MODELLING OF MUSIC AS A COMMUNICATION SYSTEM AND QUANTITATIVE DESCRIPTION OF EMOTIONS IN CARNATIC MUSIC

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I. Main Problem Being Addressed

The solution addresses two main problems:

Problem 1 - Universalization of Music: Music is known for its powerful capacity to evoke emotions. Though Music differs from place to place, the primary effect of Music remains the same i.e. it evokes emotions. Moreover, there are a lot of attempts made recently to universalise music. Any such attempt should be made based on the emotions evoked. This requires a precise quantitative description of emotions, which the solution claims to have obtained.

Problem 2 – Music Therapy: Music Therapy is an alternative form of medicine gaining popularity in recent years due to the absence of side effects. However, music therapy, to date, is being carried out only by trial and error methods. A definite quantitative description of emotions would definitely improve the quality of Music Therapy, as certain ailments are linked with certain emotions. This problem is addressed to in this solution.

The emotions evoked by music are primarily due to its melody, and Carnatic Music is known for its wide repertoire of Ragas (melodies). Hence, this solution is primarily addressed towards Carnatic Music, though the same method can be applied to any other type of music as well.

II. Summary of the Invention (Maximum of 150 words)

The hypothesis is that Music can be broken down into melody, rhythm, harmony and lyrics, Melody and harmony playing significant roles. Melody consists of notes whose emotions sum up to give total emotion of the musical piece. In this solution, Emotions of notes are quantitatively described followed by the emotions of melodies; this gives the emotion of the musical piece. The classification of emotions given by Robert Plutchik is used. Music is modelled as a communication system. Here the channel is not additive but transformative (transforms musical notes into emotions).

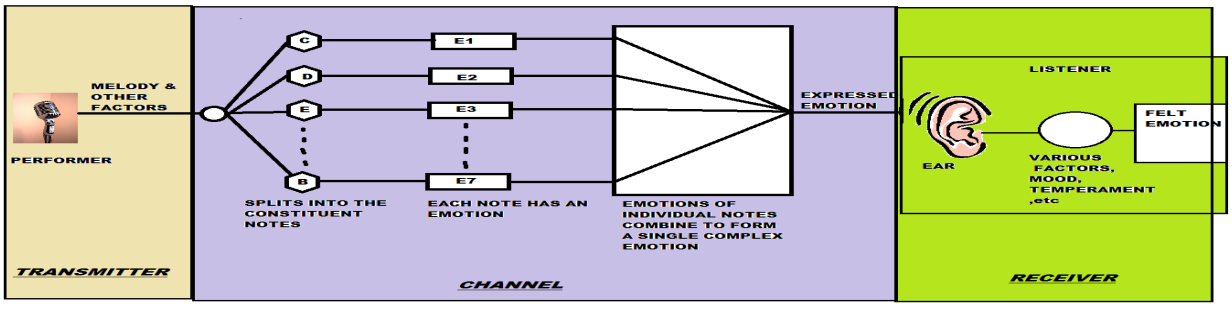

Figure 1 Music as a Communication System

A statistical approach is used where the time under consideration is the instant before the singing of a note. Two events are described. Event 'x' is the singing of a note whose chance is restricted by the melody allowing only certain notes. Probability matrix p(x) denotes probabilities of each note in the

melody i.e. Composition of the melody. Event 'y' is the arousing of an emotion in the listener, which is probabilistic, and the probability matrix p(y) denotes the "emotion profile" of the melody.

III. How is This Invention Made and Used

Two statistical events are described. Event 'x' is the singing of a note (swara). The chance of a note being sung is restricted by the melody (raga) as any raga allows only certain notes to be used. Probability matrix p(x) denotes probabilities of each swara occurring in the raga. In other words, this denotes the raga composition. Event 'y' is the arousing of an emotion in the listener. There is uncertainty in y as no emotion is sure of occurring until the swara is sung. However, 'Y' depends on the composition of the raga. Hence, before the swara is sung the probability matrix p(y) denotes the emotion profile of the raga, and after the singing of the swara, the conditional probability p(y/x) denotes the emotion of the swara sung. To obtain p(y) we can use the probability relation p(x,y) = p(y/x)p(x), where p(x,y) denotes joint probability. Then the matrix created using the sum of all elements in each column of p(x,y) gives p(y). Hence, to obtain p(y), the first step is to get p(y/x). This is done in 3 steps as follows:

STEP 1: Major notes (white keys in piano) give more pleasant feeling than minor notes (black keys). Moreover pairs of notes in cycles of fifths and fourths (c-g, d-a, c-f, etc.) yield a pleasant feeling. Notes being major/minor contribute more to emotions than them being in the cycle of 5^{th} and 4^{th}. These facts were taken into consideration, all possible combinations of note pairs (major-5th, major-4th, minor-5th, minor-4th, major-not in cycle, etc.) were listed, and arbitrary numbers were assigned to them such that they represented the "pleasantness" in the combination. These numbers were called PJ (points of joy). All swara pairs are listed and PJ's are allotted to them based on the combination under which they fall. Using this, PJ of all Melakartha ragas (a comprehensive set of Ragas each consisting of 7 notes) were calculated by adding the PJs of all swara pairs that featured in the raga. This gives the pleasantness or "positiveness of emotion" in a raga.

For example, sankarabharanam, a happy raga has a PJ of 159. Kalyani, a soothing raga, has a PJ of 147. Sad raga subhapanthuvarali has a PJ of 70 and charukesi, a raga depicting love has a PJ of 100. Then, PJ of a swara was isolated by taking the average of PJ's of all ragas having that swara in common. For example, PJ of ma (F) is 129.5, PJ of dha (G#) is 93.67 and that of Ni (Bb) is 95.83.

STEP 2: Since any parameter measured for a Melakartha raga can be isolated to that of a single swara (just like PJ), we need some means of tabulating emotions of Melakartha ragas. Here 3 means are used:

1. Referring to books on ragalakshana
2. Browsing through various reviews, reports, opinions and blogs for comments on emotions in a particular rendering.
3. Allowing people to hear certain pieces and conducting a survey of the emotions experienced, (this was done with close friends and relatives). All 3 means were adopted and the results were tabulated. For example, Sankarabharanam - joy, love, little surprise, Mechakalyani - joy, love, little surprise, little sympathy and Charukesi - little joy, sympathy, little love, submission. Then the emotions of individual swaras were isolated.

SWARA	EMOTION
SA	ATHARA SWARA(FIRMNESS TO THE RAGA)
RA	FEAR,SYMPATHY,SORROW
RI	JOY,SYMPATHY,LITTLE SURPRISE,LOVE
RU	SURPRISE,LITTLE JOY
GA	FEAR
GI	SYMPATHY,LITTLE JOY
GU	HAPPY,SURPRISE
MA	JOY,LITTLE FEAR
MI	SUBTLE JOY,SOOTHINGNESS
PA	NO EMOTION(FIRMNESSTO THE RAGA)
DHA	FEAR,SYMPATHY
DHI	JOY,SYMPATHY,LITTLE SURPRISE,LOVE
DHU	SURPRISE,LITTLE JOY,LITTLE LOVE
NA	FEAR
NI	SYMPATHY, SUBTLE JOY,SORROW,LOVE,LITTLE SUBMISSION
NU	JOY,LOVE,SURPRISE

Figure 2 Emotions of Swaras

STEP 3: The 8 basic emotions suggested by Plutchik were taken. For each emotion the swaras are classified into 3 groups (yes, no and partial) and in each group swaras are arranged in increasing/ decreasing PJ depending on whether the emotion is positive/negative. Then numbers were arbitrarily allotted such that they represent the magnitude of an emotion in a swara. These were normalized to give probabilities. Using these values a 16x8 matrix was formed, where the 16 rows denote the 16 swaras, and 8 columns denote 8 basic emotions namely joy, fear, surprise, trust, sorrow, anger, anticipation and disgust. This is the matrix p(y/x) and is as shown.

SWARA	JOY	FEAR	SURPRISE	TRUST	SORROW	ANGER	ANTICI	DISGUST
SA	0.25	0	0.25	0.25	0	0.25	0	0
RA	0.053575	0.196425	0.10715	0.25	0.196425	0.053575	0.14285	0
RI	0.214275	0.089275	0.1607	0.193361	0.035725	0.160725	0.0893	0.05664
RU	0.125	0.1607	0.214275	0	0.125	0.0893	0.035725	0.25
GA	0.071425	0.214275	0.125	0.046657	0.178575	0.035725	0.125	0.203425
GI	0.14285	0.14285	0.071425	0.186682	0.10715	0.10715	0.178575	0.06325
GU	0.23215	0.10715	0.25	0.03975	0.01785	0.14285	0	0.210336
MA	0.25	0.178575	0.178575	0.09125	0	0.071425	0.071425	0.158755
MI	0.1607	0.125	0.089275	0.0635	0.0893	0.125	0.160725	0.186513
PA	0.25	0	0.25	0.25	0	0.25	0	0
DHA	0.01785	0.23215	0.01785	0.223337	0.23215	0.01785	0.23215	0.026675
DHI	0.196425	0.01785	0.14285	0.183364	0.053575	0.23215	0.10715	0.06675
DHU	0.089275	0.071425	0.196425	0	0.160725	0.178575	0.053575	0.25
NA	0.035725	0.25	0.035725	0.075375	0.214275	0	0.214275	0.17464
NI	0.10715	0.053575	0.053575	0.186682	0.14285	0.196425	0.196425	0.063325
NU	0.178575	0.035725	0.23215	0.0516	0.071425	0.214275	0.01785	0.198419

Figure 3 Matrix P(Y/X)

Thus using the relations mentioned above the matrix p(y) is calculated. This matrix is different for each raga as each raga has a different p(x). This matrix gives emotions of a raga. Such a result obtained for raga mohanam (CDEGA on the piano) is:

JOY	FEAR	SURPRISE	TRUST	SORROW	ANGER	ANTICIPATION	DISGUST	OPTIMISM	DISAPPOINTMENT
0.229	0.043	0.21	0.183	0.02	0.207	0.04	0.0667	0.1345	0.11
LOVE	REMORSE	SUBMISSION	CONTEMPT	AWE	AGGRESSIVENESS	SYMPATHY	HUMOUR	HEROISM	
0.206	0.0438	0.113	0.1337	0.1265	0.1235	0.113	0.2195	0.182	

Figure 4 Emotion values of Mohanam Raga

The sample results for analysis of Sankarabharanam Raga (C Major) implemented using LabVIEW software is as shown below:

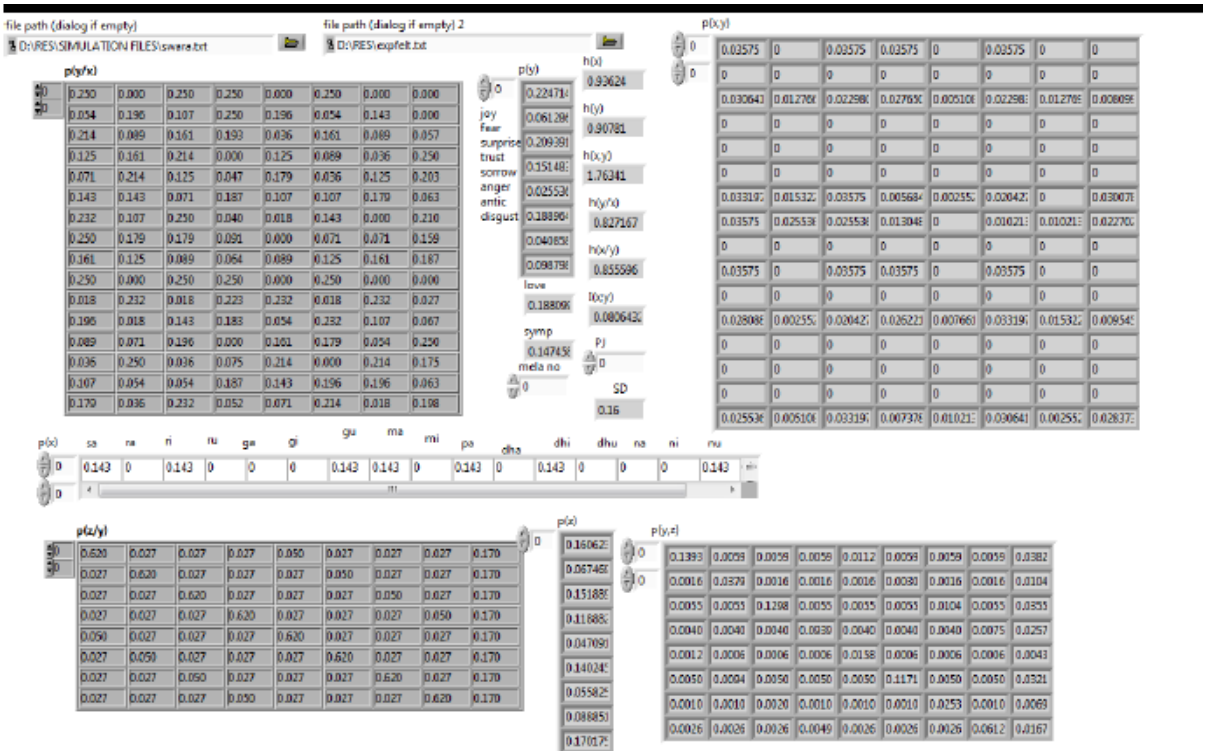

Figure 5 Results of analysis for Sankarabharanam Raga

The next step is to obtain "Emotion Metrics" of a Raga. Emotion Metrics are parameters that describe the emotional capability of a Raga. In information theory, **entropy** is a measure of the uncertainty associated with a random variable. M**utual Information** of two random variables is a quantity that measures the mutual dependence of the two variables.It measures how much knowing one of these variables reduces our uncertainty about the other. In other words, Mutual information gives the measure of how emotions are changed on singing a Swara. In other words, it denotes the Influence of a Raga. For example, the mutual information of Mohanam is 0.076 as compared with 0.081 of Sankarabharanam and 0.086 of Kalyani.

There is another emotion metric called "Richness" and is obtained by taking the standard deviation of the matrix P(Y) and denotes the variety in emotions the Raga offers. For example, Mohanam has a richness of 0.166 compared with 0.102 of Sankarabharanam and 0.152 of Kalyani.

Finally by using the relations stated above, procedures are made to obtain P(X) from a given P(Y). This helps to find out the Raga composition corresponding to a specific emotion profile. This process is called "Synthesis" as opposed to the processes above which are called "Analysis". For synthesis the matrix P(x/y) is required. This can be found out from P(y/x) and is given below:

p(x/y)

0.105	0.000	0.105	0.120	0.000	0.117	0.000	0.000
0.023	0.104	0.045	0.120	0.120	0.025	0.088	0.000
0.090	0.047	0.068	0.092	0.022	0.076	0.055	0.030
0.053	0.086	0.090	0.000	0.077	0.042	0.022	0.131
0.030	0.114	0.053	0.022	0.110	0.017	0.077	0.106
0.060	0.076	0.030	0.089	0.066	0.050	0.110	0.033
0.097	0.057	0.105	0.019	0.011	0.067	0.000	0.110
0.105	0.095	0.075	0.044	0.000	0.033	0.044	0.083
0.068	0.066	0.037	0.031	0.055	0.059	0.099	0.098
0.105	0.000	0.105	0.120	0.000	0.117	0.000	0.000
0.008	0.123	0.008	0.107	0.142	0.008	0.142	0.014
0.082	0.010	0.060	0.088	0.033	0.109	0.066	0.035
0.037	0.038	0.082	0.000	0.099	0.084	0.033	0.131
0.015	0.133	0.015	0.036	0.131	0.000	0.131	0.092
0.045	0.029	0.023	0.089	0.088	0.092	0.120	0.033
0.075	0.019	0.097	0.025	0.044	0.100	0.011	0.104

Figure 6 Matrix P(X/Y)

The synthesis can be used to find out a Raga which maximises certain emotion and also can be used to find Ragas that suit certain emotion profiles. The sample results of synthesis are given below:

NAME	SA	RA	RI	RU	GA	GI	GU	MA	MI	PA	DHA	DHI	DHU	NA	NI	NU
JOY	0.105	0.023	0.09	0.053	0.03	0.06	0.097	0.105	0.068	0.105	0.008	0.082	0.037	0.015	0.045	0.075
SORROW	0	0.12	0.022	0.077	0.11	0.066	0.011	0	0.055	0	0.142	0.033	0.099	0.131	0.088	0.044
FEAR	0	0.104	0.047	0.086	0.114	0.076	0.057	0.095	0.066	0	0.123	0.01	0.038	0.133	0.029	0.019
ANGER	0.117	0.025	0.076	0.042	0.017	0.05	0.067	0.033	0.059	0.117	0.008	0.109	0.084	0	0.092	0.1
SURPRISE	0.105	0.045	0.068	0.09	0.053	0.03	0.105	0.075	0.037	0.105	0.008	0.06	0.082	0.015	0.023	0.097
ANTICIPA	0	0.088	0.055	0.022	0.077	0.11	0	0.044	0.099	0	0.142	0.066	0.033	0.131	0.12	0.011
TRUST	0.12	0.12	0.092	0	0.022	0.089	0.019	0.044	0.031	0.12	0.107	0.088	0	0.036	0.089	0.025
DISGUST	0	0	0.03	0.131	0.106	0.033	0.11	0.083	0.098	0	0.014	0.035	0.131	0.092	0.033	0.104
OPTIMISM	0.053	0.055	0.072	0.037	0.053	0.085	0.049	0.074	0.083	0.053	0.075	0.074	0.035	0.073	0.083	0.043
LOVE	0.112	0.071	0.091	0.026	0.026	0.075	0.058	0.074	0.049	0.112	0.057	0.085	0.019	0.026	0.067	0.05
SUBMISSI	0.06	0.112	0.07	0.043	0.068	0.083	0.038	0.069	0.049	0.06	0.115	0.049	0.019	0.084	0.059	0.022
AWE	0.053	0.075	0.057	0.088	0.083	0.053	0.081	0.085	0.052	0.053	0.065	0.035	0.06	0.074	0.026	0.058
DISAPPOI	0.053	0.083	0.045	0.083	0.081	0.048	0.058	0.038	0.046	0.053	0.075	0.047	0.091	0.073	0.055	0.071
REMORSE	0	0.06	0.026	0.104	0.108	0.049	0.06	0.042	0.076	0	0.078	0.034	0.115	0.111	0.06	0.074
CONTEMP	0.059	0.013	0.053	0.086	0.062	0.042	0.089	0.058	0.078	0.059	0.011	0.072	0.107	0.046	0.063	0.102
AGGRESSI	0.059	0.057	0.065	0.032	0.047	0.08	0.034	0.038	0.079	0.059	0.075	0.087	0.059	0.066	0.106	0.056
HUMOUR	0.105	0.028	0.084	0.062	0.036	0.053	0.099	0.098	0.06	0.105	0.008	0.077	0.049	0.015	0.039	0.081
SYMPATH	0.084	0.083	0.074	0.039	0.047	0.072	0.046	0.056	0.051	0.084	0.078	0.072	0.039	0.052	0.072	0.048

Figure 7 Results of Synthesis

IV. Markets Addressed

Industry1: Music Therapy – MBK Trust, Chennai, India

American Music Therapy Association, Kansas

The Otakar Kraus Music Trust, Middlesex, England

Industry2: Music Recording – Universal Music Group

Sony Music Entertainment

Warner Music Group

Indian Music Industry, Mumbai, India

Saregama India ltd.

Industry3: Film Industry

Industry4: World Music – BBC Music

Global Music ltd.

Industry5: Education and academia – Kalakshetra

Madras Music Academy

Center for Ethnomusicology and research

Industry6: Neuropsychology – Hospitals and clinics dealing with cognitive and neuropsychological problems, Special schools for mentally spastic children etc.

V. Comparative Benefits / Advantages

There are certain advantages involved in quantitatively describing the emotions, and they are:

Advantage1: Definite approach to Music Therapy: The solution intends to remove all trial and error methods associated with music therapy and hence the chance of a patient being cured can be increased. Moreover, by using the emotion values, for a given situation (an ailment), the emotion required to cure it can be determined, and then a musical piece corresponding to the specified emotion can be played. For example, a lively and joyful piece of music can be played out to ease Depression.

Advantage2: Performers can tailor their concerts so as to suit specific themes, more so when using music for a purpose (marriage, childbirth, funeral etc.). Moreover, the solution also has the psychological advantage that, the performer, on seeing the effect of the rendered music on the listeners, gets elated and his performance gets enhanced.

Advantage3: The method proposed in this solution can be applied to other systems of music all around the world and universalization of music can be done on the basis of emotions. This could drastically improve automated methods of analyzing and synthesizing music.

Advantage4: In Carnatic Music, a vast number of Ragas are yet to be explored. By using the quantitative description of emotions and synthesis procedures, a lot of new Ragas can hit the limelight and this increases the quality of music rendered and also enhances Music Therapy.

Advantage5: For the purpose of musical curiosity, we can understand the subtle emotional differences between similar sounding melodies.

VI. Related Background

Carnatic Music is an ancient system of Classical Indian Music. It has a vast range of melodies (Ragas), pitch (Shruthi) and rhythm (Thaalam). In terms of melody, other systems of music can be derived from Carnatic Music. This is highlighted by the fact that Carnatic Composers such as Muthuswamy Dikshithar and Maharaja Swathi Thirunal have been able to compose Hindusthani and Western

Classical pieces without deviating from the rules of Carnatic Music. Hence, the key to universalize Music lies in Carnatic Music.

There are seven notes (swaras) in Carnatic Music, Sa, Ri, Ga, Ma, Pa, Dha and Ni. Five of these, (except Sa and Pa), admit of 2 variations each. Four of these (except Sa, Pa and Ma) also accept of a third variation, which are the Vivaadhi Swaras. Sa is the fundamental (Aathaara Swara). Vivaadhi Swaras bear such a relation to Sa so as to produce a discordant effect. These swaras are sung or played in the realm of neighbouring notes. For example, Vivaadhi Ri is played in the region of Ga. The list of Swaras and the corresponding notes in Western system are given below:

Serial No	Swara Name	Notation	Corresponding Western Note
1	Shadjam	Sa	C
2	Suddha Rishabham	Ra	C#
3	Chathushruthi Rishabham	Ri	D
4	Shatshruthi Rishabham	Ru	Vivaadhi Swara
5	Suddha Gandharam	Ga	Vivaadhi Swara
6	Sadharana Gandharam	Gi	D#
7	Anthara Gandharam	Gu	E
8	Suddha Madhyamam	Ma	F
9	Prathi Madhyamam	Mi	F#
10	Panchamam	Pa	G
11	Suddha Dhaivatham	Dha	G#
12	Chathushruthi Dhaivatham	Dhi	A
13	Shatshruthi Dhaivatham	Dhu	Vivaadhi Swara
14	Suddha Nishadham	Na	Vivaadhi Swara
15	Kaisiki Nishadham	Ni	A#
16	Kakali Nishadham	Nu	B

Figure 8 The 16 Swaras in Carnatic Music

Negligible amount of work has been done regarding Emotions in Carnatic Music. The main reason for this is the notion that emotion is abstract and cannot be described mathematically, and is something to be felt, principally between two people, the singer and the listener. Moreover, the emotions are highly random in nature.

The basis for the solution lies in Plutchik's classification of emotions into basic and advanced. This is shown as follows:

BASIC EMOTION	BASIC OPPOSITE
JOY	*SADNESS*
TRUST	*DISGUST*
FEAR	*ANGER*
SURPRISE	*ANTICIPATION*
SADNESS	*JOY*
DISGUST	*TRUST*
ANGER	*FEAR*
ANTICIPATION	*SURPRISE*

ADVANCED EMOTION	COMPOSED OF...	ADVANCED OPPOSITE
OPTIMISM	ANTICIPATION + JOY	*DISAPPOINTMENT*
LOVE	JOY + TRUST	*REMORSE*
SUBMISSION	TRUST + FEAR	*CONTEMPT*
AWE	FEAR + SURPRISE	*AGGRESSIVENESS*
DISAPPOINTMENT	SURPRISE + SADNESS	*OPTIMISM*
REMORSE	SADNESS + DISGUST	*LOVE*
CONTEMPT	DISGUST + ANGER	*SUBMISSION*
AGGRESSIVENESS	ANGER + ANTICIPATION	*AWE*

Figure 9 Basic and advanced emotions according to Robert Plutchik

There appears to have been no past work regarding the quantitative description of emotions in music and this solution appears to be the first of its kind.

VII. Extensions

Having described quantitatively the emotions and the procedures for analyzing and synthesizing the same, the next step is to find universal ways for representing emotions and music. On studying various works done in this field, the work titled “Relations between expressed and felt emotions in music” by Paul Evans and Emery Schubert, was studied. In this work, a dimensional model of emotion is mentioned, which states that emotions are 2- dimensional, the dimensions being valence (pleasentness/ positiveness of emotion) and arousal (energy/ activeness of emotion). An example of this is shown below:

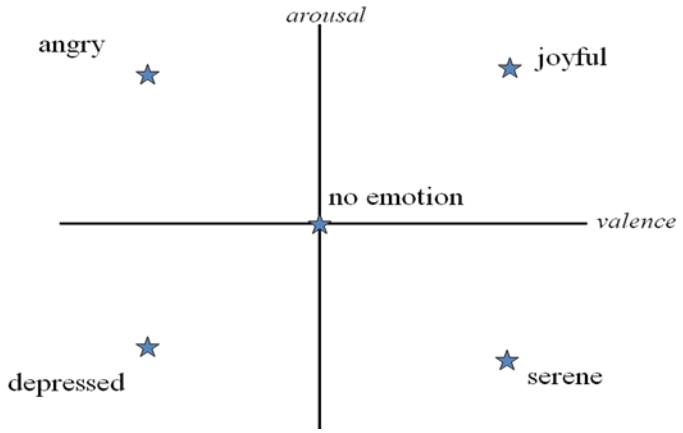

Figure 10 Dimensional model of emotion

Also on further studies from the branch of neuro science, the concept of brainwaves and the effect of music on them was understood. Briefly outlined below:

1. Brainwaves refer to the electrical activity of the brain and the pulses can be measured with the help of an EEG.

2. The brainwaves are of different frequencies depending on the activity of the brain. These are called different states:

3. 1. GAMMA STATE: Above 30Hz : Extensive brainwork, programming, calculations etc..

   2. BETA STATE: 14-30Hz: The normal state of the brain.

   3. ALPHA STATE: 7 -14Hz: Relaxed, free-flowing thoughts, day-dreaming

   4. THETA STATE: 3-7Hz: Sleep with dreams, Rapid Eye Movements sleep (REM)

   5. DELTA STATE: 1-3Hz: Sound Sleep without dreams, brink of unconsciousness

4. It is possible to make a person reach any of these states using music, the basic ideology here being that by making the ear/brain perceive the corresponding frequency either as a result of difference between two tones or as a difference between two successive tones.

Using these information, a theory is proposed stating that, “Arousal in emotions occurs due to brainwaves”. Also a proposal is made that takes into account the arousal factor and proposes a **Brainwave Spectrum** model of emotions much similar to the electromagnetic spectrum, as follows:

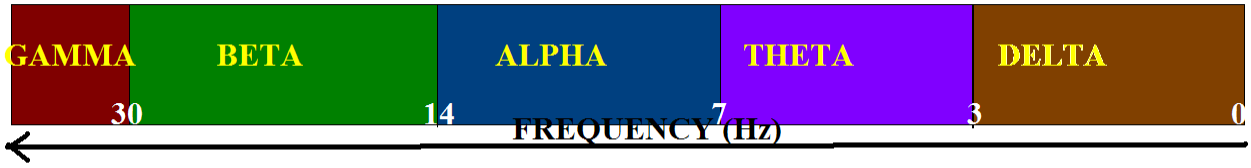

Figure 11 Brainwave spectrum

This spectrum can be analysed in 2 parts:

1. Beta band, akin to the visual spectrum: In this region, all emotions are felt and experienced, and this is the region of interest to the work. It is here that the valence-arousal theory is applied to its fullest.

2. Non-Beta band: Usually Gamma is excluded, and this region extends from alpha to delta, and this region is very similar to the RF to IR region of electromagnetic spectrum. In this region no emotions are felt and calmness and tranquillity prevails. This region is very helpful for easing out tension and anxiety for people seeking peace etc. Valence does not play a significant role in this region, but arousal is significant.

To analyse the effects of the ragas in the non beta region, the frequencies of the notes need to be known. This is given as follows, with the base frequency for Sa being 100Hz:

SERIAL NO.	NAME	RAGA EXAMPLE	FREQUENCY
1	ACHALA SHADJAM	ALL RAGAS	100
2	EKASRUTHI RISHABHAM	GOULA	105.35
3	DVISHRUTHI RISHABHAM	MAYAMALAVAGOULA	106.66
4	THRISHRUTHI RISHABHAM	BHAIRAVI	111.11
5	CHATHUSRUTHI RISHABHAM	KHARAHARAPRIYA	112.50
6	SUDDHA GANDHARAM	THODI	118.5
7	SADHARANA GANDHARAM	BHAIRAVI	120
8	ANTHARA GANDHARAM	SANKARABHARANAM	125
9	CHYUTHA MADHYAMA GANDHARAM	MAYAMALAVAGOULA	126.6
1O	SUDDHA MADHYAMA	KHARAHARAPRIYA	133.3
11	THIVRA SUDDHA MADHYAMAM	BEGADA	135
12	PRATHI MADHYAMAM	KALYANI	140.62
13	CHYUTHA PANCHAMA MADHYAMAM	VARALI	142.38
14	ACHALA PANCHAMAM	ALL MELAKARTHA RAGAS	150
15	EKASRUTHI DHAIVATHAM	SAVERI	158.02
16	DVISHRUTHI DHAIVATHAM	MAYAMALAVAGOULA	160
17	THRISHRUTHI DHAIVATHAM	SANKARABHARANAM	166.66
18	CHATHUSHRUTHI DHAIVATHAM	VASANTHA	168.75
19	KAISIKI NISHADHAM	SURUTTI	177.77
20	THIVRA KAISIKI NISHADHAM	KHARAHARAPRIYA	180
21	KAKALI NISHADHAM	SANKARABHARANAM	187.5
22	THIVRA KAKALI NISHADHAM	NEELAMBARI	189.94

Figure 12 Frequencies for 22 notes

Now to analyse the effect of any raga in the alpha/theta/delta regions, the procedure is as follows:

1. List out the frequencies used by the raga.
2. List the frequency differences that are in the required range and compute the number of such differences.
3. A higher number of alpha/ theta/ delta does not imply that the raga can go deeper into the region. It only implies that the raga supports a larger number of combinations to go into a particular state.

For example, for Raga Bhoopalam (CDbEbGAb), when the above procedure is used, we get 2 Alpha combinations and 1 Theta combination. In Beta Band the Ragas are analysed in a different way. Initially the 8 basic emotions are plotted as valemce- arousal coordinate points, and their angles are noted. Then for any raga, the sum total of weightage of all basic emotiona multiplied by their corresponding angles give the coordinate position for the raga. This is done for all Melakartha Ragas, and a few Janya Ragas, and results are attached herewith.

VIII. References

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