GRAHA BHEDAM
APP DEVELOPMENT PROJECT

PRANEETH SRIVANTH

OUTLINE

- OBJECTIVE
- CONCEPT USED FOR IMPLEMENTATION
- THREE CATEGORIES FOR GRAHA BHEDAM IMPLEMENTATION
  - SYMMETRIC JANYA RAGAS
  - MELAKARTA RAGAS
  - ASYMMETRIC JANYA RAGAS
- TECHNIQUES FOR TONE PRODUCTION
  - COMPUTER GENERATED TONE OF ONE FREQUENCY
  - COMPUTER GENERATED TONE OF MULTIPE FREQUENCIES
  - VOCAL RENDITION
- FINAL PRODUCT
- ADDITIONAL FEATURES

OBJECTIVE

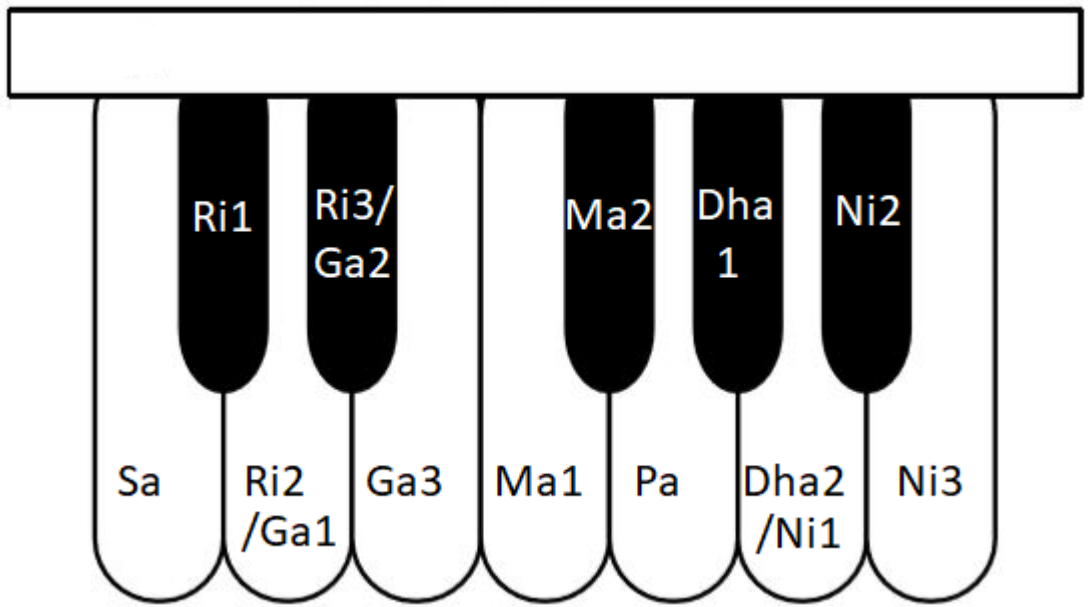
- TO DEMONSTRATE THE CONCEPT OF GRAHA BHEDAM TO A **CARNATIC RASIKA** IN A SIMPLISTIC MANNER

- TO DEVELOP A **AUDIO-VISUAL DEMONSTRATION** TOOL FOR DEMONSTRATING THE CONCEPT OF GRAHA BHEDAM

- TO EVENTUALLY LEAD TO A **MOBILE APP DEVELOPMENT**

CONCEPT USED FOR IMPLEMENTATION

- SWARA STHANAS ARE REPRESENTED BY A STRING OF 12 DIGITS,
- 1 DENOTES THE PRESENCE OF THE SWARA AND 0 REFERS TO THE ABSENCE OF THE SWARA.



- EG: FOR RAGA MOHANAM

Sa	R1	R2	G2	G3	M1	M2	P	D1	D2	N2	N3	Sa*
1	0	1	0	1	0	0	1	0	1	0	1	0

Ref: A Karnatik Music Primer by P Sriram

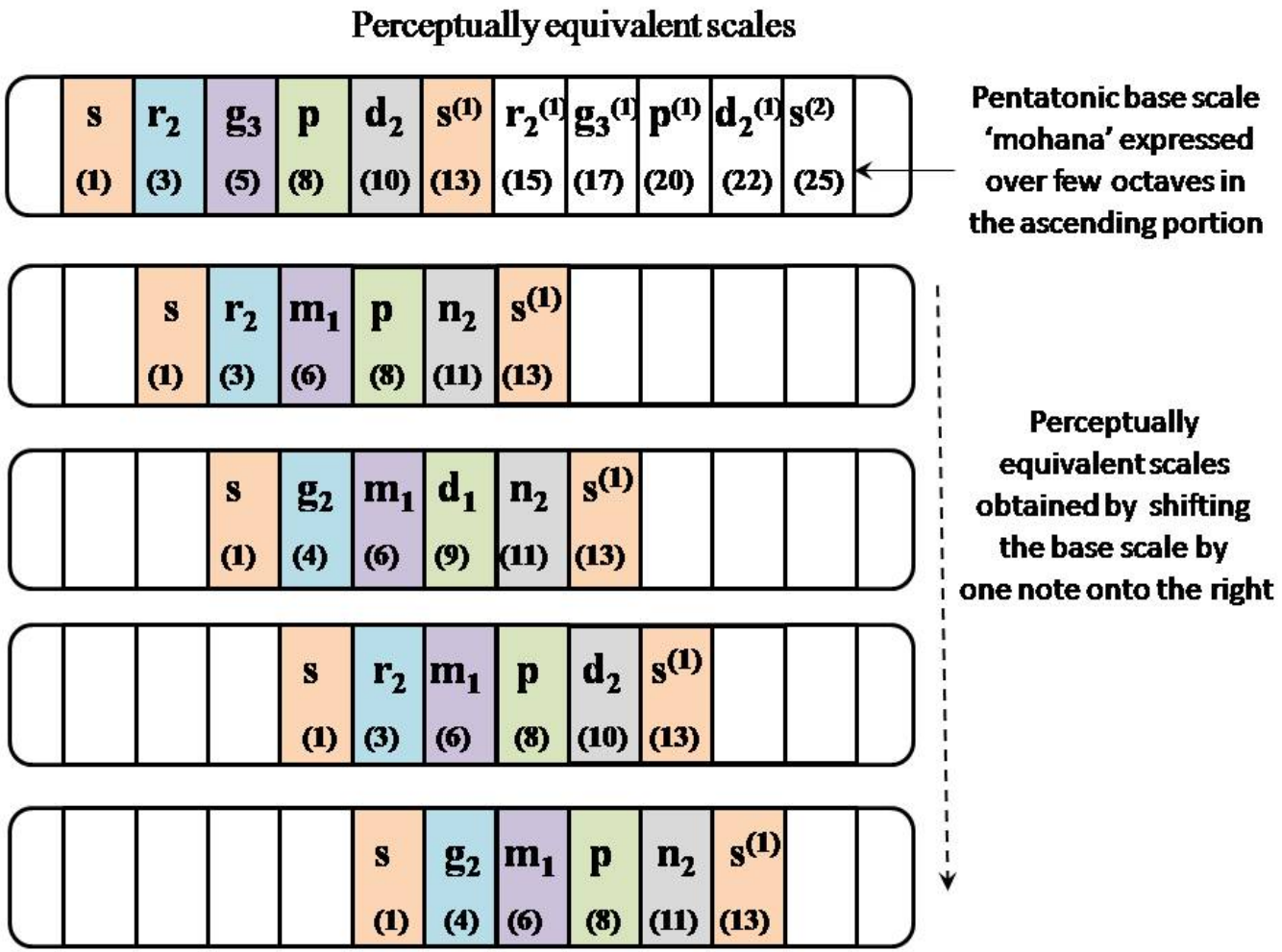
THREE CATEGORIES FOR GRAHA BHEDAM IMPLEMENTATION

- GRAHA BHEDAM FOR SYMMETRIC JANYA RAGAS
- GRAHA BHEDAM FOR MELAKARTA RAGAS
- GRAHA BHEDAM FOR ASYMMETRIC JANYA RAGAS

CATEGORY 1

GRAHA BHEDAM FOR SYMMETRIC JANYA RAGAS

GRAHA BHEDAM FOR MOHANAM RAGA

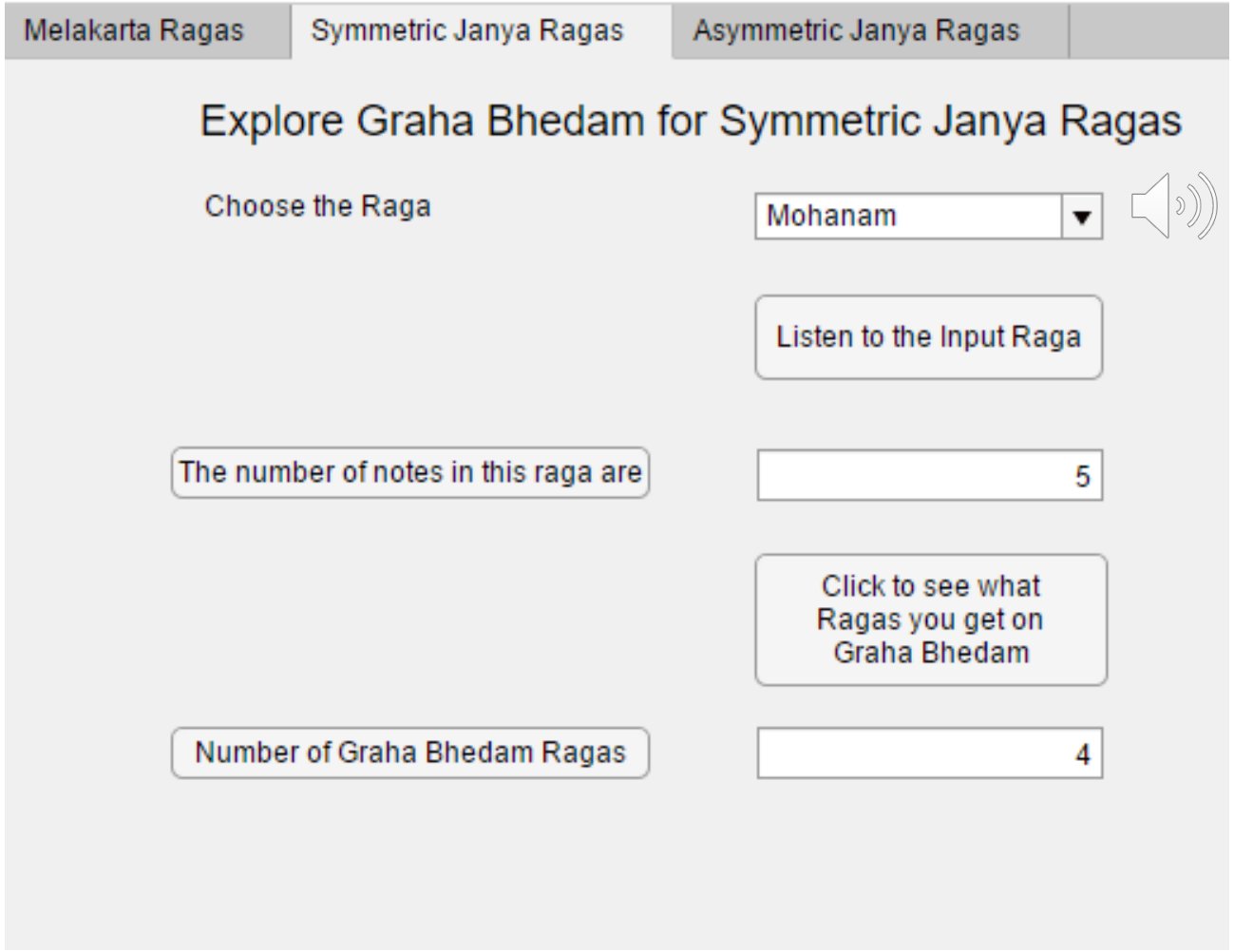


Ref: Shyam G. Srinivasa, Harish Seshadri, Music and symbolic dynamics: The science behind an art

GRAHA BHEDAM FOR MOHANAM RAGA

Raga name	**S**		**R2**		**G3**			**P**		**D2**			**S***		**R2***		**G3***			**P***		**D2***		
Mohanam (lower and upper octave)	1	0	1	0	1	0	0	1	0	1	0	0	1	0	1	0	1	0	0	1	0	1	0	0
			S		**R2**			**M1**		**P**			**N2**		**S***									
Madhyamavathi			1	0	1	0	0	1	0	1	0	0	1	0	1									
					S			**G2**		**M1**			**D1**		**N2**		**S***							
Hindolam					1	0	0	1	0	1	0	0	1	0	1	0	1							
								S		**R2**			**M1**		**P**		**D2**			**S***				
Shudha Saveri								1	0	1	0	0	1	0	1	0	1	0	0	1				
										S			**G2**		**M**		**P**			**N2**		**S***		
Shudha Dhanyasi										1	0	0	1	0	1	0	1	0	0	1	0	1		

A PROTOTYPE DEVELOPED IN MATLAB SOFTWARE
SYMMETRIC JANYA RAGAS



Output Window

	Graha Bhedam from Swara	Yields Raga
1	Ri 2	Madhyamaavathy
2	Ga 3	Hindolam
3	Pa	Sudha Saaveri
4	Dha 2	Sudha Dhanyaasi

CATEGORY 2

GRAHA BHEDAM FOR MELAKARTA RAGAS

GRAHA BHEDAM FOR KAMAVARDHINI RAGA

Raga name	**S**	**R1**			**G3**		**M2**	**P**	**D1**			**N3**	**S***	**R1 ***			**G3 ***		**M2 ***	**P ***	**D1 ***			**N3 ***
Kamavardhini	1	1	0	0	1	0	1	1	1	0	0	1	1	1	0	0	1	0	1	1	1	0	0	1
Graha bhedam from Swara N3												**S**	**R1**	**G1**			**M1**		**P**	**D1**	**N1**			**S***
Kanakangi												1	1	1	0	0	1		1	1	1	0	0	1

GRAHA BHEDAM FROM OTHER SWARAS DO NOT RESULT INTO MELAKARTA RAGAS

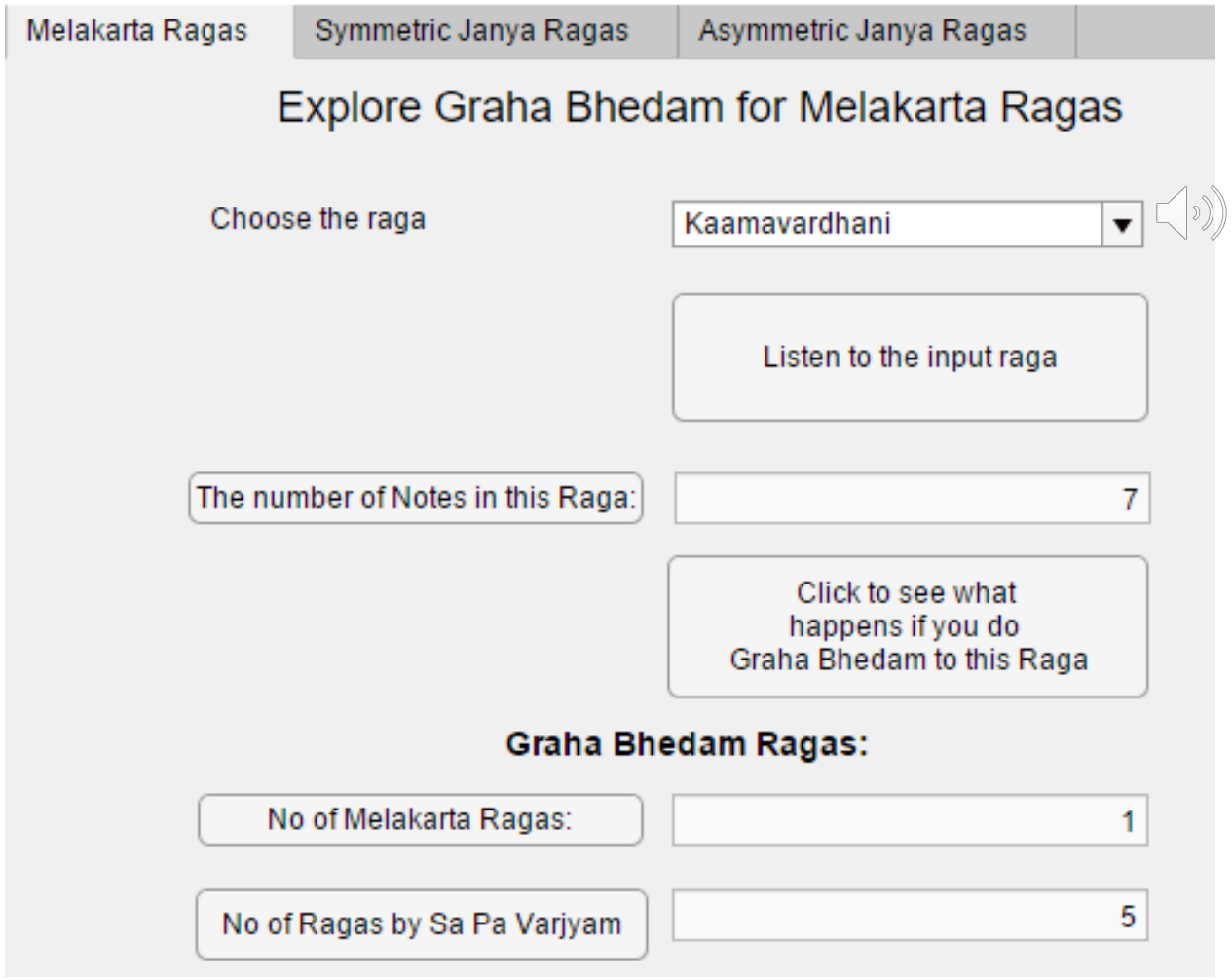
(They either result into ragas which have no Panchamam or result in other ragas which have two madhyamams)

GRAHA BHEDAM FOR KAMAVARDHINI RAGA

SHADJAMA PANCHAMA VARJYAM

Raga name	**S**	**R1**			**G3**		**M2**	**P**	**D1**			**N3**	**S***	**R1 ***			**G3 ***		**M2 ***	**P ***	**D1 ***			**N3 ***
Kamavardhini	1	1	0	0	1	0	1	1	1	0	0	1	1	1	0	0	1	0	1	1	1	0	0	1
From Swara R1		**S**			**G2**		**M1**		**P**			**N2**		**S***										
Shudha Dhanyasi		1	0	0	1	0	1	~~1~~	1	0	0	1	~~1~~	1										
From Swara G2					**S**		**R2**		**G3**			**P**		**D2**			**S***							
Mohanam					1	0	1	~~1~~	1	0	0	1	~~1~~	1	0	0	1							
From Swara M2							**S**		**R2**			**M1**		**P**			**N2**		**S***					
Madhyamavathi							1	~~1~~	1	0	0	1	~~1~~	1	0	0	1	0	1					
From Swara D1									**S**			**G2**		**M1**			**D1**		**N2**		**S***			
Hindolam									1	0	0	1	~~1~~	1	0	0	1	0	1	~~1~~	1			
From Swara N2												**S**		**R2**			**M1**		**P**		**D2**			**S***
Shudha Saveri												1	~~1~~	1	0	0	1	0	1	~~1~~	1	0	0	1

A PROTOTYPE DEVELOPED BY ME IN MATLAB SOFTWARE



Output Window

	Graha Bhedam from Swara	Yields Melakarta No.	Melakarta Raga
1	Ni 3	1	Kanakaangi

	Graha Bhedam from Swara	YieldsRaga
1	Ri 1	Sudha Dhanyaasi
2	Ga 3	Mohanam
3	Ma 2	Madhyamaavathy
4	Dha 1	Hindolam
5	Ni 3	Sudha Saaveri

CATEGORY 3

GRAHA BHEDAM FOR ASYMMETRIC JANYA RAGAS

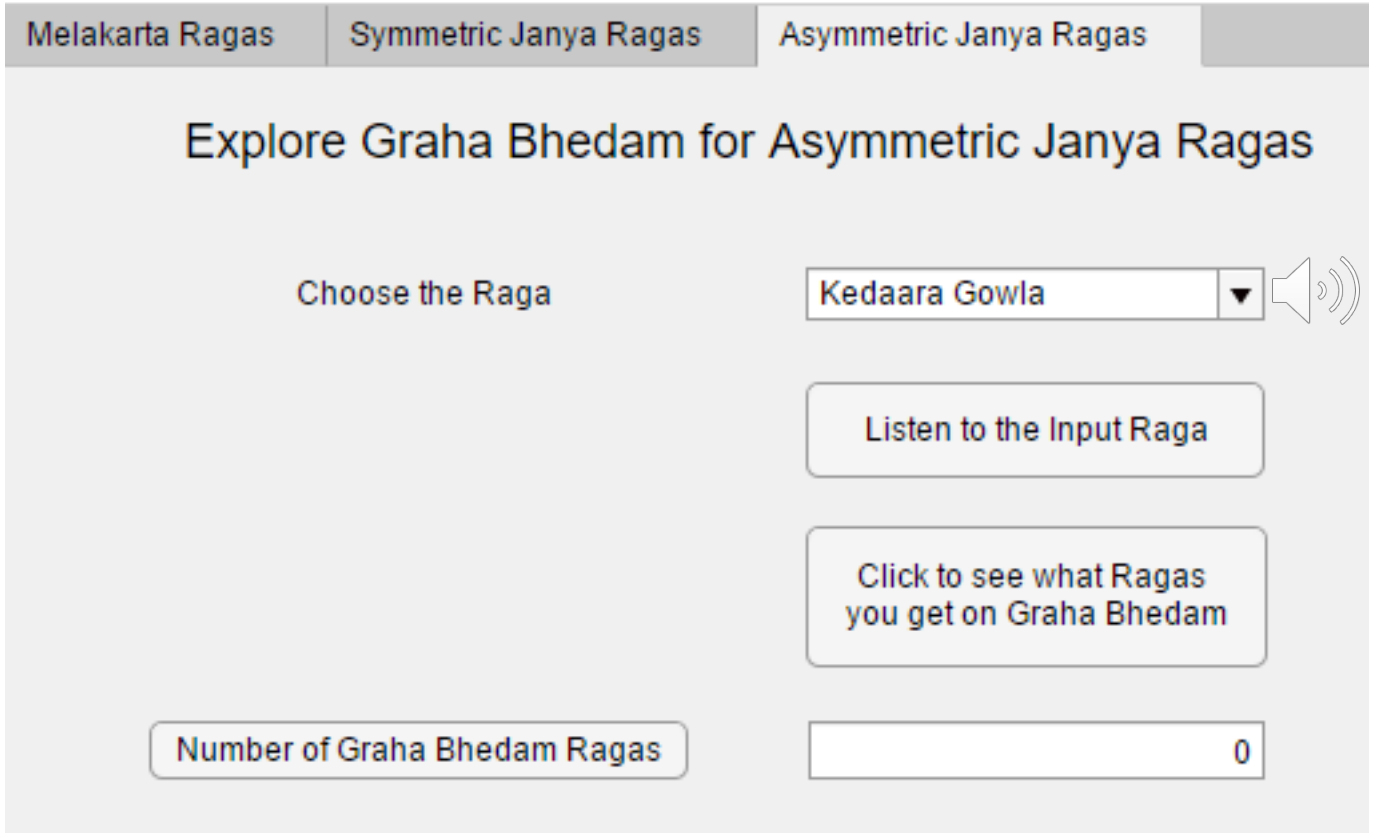
GRAHA BHEDAM FOR KEDARAGOWLA RAGA

Raga name																							
Kedaragowla																							
Aarohanam	**S**		**R2**			**M1**		**P**			**N2**		**S***		**R2 ***			**M1 ***		**P***			**N2 ***	
	1	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**0**
Avarohanam	**S**		**R2**		**G3**	**M1**		**P**		**D2**	**N2**		**S***		**R2 ***		**G3 ***	**M1 ***		**P***		**D2 ***	**N2 ***	
	1	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**1**	**0**
From swara M1, Aarabhi																								
Aarohanam						**S**		**R2**			**M1**		**P**		**D2**			**S***						
						1	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**1**						
Avarohanam						**S**		**R2**		**G3**	**M1**		**P**		**D2**		**N3**	**S***						
						1	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**1**						

GRAHA BHEDAM FOR KEDARAGOWLA RAGA

From swara Pa, Aabheri																				
Aarohanam							**S**			**G2**		**M1**		**P**			**N2**		**S***		
							1	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**1**		
Avarohanam							**S**		**R2**	**G2**		**M1**		**P**		**D2**	**N2**		**S***		
							1	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**1**	**0**	**1**		
From swara N2, Mohanakalyani																				
Aarohanam									**S**		**R2**		**G3**			**P**		**D2**			**S***
									1	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**1**
Avarohanam									**S**		**R2**		**G3**		**M2**	**P**		**D2**		**N3**	**S***
									1	**0**	**1**	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**1**

A PROTOTYPE DEVELOPED IN MATLAB SOFTWARE



	Graha Bhedam from Swara	Yields Raga
1	Ma 1	Aarabi
2	Pa	Aabheri
3	Ni 2	Mohana Kalyaani

TECHNIQUES FOR TONE PRODUCTION

METHOD 1

USING A COMPUTER GENERATED TONE OF ONE FREQUENCY

METHOD 2:

USING A COMPUTER GENERATED TONE WITH HARMONICS

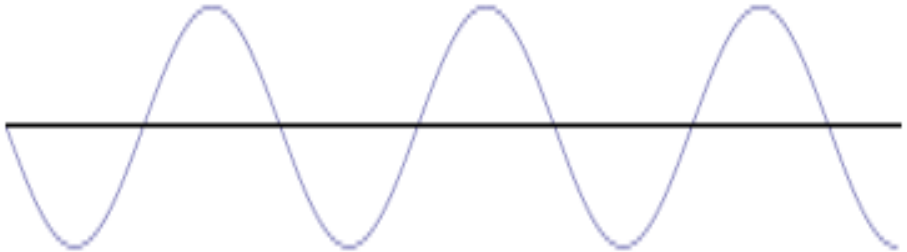
METHOD 3:

USING A VOCAL RENDITION

METHOD 1: USING A COMPUTER GENERATED TONE OF ONE FREQUENCY

Swara	Amplitude of swara	Frequency of swara (Hz)
Sa	42	240
Ri1	44.7	256
Ri2	46	270
Ga1	46.4	288
Ga2	41.7	300
Ma1	46.8	320
Ma2	42	336
Pa	40.7	360
Dha1	35.5	384
Dha2	41.1	400
Ni1	40.2	426.67
Ni2	39.5	450

$$\sum_{t=1}^{t=1/Fs} A_{swara} \times \cos(2 \times \pi \times f_{swara} \times t)$$



TONAL QUALITY HAS ONLY A SINGLE FREQUENCY – **NOT AN AESTHETIC TONE**

Ref: http://www.engineeringenotes.com/electrical-engineering/harmonics/

METHOD 2: USING A COMPUTER GENERATED TONE OF MULTIPLE HARMONICS, EG. 8 HARMONICS

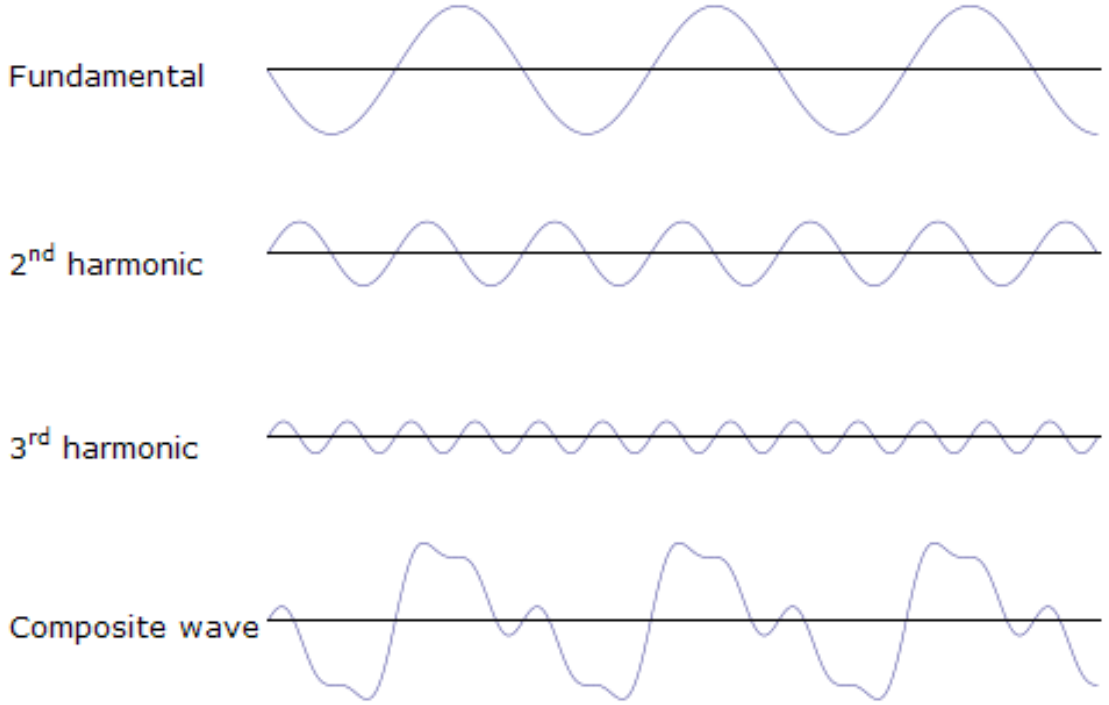
$$\sum_{t=1}^{t=1/Fs} A_{swara} \times \cos(2 \times \pi \times f \times t)$$

$$\sum_{i=1}^{8} \sum_{t=1}^{t=1/Fs} A_{swara} \times e^{-(i-1)} \times \cos(i \times 2 \times \pi \times f \times t)$$

$$= \sum_{t=1}^{t=1/Fs} A_{swara} \times \cos(2\pi f \times t) + A_{swara} \times e^{-1} \times \cos(2\pi \times 2f \times t)$$

$$+ A_{swara} \times e^{-2} \times \cos(i \times 2 \times \pi \times 3f \times t)$$

$$+ \ldots\ldots\ldots + A_{swara} \times e^{-7} \times \cos(i \times 2 \times \pi \times 8f \times t)$$



TONAL QUALITY IS MORE **PLEASING TO THE EARS**

Ref: http://www.engineeringenotes.com/electrical-engineering/harmonics/

METHOD 3: USING A VOCAL RENDITION

- THE CURRENT IMPLEMENTATION INVOLVES ONLY A **COMPUTER GENERATED INSTRUMENTAL TONE**

- ONLY IF IT IS **DEMONSTRATED BY SINGING** WOULD IT BE POSSIBLE TO CLEARLY UNDERSTAND WHAT SWARA IS BECOMING THE NEW SHADJAM.

- AS A TRIAL RUN, THE AUDIO RECORDINGS WERE SOURCED FROM RAGASURABHI.COM
  - (SAMPLES OF THE 12 SWARASTHANAS SUNG BY SMT. UMA RAMASUBRAMANIAM (PITCH F) WERE TAKEN FROM RAGASURABHI.COM.)

THE PROBLEM – GRAHA BHEDAM FOR ABOGHI RAGA

Raga name	**S**		**R2**	**G2**		**M1**				**D2**			**S***		**R2***	**G2***		**M1***				**D2***		
Aboghi	1	0	1	1	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	0	1	0	1
Graha bhedam from Swara Pa						**S**				**G3**			**P**		**D2**	**N2**		**S***						
Valaji						1	0	0	0	1	0	0	1	0	1	1	0	1						
Pitch shift by 5 semi-tones																								

- PITCH SHIFTING ALGORITHM GIVES A DECENT SOUND QUALITY FOR A MAXIMUM OF -3/-3 SEMITONES.
  - ABHOGHI RAGA VOCAL RECORDING
  - VALAJI RAGA VOCAL RECORDING (PITCH SHIFTED BY 5 SEMITONES)
- THIS PROBLEM CAN PROBABLY BE SOLVED BY ENHANCED SAMPLE ACQUISTION FROM DIFFERENT SINGERS.

Samples of the 12 swarasthanas sung by Smt. Uma Ramasubramaniam (*pitch F*) were taken from RagaSurabhi.com.

FINAL PRODUCT

- A **MOBILE-BASED APPLICATION**, WHICH CARNATIC MUSIC RASIKAS, CONNOISSEURS, STUDENTS, TEACHERS CAN USE FOR UNDERSTANDING THE GRAHA BHEDAM CONCEPT

- TO ENABLE CARNATIC MUSIC RASIKAS TO **PLAY AROUND** WITH DIFFERENT RAGAS TO SEE WHAT HAPPENS ON GRAHA BHEDAM

- TO IMPROVE THE **AWARENESS** OF THE CONCEPT OF GRAHA BHEDAM AND MAKE IT **EXTREMELY EASY TO INTERPRET**

ADDITIONAL FEATURES

- **ESTABLISHMENT** OF **RULES** FOR MURCHANAAKARA & AMURCHANAAKARA MELAKARTA RAGAS

- INCLUSION OF **ADVANCED EXAMPLES** OF SHRUTHI BHEDAM
  - POSSIBLY LINKING TO THE IDEA OF **CONSONANCE, DISSONANCE, VAADHI, SAMVADHI** (AS IS THE CASE FOR RAKTHI BASED GRAHA BHEDAM)

- ESTABLISHING A CONNECTION WITH THE IDEA OF **MADHYAMA SHRUTHI**

- ANY OTHER ADDITIONAL FEATURES, IF ANY

ADDITIONAL SLIDES FOR REFERENCES

EXISTING TOOLS
FOR GRAHA BHEDAM DEMONSTRATION

1. GRAHA BHEDAM EXCEL SHEET

2. GRAHA BHEDAM DEMO EXPLORER

3. INTERACTIVE AUDIO VISUAL TOOL – “RASIKA”

EXISTING GRAHA BHEDAM TOOLS

1) GRAHA BHEDAM EXCEL SHEET

Clear Inputs		S	R1	R2/G1	G2/R3	G3	M1	M2	P	D1	D2/N1	N2/D3	N3	S				
		1		1		1			1		1			1				
S	1	S		R2/G1		G3			P		D2/N1			S				
R2/G1	1			S		R2/G1			M1		P			N2/D3		S		
G3	1					S			G2/R3		M1			D1		N2/D3		S

- REPRESENTS THE CONCEPT OF TONIC SHIFTING IN THE FORM OF AN EXCEL SHEET
- CONSIDERS ONLY SYMMETRIC SCALES
- OUTPUTS THE SET OF NEW NOTES IN THE NEW SCALE - NO MENTION OF RAGA NAME/VALIDITY OF RAGA

Ref: BkE-Graha Bhedam Calculator-0031.xls - Ibiblio

EXISTING GRAHA BHEDAM TOOLS
2) GRAHA BHEDAM DEMO EXPLORER

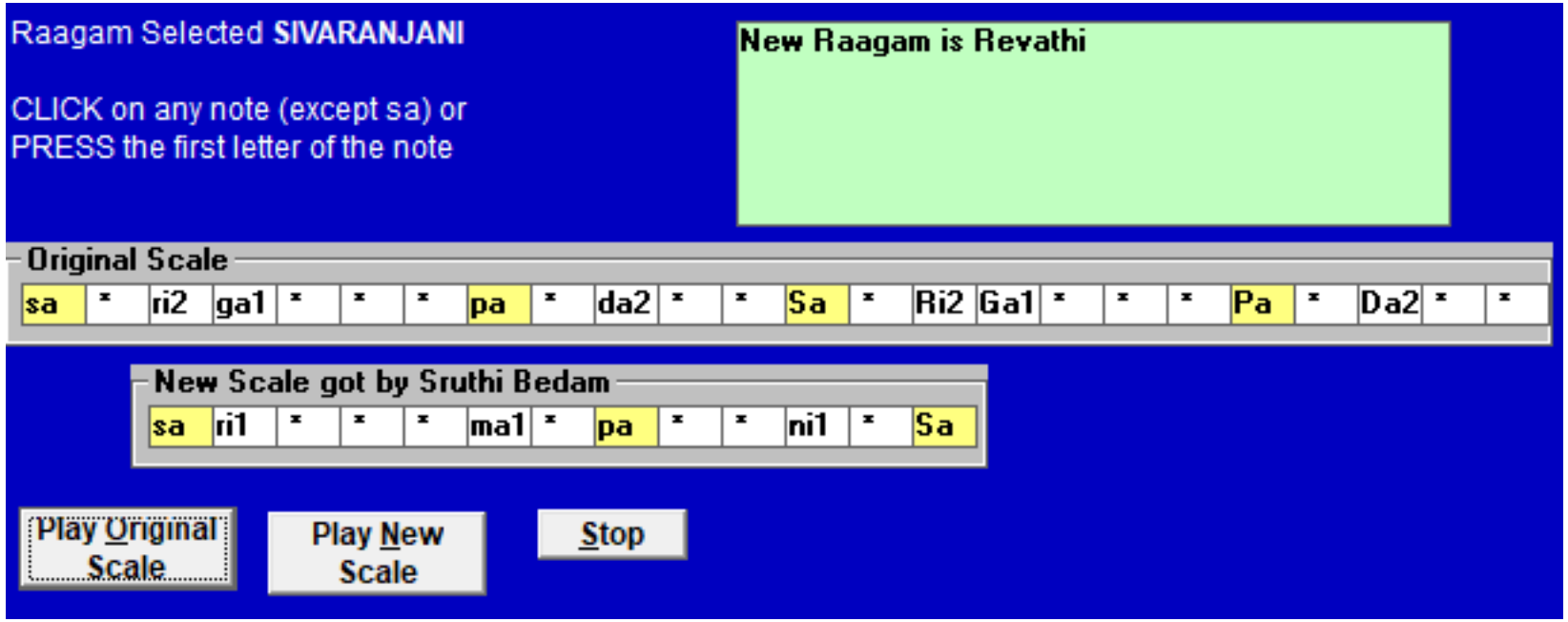
MOHANA KALYĀNI AROHANAM: SRGPDS AVAROHANAM: SNDPMGRS

r	R	G	G	m	M	P	D	D	N	N
N/A	**SRmPnṠ** Bhuvanagandhari Devakriya Hindustani Kapi Madhyamavathi ... 5 more	N/A	**SgmdnṠ** Hindolam Jayanthashrī Malkosh	N/A	N/A	**SRmPDṠ** Ghanashyamala Mandamari Mangalavathi Salagabhairavi ... 20 more	N/A	**SgmPnṠ** Dhanyasi Dhanashree Sindhu Dhanyasi Shuddha ... 6 more	N/A	N/A

- DOES NOT PROVIDE UNIQUE GRAHA BHEDAM RAGA DERIVED FROM A PARTICULAR NOTE
  ANY RAGA WHICH MATCHES AAROHANAM/AVAROHANAM FROM A NOTE IS ACCEPTED AS GRAHA BHEDAM RAGA
- RESULTS IN AN EXTRANEOUS AMOUNT OF RAGAS AS GRAHA BHEDAM DERIVATIVES.

Ref: http://sriku.org/demos/bhedam/

EXISTING GRAHA BHEDAM TOOLS
3) INTERACTIVE AUDIO VISUAL TOOL – "RASIKA"



- AUDIO DEMONSTRATION TOOL PLAYS THE NOTES IN AN INSTRUMENTAL TONE
  - VOCAL RENDITION WOULD COMMUNICATE THE CONCEPT EVEN BETTER
- DOES NOT COVER GRAHA BHEDAM RAGAS OBTAINED BY SHADJAMA PANCHANA VARJYAM
- DOES NOT COVER RAKTHI BASED SHRUTHI BHEDAM

Ref: Rasika – Carnatic Music Software developed by M. Subramanian

THE PROBLEM WITH VOCAL RENDITION

AND

HOW SAMPLE ACQUISITION WOULD SOLVE IT

DEMONSTRATION BY VOCAL RENDITION (AS OPPOSED TO INSTRUMENTAL TONE)

- THE CURRENT IMPLEMENTATION OF THE AUDIO INTERFACE IN MY PROTOTYPE INVOLVES ONLY A **COMPUTER GENERATED INSTRUMENTAL TONE** WHICH ON SHIFTING TONIC PROVIDES A NEW TONE.

- MY IDEA ON THE IMPLEMENTATION, SAY FOR RAGA ABHOGI, GRAHA BHEDAM FROM MADHYAMAM,
  - M D_2 S* R_2* G_2* M* M* G_2* R_2* S* D_2 M
  - S G_3 P D_2 N_2 S* S* N_2 D_2 P G_3 S

- ONLY IF IT IS **DEMONSTRATED BY SINGING** WOULD IT BE POSSIBLE TO CLEARLY UNDERSTAND WHAT SWARA IS BECOMING THE NEW SHADJAM.

- IF **ABHOGI** IS SUNG IN **SHRUTI C** FROM MADHYAMAM TO TAARA STHAAYI MADHYAMAM, THE GRAHA BHEDAM RAGA **VALAJI** SHOULD BE PLAYED IN **SHRUTI F**.

THE PROBLEM

- SAMPLES OF THE 12 SWARASTHANAS SUNG BY SMT. UMA RAMASUBRAMANIAM (*PITCH F*) WERE TAKEN FROM RAGASURABHI.COM AND VALAJI RAGA WAS SYNTHESIZED BY TRANSPOSING THE PITCH BY 5 SEMITONES (USING A PITCH SHIFTING ALGORITHM).

- HOWEVER, THE PITCH SHIFTING ALGORITHM GIVES A DECENT SOUND QUALITY FOR A MAXIMUM OF -3/-3 SEMITONES PITCH SHIFT, BEYOND WHICH THE TONAL QUALITY BECOMES TOO ARTIFICIAL

- THERE IS A PROBLEM OF LACK OF ENOUGH SAMPLES WHICH CANNOT DEMONSTRATE GRAHA BHEDAM FOR MORE THAN 3 SEMITONES.

SAMPLE ACQUISITION

- RECORDINGS OF THE TWELVE SWARASTHANAS (PLAIN NOTES) WITH MEL SHADJAM (EACH FOR TWO SECONDS EACH) IN PITCH C, D#, F#, A, C+ OR A, C, D#, F# OR A, OR ANY OTHER **SET OF 5 SHRUTHIS EACH OF WHICH ARE SEPARATED BY 3 SEMITONE VALUES** WOULD BE NEEDED TO OBTAIN GOOD GRAHA BHEDAM DEMONSTRATIONS.

C	C#	D	**D#**	E	F	**F#**	G	G#	**A**	A#	B	**C+**
1	1.5	2	**2.5**	3	4	**4.5**	5	5.5	**6**	6.5	7	**1+**

OR

A	A#	B	**C**	C#	D	**D#**	E	F	**F#**	G	G#	**A**
-6	-6.5	-7	**1**	1.5	2	**2.5**	3	4	**4.5**	5	5.5	**6**

- VOCAL RECORDINGS OF 12 SWARASTHANAS CAN BE OBTAINED MORE EASILY IF AROHANAM AND AVAROHANAM RECORDINGS OF 6 RAGAS SHANKARABARANAM, HARIKAMBOJI, KHARAHARAPRIYA, HANUMATHODI, NATABHAIRAVI, MECHAKALYANI **RENDERED IN PLAIN NOTES (WITH NO GAMAKAM) IN 5 SHRUTHIS** ARE PROCURED.

HOW THE PROBLEM WOULD BE SOLVED

	C	**C#**	**D**	**D#**	**E**	**F**	**F#**	**G**	**G#**	**A**	**A#**	**B**	**C+**
	1	1.5	2	2.5	3	4	4.5	5	5.5	6	6.5	7	1+
Abhogi in C Shruti	Sa		R_2	G_2		M_1				D_2			S*
Abhogi Raga in C Shruti would be synthesized from Kharaharapriya Aarohana/Avarohana Recording in C Shruti Valaji in D # is synthesized from Harikamboji in D #. Shifting the pitch by 2 semitones would be acomplished by the algorithm to give Valaji in F Shruti.													
Valaji in D# Shruti				Sa				G_3			Pa		
Valaji in F Shruti						Sa				G_3			Pa