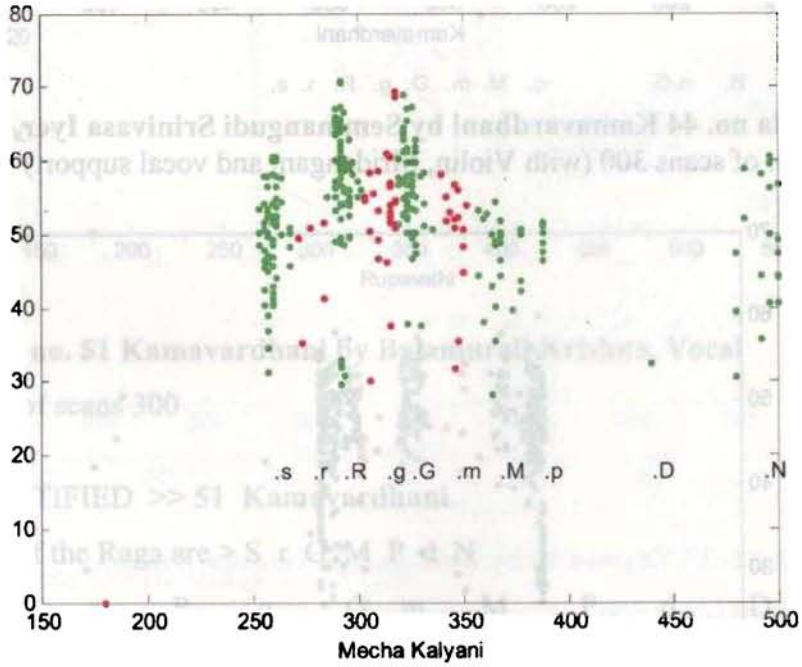
Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>260	279	299.7	311.3	329	355.9	372.6	386	408	0.0	0.0	496
Amplitude	>44	49.2	45.4	41.1	49.5	45.7	46.0	36.0	43	0.0	0.0	44
SwaraCount	>175	28	7.0	3.0	73	21	185	2.0	1.0	0.0	0.0	5.0

Sruti Consistency Coefficient is >> 98.91

Raga Consistency Coefficient is >> 87.90

6.2.12 Mela no. 44 Mecha Kalyani by Semmangudi Srinivasa Iyer, Vocal

Sruti B, No. of scans 300 (with Violin, Mridangam and vocal support)



RAGA IDENTIFIED >> **65 Mecha Kalyani**

The Swaras of the Raga are > S R G M P D N

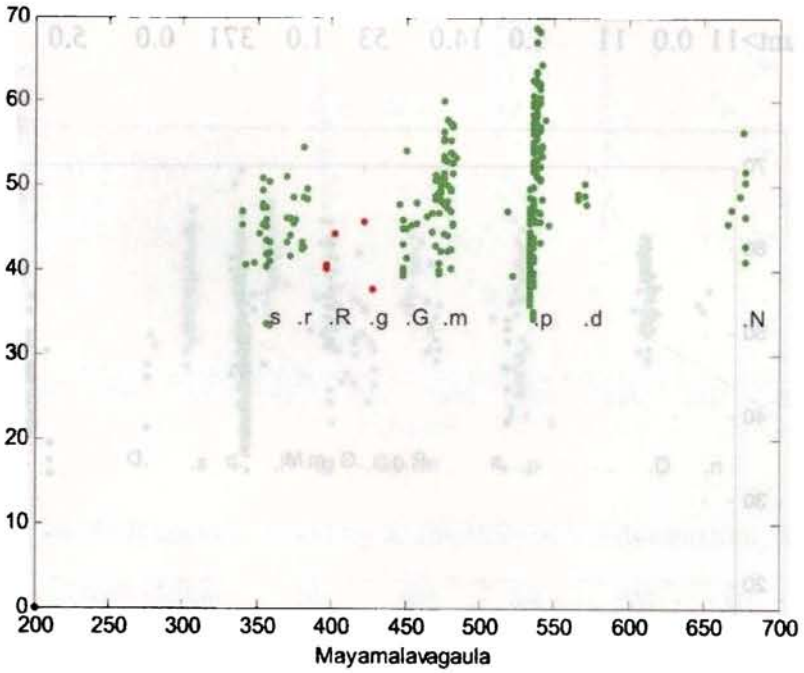
Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>259	278	293.1	313.5	325	346.5	367	388.0	0.0	440	0.0	492

Amplitude>49	45.7	56.9	53.6	56.5	50.1	46.5	49.3	0.0	32.3	0.0	48
SwaraCount>65	5	74.0	29.0	60.0	15.0	26.0	6.0	0.0	1.0	0.0	19.0

Sruti Consistency Coefficient is >> 99.08
Raga Consistency Coefficient is >> 92.13

6.2.13 Mela no. 15 Mayamalavagaula by T.N.Krishnan, Violin

Source-www.sangeethapriya.org
Sruti f, No. of scans 300



RAGA IDENTIFIED >> **15 Mayamalavagaula**

The Swaras of the Raga are > S R g m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>	353	376.7	398	425	448.9	475	0.0	536	568.8	0.0	0.0	674
Amplitude >	44	46	41.7	41	44.3	49	0.0	48	48.8	0.0	0.0	47.8
Swara count>	23	17	3.0	2.0	11.0	60	0.0	169	5.0	0.0	0.0	9.0

Sruti Consistency Coefficient is >> 98.82

Raga Consistency Coefficient is >> 91.58

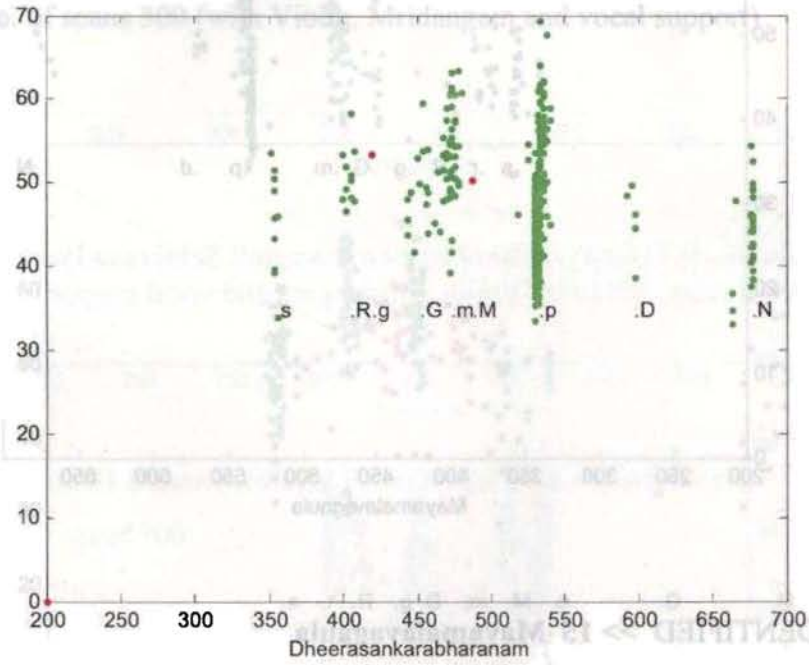
6.2.14 Mela no. 64 Dheerasankarabharanam by T.N.Krishnan, Violin

Source-www.sangeethapriya.org
Sruti f, No. of scans 300 (with violin)

RAGA IDENTIFIED >> **29 Dheerasankarabharanam**

The Swaras of the Raga are > S R G m P D N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>354	0.0	404	420	451	472	488	531.8	0.0	596.4	0.0	675.9
Amplitude	>45	0.0	50.7	53.4	49.1	52.9	50	46.1	0.0	45.5	0.0	44.0
Swara count	>11	0.0	11	1.0	14.0	53	1.0	371	0.0	5.0	0.0	33.0



Sruti Consistency Coefficient is >> 99.36 %

Raga Consistency Coefficient is >> 92.15 %

6.2.15 Mela no. 22 Kharaharapriya by U.Srinivasan, Mandolin

Sruti C, No. of scans 300, Source-World Space Radio

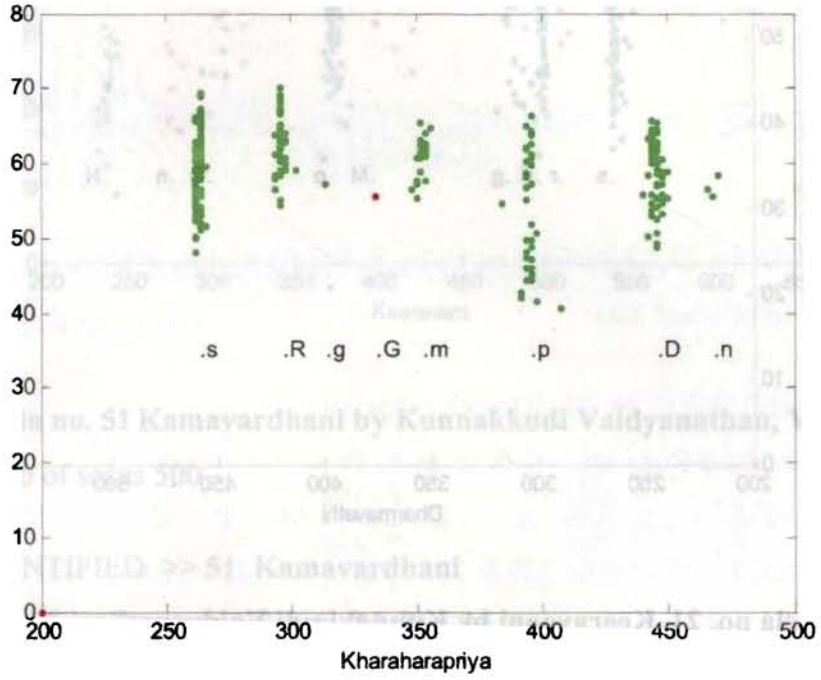
RAGA IDENTIFIED >> **22 Kharaharapriya**

The Swaras of the Raga are > S R g m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>263	0.0	296	314	334	352	0.0	395	0.0	445	468	0.0
Amplitude	>59.5	0.0	63	57.3	55	60.6	0.0	53.6	0.0	59.2	56.7	0.0
Swaracount	>114	0.0	50	1.0	1.0	28	0.0	37	0.0	66.0	3.0	0.0

Sruti Consistency Coefficient is >> 99.57

Raga Consistency Coefficient is >> 97.01



6.2.16 Mela no. 22 Dharmavathi by U.Sreenivasan, Mandolin
Source-World Space Radio(Begin after 1/4th)
Sruti C, No. of scans 300

RAGA IDENTIFIED >> **59 Dharmavathi**

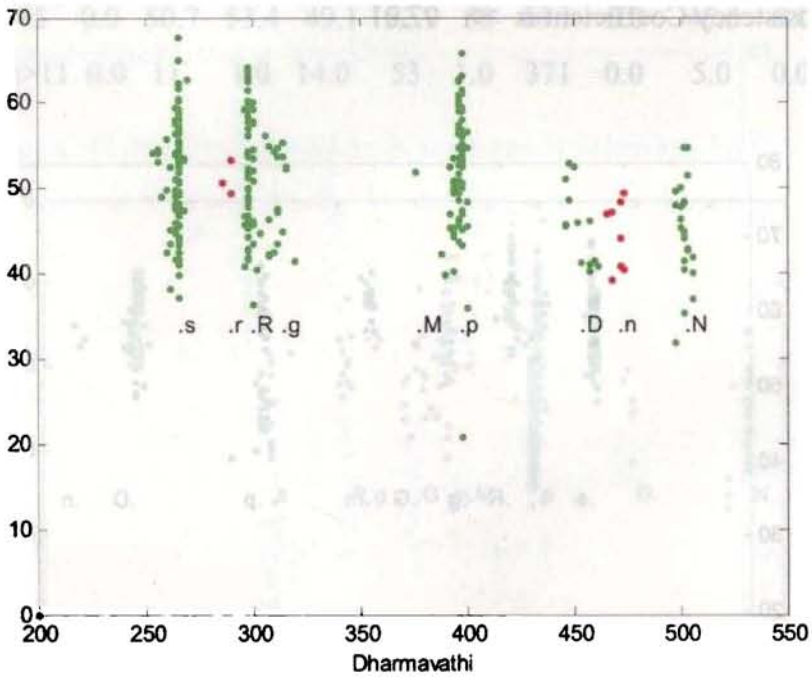
The Swaras of the Raga are > S R g M P D N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N

Frequency>264	288	299	313	0.0	0.0	376	396.4	0.0	452.8	470	502
Amplitude>51	51.1	51	49.5	0.0	0.0	51.8	51.9	0.0	45.7	44.6	44.7
Swara count>92	3.0	67	13	0.0	0.0	1.0	76.0	0.0	13.0	8.0	24

Sruti Consistency Coefficient is >> 99.13

Raga Consistency Coefficient is >> 93.89



6.2.17 Mela no. 21 Keeravaani by Kunnakkudi Vaidyanathan, Violin

Sruti D#, No of scans 500

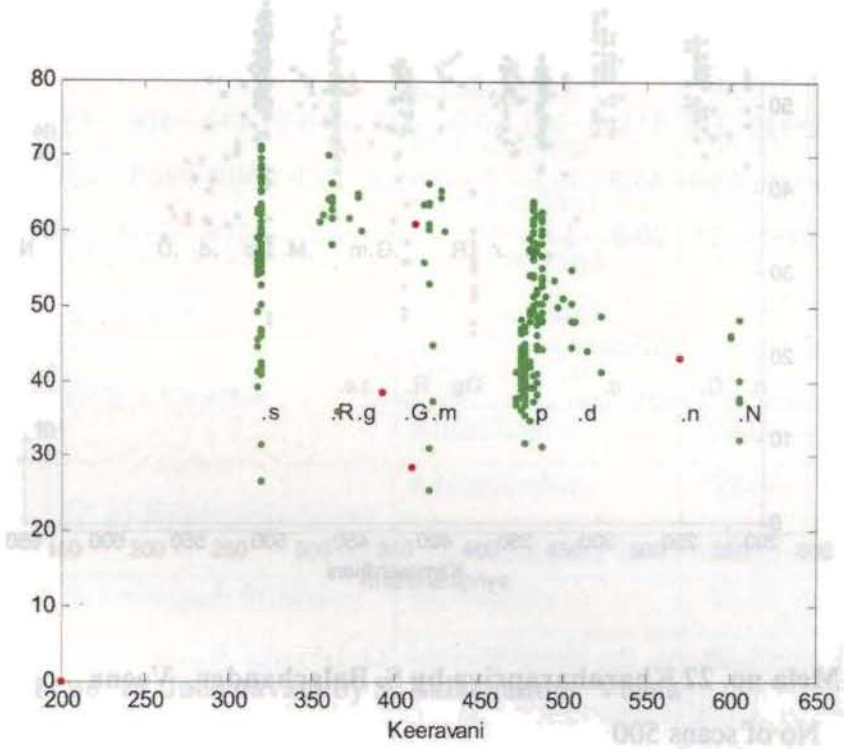
RAGA IDENTIFIED >> **21 Keeravaani**

The Swaras of the Raga are > S R g m P d N

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency>319	0.0	361.3	376.9	405	421	0.0	479.7	508.5	0.0	570	603.6	
Amplitude>56	0.0	61.2	62.7	42.6	55	0.0	46.5	48.1	0.0	43.1	41.1	
Swara count>62	0.0	12	4.0	3.0	16	0.0	166	10.0	0.0	1.0	7.0	

Basc Sruti Consistency Coefficient is >> 99.32

Total Sruti Consistency Coefficient is >> 95.21



6.2.18 Mela no. 51 Kamavardhani by Kunnakkudi Vaidyanathan, Violin

Sruti D#, No of scans 500

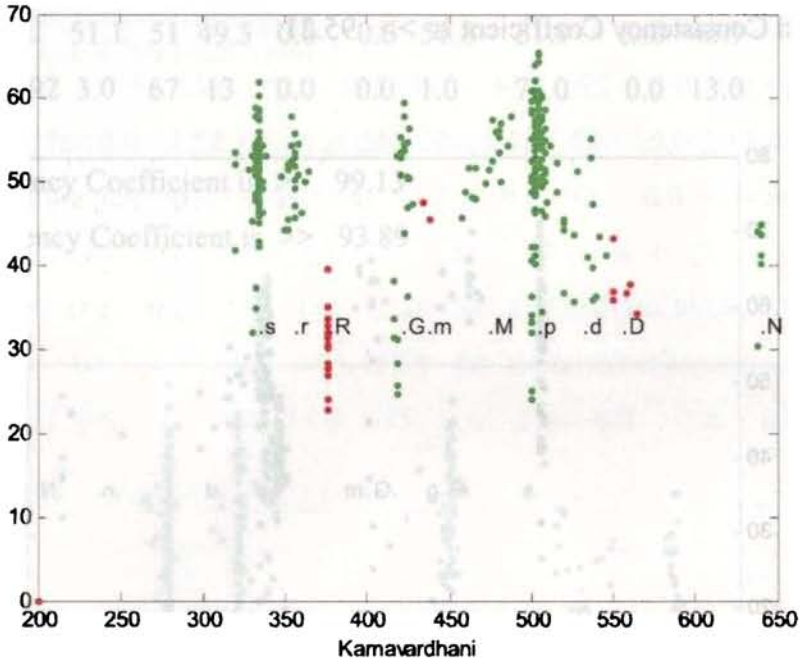
RAGA IDENTIFIED >> **51 Kamavardhani**

The Swaras of the Raga are > S r G M P d N

Swaras >S	r	R	g	G	m	M	P	d	D	n	N
Frequency>332	355	376	0.0	420	436	472	503	531.8	555	0.0	639
Amplitude>51	50.6	30	0.0	45.2	46.6	52.3	52.3	43.5	37.4	0.0	40.8
Swara count >83	23	14	0.0	29.0	2.0	17.0	102	16.0	6.0	0.0	6.0

Sruti Consistency Coefficient is >> 99.19 %

Raga Consistency Coefficient is >> 94.36 %



6.2.19 Mela no. 22 Kharaharapriya by S. Balachander, Veena

Sruti D#, No of scans 500

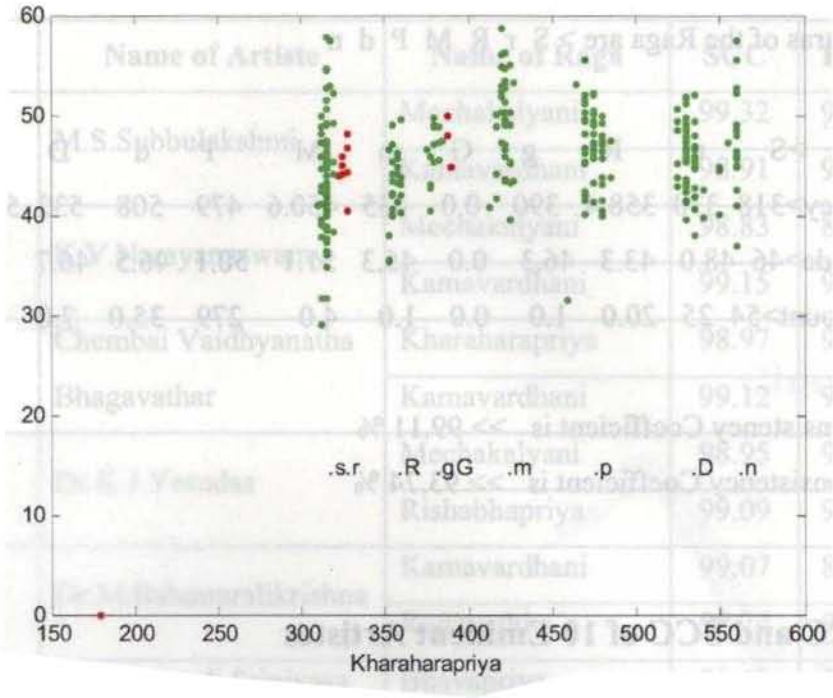
RAGA IDENTIFIED >> **22 Kharaharapriya**

The Swaras of the Raga are > S R g m P D n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>314	325	356	379.8	388	421	0.0	474	0.0	532	559.7	0.0
Amplitude	>43	44.9	43.1	46.3	47.5	49	0.0	46.7	0.0	45.7	47.3	0.0
Swara count	>78	8.0	27	14.0	3.0	42	0.0	52.0	0.0	59.0	17.0	0.0

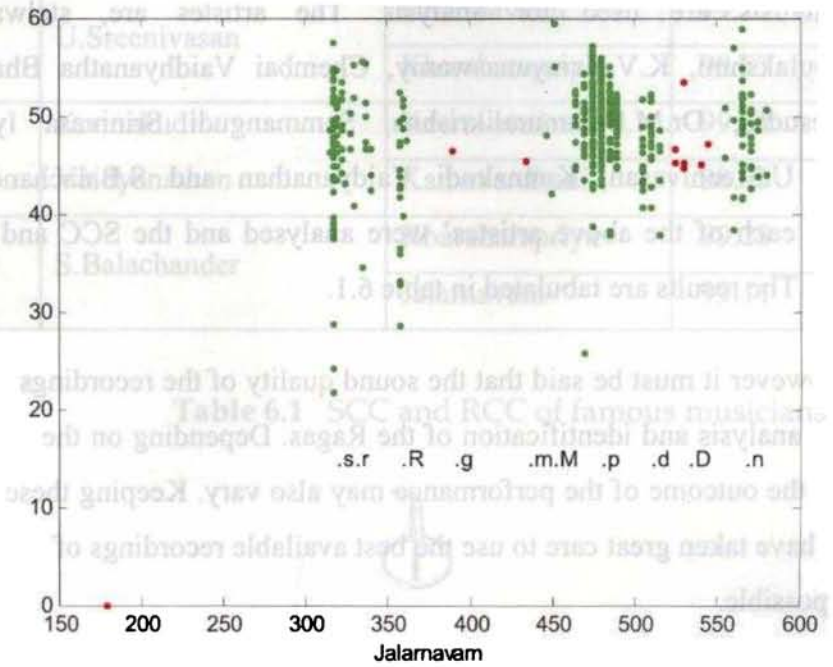
Sruti Consistency Coefficient is >> 99.29 %

Raga Consistency Coefficient is >> 95.04 %



6.2.20 Mela no. 14 Jalarnavam by S. Balachander Veena

Sruti D#, No of scans 500



RAGA IDENTIFIED >> **38 Jalarnavam**

The Swaras of the Raga are > S r R M P d n

Swaras	>S	r	R	g	G	m	M	P	d	D	n	N
Frequency	>318	330	358.4	390	0.0	435	450.6	479	508	532	566.8	0.0
Amplitude	>46	48.0	43.3	46.3	0.0	45.3	51.1	50.1	46.5	46.7	48.1	0.0
Swara count	>54	25	20.0	1.0	0.0	1.0	4.0	279	35.0	7.0	42.0	0.0

Sruti Consistency Coefficient is >> 99.11 %

Raga Consistency Coefficient is >> 93.74 %

6.3 RCC and SCC of 10 Eminent Artistes

In the above analysis the most popular Melakartha Ragas like Mechakalyani, Kharaharapriya, Kamavardhani, Dheerasankarabharanam, Mayamalavagaula, Dharmavathi and Keeravaani etc. are used. The recordings of both vocalists and instrumentalists are used for analysis. The artistes are, stalwarts, like M.S.Subbulakshmi, K.V.Narayanaswamy, Chembai Vaidhyanatha Bhagavathar, Dr.K.J.Yesudas, Dr.M.Balamuralikrishna, Semmangudi Srinivasa Iyer, T.N. Krishnan, U.Sreenivasan, Kunnakudi Vaidyanathan and S.Balachander. Two recordings each of the above artistes' were analysed and the SCC and RCC are calculated. The results are tabulated in table 6.1.

However it must be said that the sound quality of the recordings may affect the proper analysis and identification of the Ragas. Depending on the mood of the performer the outcome of the performance may also vary. Keeping these factors in mind, we have taken great care to use the best available recordings of the artistes as much as possible.

Sl.No.	Name of Artiste	Name of Raga	SCC	RCC
1	M.S.Subbulakshmi	Mechakalyani	99.32	90.24
		Kamavardhani	98.91	90.07
2	K.V.Narayanaswamy	Mechakalyani	98.83	89.77
		Kamavardhani	99.15	92.64
3	Chembai Vaidhyanatha Bhagavathar	Kharaharapriya	98.97	90.92
		Kamavardhani	99.12	90.54
4	Dr.K.J.Yesudas	Mechakalyani	98.95	90.00
		Rishabhapriya	99.09	91.26
5	Dr.M.Balamuralikrishna	Kamavardhani	99.07	85.00
		Rupavathi	98.74	91.66
6	Semmangudi Srinivasa Iyer	Bhavapriya	98.48	87.90
		Mechakalyani	98.98	92.13
7	T.N. Krishnan	Sankarabharanam	99.36	92.15
		Mayamalavagaula	99.10	89.99
8	U.Srcenivasan	Dharmavathi	99.13	93.89
		Kharaharapriya	99.57	97.01
9	Kunnakudi Vaidyanathan	Keeravaani	99.32	91.64
		Kamavardhani	98.99	89.48
10	S.Balachander	Kharaharapriya	99.29	93.36
		Jalarnavam	99.11	91.05

Table 6.1 SCC and RCC of famous musicians

Chapter 7

The User Manual

The programs ***mrag*** *and* ***frag*** *are used for identification of Ragas and computation of SCC and RCC, while* ***Sruti*** *is developed for other applications.*

This chapter gives an account of the steps involved in the analysis of musical performances, using the software **mrag**, **frag** and **Sruti**. The programs **mrag** and **frag** are used for identification of Ragas and computation of **SCC** and **RCC**, while **Sruti** is developed for other applications. These programs will run in Matlab.

7.1 Hardware requirements

Use any multimedia desktop PC or laptop, with provision for external microphone and speaker. Memory requirements are standard.

7.2 Software requirements

Software required are, Microsoft windows operating system and Matlab, which are installed in a PC or a laptop. The programs mrag.m, frag.m are used for identification of Raga and Sruti.m is used to determine the frequency generated by musical instruments. These programs will work in Matlab environment.

7.3 Features of the software

For Raga identification and analysis, we have developed two programs, **mrag** and **frag**. For other applications, such as finding the frequency of turning fork etc., we have developed the program **Sruti**. These programs were developed in Matlab and runs in the Matlab environment. However, the software can also be developed as an independent C program with some more efforts.

7.3.1 Potential of the software

The software developed can be used for the following applications:

1. Real time Raga detection with input from microphone.
2. Detection of Raga with input from secondary memory.
3. Computation of the details of the Swaras, such as frequency and amplitude.
4. Computation of Sruti Consistency Coefficient.
5. Computation of Raga Consistency Coefficient.
6. Calibration of tuning fork.
7. Calibration of musical instruments.

The software developed can be used for the identification and analysis of the 72 Melakartha Ragas. A live program can be input to the software with the help of a microphone attached to the computer. If it is a recorded performance in any of the sound file formats, such as wav, mp3 etc., compatible software players can be used as an interface to input the file to the software for the analysis. The result of the analysis is made available in two forms, as a listing and as a graph.

7.4 Procedure of analysis using mrag and frag

Step 1.

Choose the mode of input of sound from the Microsoft windows control panel. Choose a microphone, wave out mix or line in as the input source. Set the input level to 40% of the maximum, so that we can here the sound at a medium level volume. Mute all other inputs.

Step 2.

Choose any one of the programs **mrag**, or **frag** depending on the requirement. For identification of the Raga, **mrag** or **frag** has to be used. If the

singer is a male or the playing instrument is a male instrument, for instance Veena, choose **mrag** as the program. If the singer is female or the instrument used is female, for example Violin, Flute or Mandolin, choose **frag** as the program.

Step 3.

For **mrag** and **frag**, give the base Sruti of the singer or the instrument as one of the inputs. Sruti will be entered as any of the alphabets a, A, b, c, C, d, D, e, f, F, g, G. The details are given in table 3.1 in chapter 3

Step 4.

Give the number of scans equal to 300 as the second input. The no of scans depends on the performer. The no of scans can be 200 if he or she covers all the notes of the middle octave in 100 seconds. Usually, in Raga aalapana, the no of scans may be 300. Better result is obtained while number of scan is 500. Any form of Raga, like Varna, Keerthana, Raga aalapana can be used for Raga identificationtion. While a Raga is rendered by a singer, analysis would be better if no other instrument is used as an accompaniment. Satisfactory results can also obtained while accompaniments are used, but at a subdued level. Only solo singing is recommended.

Prominent frequencies and the corresponding Swaras are determined based on the initial base frequency (of **sa**). Then the sequence of Swaras is matched with the Swara sequence of the 72 Melakartha Ragas, to identify the Raga. The following details of the analysis are displayed as default: 1) The Melakartha number of the Raga. 2) The name of the Raga detected. 3) The Swara sequence of the identified Raga. There is a provision for displaying more details of the Raga. The following details can be had as per requirements. 1) The average frequency of all the Swaras identified. 2) The average amplitude of the corresponding Swaras. 3) The number of times each Swara has been detected. 4) The graphical display of the

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observed frequency against amplitude. The graphical display of the Swara positions of the Raga are marked with green dots and those Swaras which are outside the Raga are marked with red dots. In the black and white printout the dots will be gray and black respectively. 5) The Sruti Consistency Coefficient of the artiste. 6) The Raga Consistency Coefficient of the artiste.

7.5 Procedure of analysis using Sruti

The program **Sruti** is used for the calibration of the tuning fork and other musical instruments. The frequency generated by these acoustic instruments can be measured using **Sruti**. The steps followed for the analysis are:

Step 1

Same as the step 1 of 7.4 above

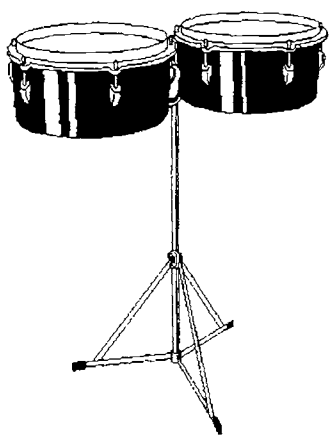
Step 2

Run the program and sound the instrument, keeping the microphone near the instrument. It will detect the sound and measure the frequency and the result will be displayed. Here the time duration may be taken to be 1sec. for a resolution of 1Hz.

7.6 Remark

The software can easily be modified to suit any other application in this area.

Chapter 8



Conclusion

On the basis of the present study, it becomes possible to develop a model which can handle all the 22 Srutis to analyse a Raga.

The model developed in this project is capable of identifying all the 72 Melakartha Ragas. Performance by vocalist and instruments were tested to satisfaction. One of the prominent observations is that, some of the publicly available performances, both vocal and instrumental, are found to be substantially deviated from the theory. Many of the performances are not strictly in the Ragas as claimed. While some cases can be classified as deviations in the features of the Raga from theory, others are mistakes.

8.1 Performance evaluation

One of the prominent achievements of this study is that it has been able to come up with a performance index for musicians, namely Sruti Consistency Coefficient (SCC) and Raga Consistency Coefficient (RCC). It is heartening to note that SCC and RCC are in total agreement with the popular evaluation of performing musicians, such as M.S. Subbulakshmi, K.V.Narayanaswamy, Dr.M.Balamuralikrishna and Dr.K.J.Yesudas, who have secured very high SCC and RCC in our evaluation.

The identification of Raga in a live concert is difficult as the various accompaniments will be producing sound at multiple frequencies. While the Raga is to be detected from the performance of the vocalist, sound from musical instruments would interfere, hampering voice frequencies. When a vocalist is accompanied by a violinist, the violinist will be playing frequencies which are double that of the vocalist (explained in chapter 3). In such situations, detection may not be accurate. Similarly, with mridangam, producing multiple frequencies, the detection may fail. However, if the accompaniments are played at subdued

level, or with the help of a good sound mixer, the track of the vocalist can be isolated; identification of the Raga is possible. Undoubtedly, a good environment for identification of the Raga is, either a vocalist alone or an instrument alone. At any cost, if tampura is used, its level must be very low.

Analysing the sound generated by different sound sources, it was found that a musical Note or Sruti contains a number of frequencies. The prominent frequencies are the fundamental and the overtones. But it also contains many other frequencies and spread over many octaves. From among all the generated frequencies, we can find out the Swaras of the Raga rendered.

8.2 Western Music

It must be said that the present model has immense scope. For instance, with some modifications, the same set of programs can be used to identify the musical scale of a Western Music or the Notes of a chord played. Since the Western Music doesn't have the concept of Gamaka, the musical Note converges to a single frequency. This makes the identification of the Notes very easy. Hence the Scales in the Western Music can be determined easily.

8.3 Hindustani Music

The basis of Hindustani Music is the same as that of Carnatic Music. But instead of Melakartha Ragas, it has 10 Thats. By suitably modifying the program we can identify Hindustani Ragas also.

8.4 Film songs

This model can also have popular applications like identification of Raga in a Raga based film song. If the song is in any one of the 72 Melakartha Ragas, it will be identified by the program.

8.5 Calibration of acoustic instruments

The software **Sruti** can also be used for calibration of musical instruments and laboratory equipments used for sound based experiments. For example the exact frequency of a tuning fork can be found out. It is interesting to note that at least in some cases the actual frequency of the tuning forks, available in the market, are not as marked. Similarly the fret positions of string instruments, like in a guitar can be determined and checked.

8.6 A tool for students

The software: **mrag**, **frag** and **Sruti** can be used as training kit for the students of music. These programs can be installed in his personal computer at home and the practice sessions could be continuously monitored and evaluated. By using **Sruti,** the base Sruti of the student can be checked and stabilised. This would greatly improve the quality of his performance. More over his performance can be checked by evaluating his SCC and RCC.

An advanced student of Carnatic Music, while practicing different Ragas in the 16 Sruti system, can see that he is going through the different Sruti positions of the 22 Sruti system during his routine rendering sessions. On the basis of the present study, it becomes possible to develop a model which can handle all the 22 Srutis to analyse a Raga.

For all the reasons cited above, it is quite evident that the model presented in this thesis has the potential to be an invaluable tool for professional musicians as well as scholars and students of music around the world.

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Abbreviations

♭	flat
A	Note A of Western Music
A#	Note A sharp of Western Music
A/D	Analog to Digital
A♭	Note A flat of Western Music
B	B note in Western Music
C	C note in Western Music
C#	C sharp note in Western Music
D	D note in Western Music
D#	D sharp note in Western Music
da, Da	Dhaivatham, sixth of the seven swaras in Carnatic music
E	E note in Western Music
F	F note in Western Music
F#	F sharp note in Western Music
FFT	Fast Fourier Transformfrag
frag	Program frag.m used for identification of Ragas for female
voice	and female instruments.
G	G note in Western Music
G#	G sharp note in Western Music
ga, Ga	Gandharam, third of the seven swaras in Carnatic Mus
Hz or hz	Hertz, unit of frequency i.e. number of cycles per second.
ma, Ma	Madhyamam, fourth of the seven swaras in Carnatic Music
	mrag
mrag	Program mrag.m used for identification of Ragas for male
voices	and male instruments

ni, Ni Nishadam, seventh of the seven swaras in Carnatic Music

Note Western Music note like A, A# , B, C, C# etc.

pa, Pa Panchamam, fifth of the seven swaras in Carnatic Music

ri, Ri Rishabam, second of the seven swaras in Carnatic Music

s, sa, s, sa shadjam, first of the seven swaras in Carnatic Music

S, Sa, S, Sa Thara shadjam, upper sa in the middle octave

sa, ri, ga, ma, pa, dha, ni Saptha swaras of Carnatic Music

Sa, Ri, Ga, Ma, Pa, Dha, Ni Saptha swaras of Carnatic Music

Sruti Base Sruti

Sruti Program **Sruti**

Swara Carnatic Music notes like sa, ri, ga, ma etc.