Karnatik Ragas as a Network – An Exploration

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Abstract

Social Network Analysis (SNA) is a simple and efficient way to analyze data as a network especially when there's significant correlation or similarity between observations. This paper analyzes Karnatik ragas as an undirected network by comparing melodic structure of ragas using Longest Common Sequence (LCS) algorithm. To draw an edge between nodes, a cut-off of 0.9 was used for the LCS similarity ratio. The analysis reveals that ragas Harikaambhoji, Kharaharapriya, Shankarabharanam, Mayamalavagaula and Natabhairavi emerges as the hubs of the network illustrating the influence of these ragas in the evolution of Karnatik music.
Keywords: Karnatik Ragas, Social Network Analysis

I. Introduction

Karnatik Music is an ancient art form of India is also called as "*Sasthriya Sangeeta*", depicting that it is "*Music Driven by Science*". Though there are several complex attributes associated, Karnatik music fundamentally encircles around *raga* which in its abstract form is the melodic pattern associated with a music composition (Dr. Bhagyalekshmy, 1990). The melodic structure, essentially a specific sequence of musical note/ frequency, to be adhered to while rendering sounds in an ascending / increasing pattern of frequency is known as arohanam (referred to as "ar" henceforth) and the descending pattern is known as avarohanam (referred to as "av" henceforth). There are two categories of ragas– Parent or *Melakartha,* whose descending pattern would be an exact reverse of ascending pattern and Derived or *Janya, whose descending pattern and ascending pattern would either differ or would have different sequence of notes,* with different patterns of melodic structure. There are 72 *Melakartha* and several thousand *Janya* ragas, which are derived from each *Melakartha* and has evolved over a period of time. This sizable list of ragas poses a fundamental problem of selecting an appropriate raga to start with for the Karnatik music training as well to identify those ragas whose learning can offer significant insight into the entire list of available ragas. Traditionally, the raga named *Mayamalavagaula* is the one with which a beginner would start off with the training as this has been the practice that was followed, in general, for several decades. This evolution of ragas over time, prompted to visualize & analyze ragas as a network so as to analyze them through the lens of Social Network Analysis (SNA) (Wasserman & Faust, 1994), determine key characteristics of ragas network and draw inferences. The analysis fundamentally aims to find a naïve explanation to the practice of starting the Karnatik music learning with raga *Mayamalavagaula* and to determine whether there are other ragas that are as significant as *Mayamalavagaula* off with raga.

The rest of this document is divided into following sections: *Methodology* – illustrating the analysis approach, *Analysis Summary* – Summarizes analysis findings, *Discussion* – Illustrates key insights from the analysis by drawing an analogy with the current practices in the domain and *Conclusion* – offers insights into next steps and future studies recommended.

II. Methodology

Our proposed methodology was to analyze a significant number of unique ragas (*N=4446*) – both Parent (*Melakartha*) and Derived (*Janya),* by visualizing them as an undirected network. The data for building the network was derived from the website Karnatik.com (Santhanam, 2008). The list of ragas not only contained name but also had associated melodic structure – *arohanam* and *avarohanam*. Collected data was then cleaned to remove duplicates and assigned a code for each raga. If a combination of ragas were found to have the same ascending or descending pattern, then they were combined into a single tuple so as to maintain uniqueness in each row of the dataset. Network edges were drawn between ragas with semantic / structural similarity equal to or greater than 90% match. The calculation of sequence matching similarity is performed using Longest Continuous Sequence (LCS) algorithm and is illustrated below with an example of two strings with fist string representing arohanam for raga *Mayamalavagaula* and second string representing arohanam for raga *Shankarabharanam*.

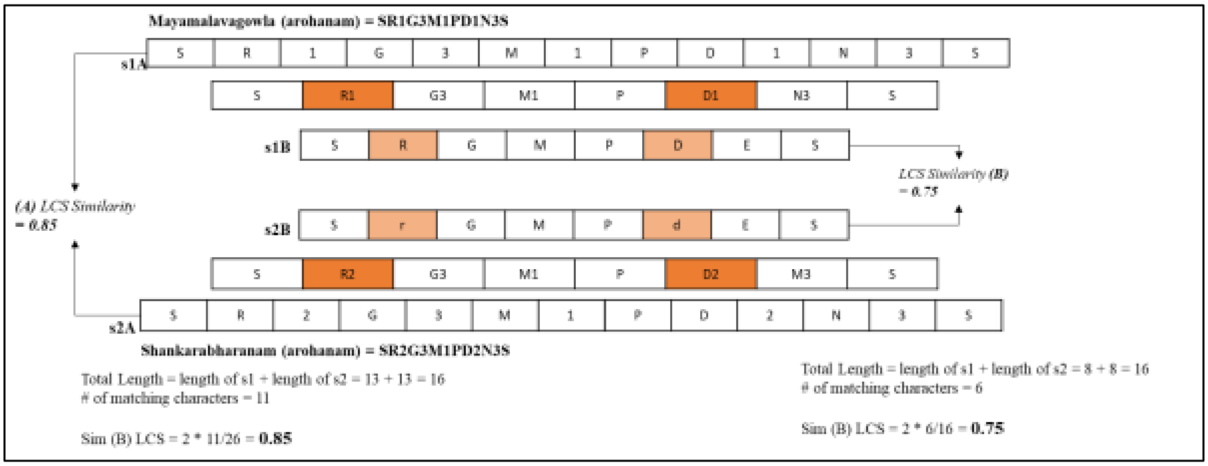

Fig. 1: Illustration of LCS similarity calculation

The LCS algorithm calculates the similarity using the following formula (Maier, 1978), $Sim = 2 * m/N$, where m is the number of matching characters between 2 strings and N is the total length of combined string.

As an e.g., on comparing ascending pattern of ragas *Mayamalavagowla* and *Shankarabharanam* (represented by s1A and s2A respectively in the figure above), it was found that the LCS similarity is 0.85 (m=11, since there are 11 matching characters and N=16, since total length of combined string is 16). However, the similarity gained through this comparison is over stated since each character is compared separately. i.e., the note "G3" in both ragas are split into "G" and "3" before comparison. Hence to overcome this issue, we coded each note to be a single character using the following coding method. *S->S, R1->R, R2->r, R3->A, G1->G, G2->g, G3->B, M1->M, M2->m, P->P, D1->D, D2->d, D3->C, N1->N, N2->n and N3->E*. This single character encoding ensured that similarity was calculated correctly in the context of musical note than in the context of character comparison. Overlapping note combinations such as "R2" - "G1", "R3" - "G2", "D2" - "N1" and "D3" - "N2" (Subramany, 2007) (Pratvs, 2020) were coded separately rather than giving them same code. For e. g. "R2" and "G1" were encoded as "r" and "G" respectively rather than giving same code. This is because there's a difference in the frequencies between these notes from a Karnatik music theory stand point though both notes might sound similar. Karnatik music considers one octave to be 16 notes (Krishnaswamy, 2003) where are western music considers one octave to be spread across 12 notes (Krishnaswamy, 2003). Hence in order to represent the Karnatik music notation on a piano, the commonly used method is to assume the note combinations "R2" - "G1", "R3" - "G2", "D2" - "N1" and "D3" - "N2" to be having same frequency (Krishnaswamy, 2003), there by compressing the Karnatik notes into a format that can be superimposed on a piano octave. However, in the proposed encoding method this compression technique was avoided and hence encoded separately.

After encoding, the same ragas (encoded string represented as s1B and s2B respectively in the figure above) were compared again to find that the similarity dropped to 0.75 which is a more rational representation. Hence the encoding method was followed to calculate similarity between ragas. In addition, the raga similarity was calculated on the string derived after combining the ascending and descending pattern rather than calculating similarity for each pattern separately.

III. Analysis Summary

For the first analysis, three different networks were considered to analyze how the characteristics changed with the edge specific filters. The first network had nodes with zero or more edges, the second network had nodes with one or more edges and third network had nodes with 2 or more edges. For each of the networks several metrics were recorded including Degree, Density, top five Centrality measures, Cliques, Communities and Transitivity. The figures 2,4 and 6 below illustrates the network structure of each of the derived network. The degree distribution, both histogram and log distribution are also derived and illustrated along with summary statistic (mean, std. deviation, median, min, max and IQR) of the degrees of each network.

Network Structure	**Degree Distribution / Summary Statistics**

Network I – Network of raga with similarity coefficient >= 0.9

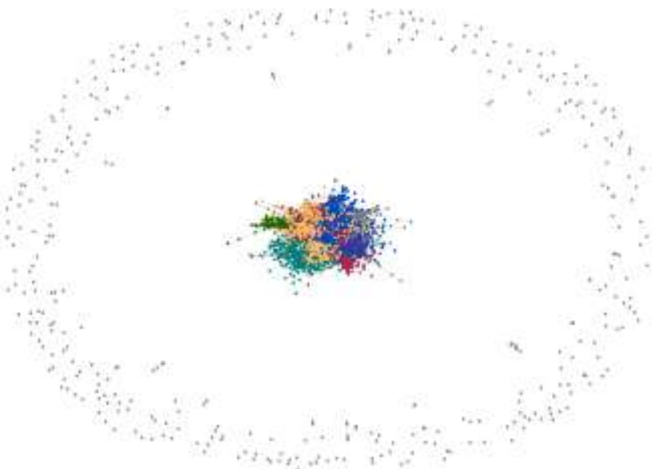

Fig. 2: Network Structure – I

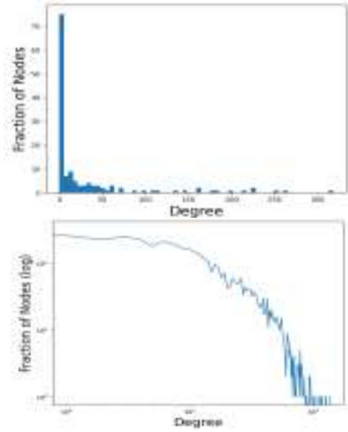

Fig. 3.: Network I Degree Distributions – Histogram and Log scale

Mean	: **32.45**	Min	: **0**
Sd	: **62.30**	Max	: **318**
Median	: **3**	IQR	: **32**

Table 1: Network I – Summary Statistics of Degree

Network II – Network of raga with similarity coefficient >= 0.9 and nodes with edges >=2

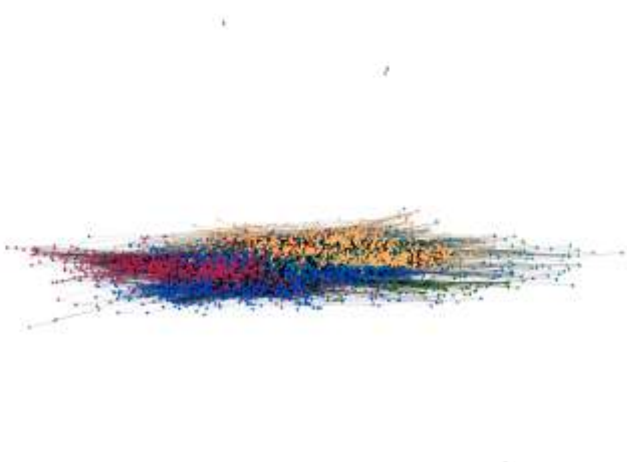

Fig. 4: Network Structure – II

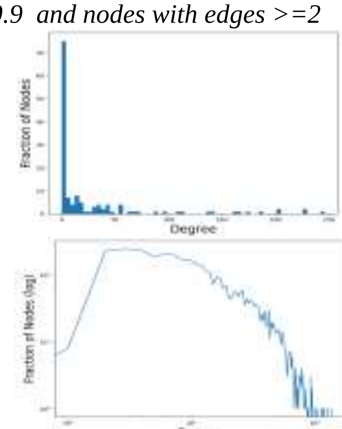

Fig. 5.: Network II Degree Distributions – Histogram and Log scale

Mean	: **28.13**	Min	: **0**
Sd	: **53.39**	Max	: **246**
Median	: **3**	IQR	: **30**

Table 2: Network II – Summary Statistics of Degree

Network III – Network of raga with similarity coefficient >= 0.9 and nodes with edges >=3

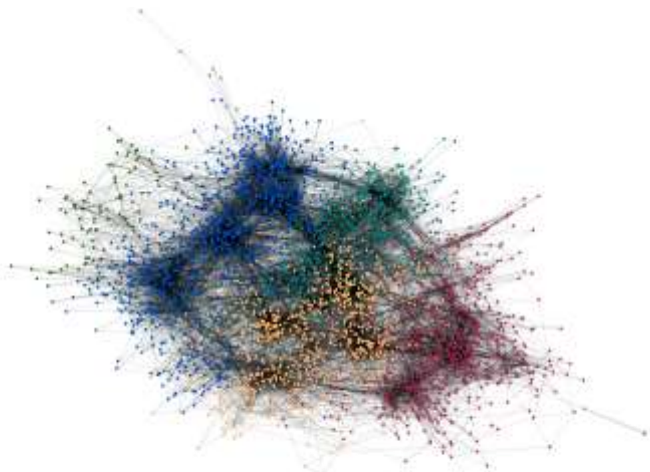

Fig. 6: Network Structure – III

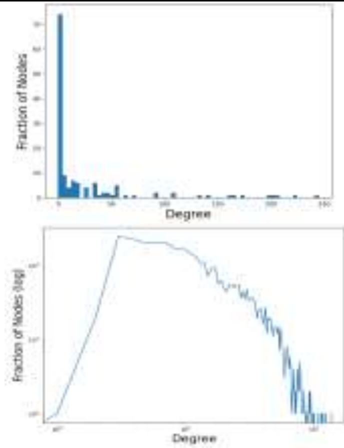

Fig. 7.: Network III Degree Distributions – Histogram and Log scale

Mean : **26.45**	Min : **0**
Sd : **50.56**	Max : **245**
Median : **3**	IQR : **26**

Table 3: Network I – Summary Statistics of Degree

Visual interpretation of the networks reveals that Network III is more suitable for a deeper analysis as there are no stand alone / unconnected nodes in the network whose presence may skew the inference. In addition, the communities (colored nodes) clearly separate themselves in Network III.

Table – 4
Comparison of Network characteristics

Metrics	***Network I (90% Sequence Match - All nodes)***	***Network II (90% Sequence Match - nodes with 2 or more edges)***	***Network III (90% Sequence Match - nodes with 3 or more edges)***
# of nodes	*4446*	*3854*	*3623*
# of edges	*32980*	*32735*	*32396*
Average Degree	***14.836***	***16.988***	***17.82***
Density	***0.0033***	***0.0044***	***0.0049***
Degree Centrality (Max)	*0.0306*	*0.0353*	*0.0375*
Closeness Centrality (Max)	*0.2149*	*0.2382*	*0.2414*
Eigenvector Centrality (Max)	*0.1642*	*0.1643*	*0.1644*
# of Cliques	*9758*	*9195*	*8879*
# of Triangles	*1400*	*1443*	*1291*
# of Communities	*364*	*15*	*12*
# of nodes in largest community	*1130*	*1199*	*1144*
Max Degree	***136***	***136***	***146***
Transitivity	*0.3619*	*0.3630*	*0.3655*

On extracting summary statistics, it was observed that raga network is a heterogenous network with low density and non-normal nodes degree distribution along with a significant presence of triads across all networks, with max degree of node (hub) ranging from 136 to 146. These characteristics is synonymous with the fact that ragas have evolved over a period of time with contributions of schools & scholars belonging to multiple regions, of varied attributes, thereby ascribing to heterogeneity. The degree distribution of each network indicates a scale-free network since the visual interpretation of the degree distribution illustrates a power law distribution. To confirm, power law fitness test (Clauset, 2009) was performed.

As indicated by (Clauset, 2009) , power law obeys the equation,

$$\ln p(x) = \alpha \ln x + constant$$

where $\alpha > 1$ (since $\alpha < 1$ cannot be normalized and cannot occur in nature).

The proposed method uses Maximum Likelihood Method (MLE) for estimating α.

For Network I, power law test indicated that the $\alpha = 2.0131$, $x_{min} = 30$ and $\sigma = 0.1644$. These measures indicate a power law distribution of the degree distribution for Network I. Similarly, for Network II, the power law test indicated that $\alpha = 2.0560$, $x_{min} = 29$ and $\sigma = 0.1760$; and for Network III, the power law test indicated that $\alpha = 2.19$, $x_{min} = 33$ and $\sigma = 0.2086$. The tests confirmed that all three networks obey power law distribution and hence indicating that the network may be scale-free network. As suggested by (Broido, 2019), since the networks following power law may be scale-free, the raga network may be considered as a rare network. The summary characteristics revealed that raga *Harikaamboji* (*ar: SR2G3M1PD2N2S, av: SN2D2PM1G3R2S*) (Iyer, 2018) acts as the *hub* in the network (Degree = Max Degree = 136). A hub in a network is the most connected node or node with maximum number of edges. In the context of ragas, *Harikaamboji* has the greatest number of edges with other ragas indicating that this raga is semantically or structurally similar to the greatest number of ragas in the network. The table below illustrates list of top five ragas with maximum degree.

Table – 5
Top 5 ragas based on degree distribution

Rank	Raaga Name	Degree	Arohanam	Avarohanam
1	Harikaambhoji	136	SR2G3M1PD2N2S	SN2D2PM1G3R2S
2	Kharaharapriya	125	SR2G2M1PD2N2S	SN2D2PM1G2R2S
3	Shankarabharanam	118	SR2G3M1PD2N3S	SN3D2PM1G3R2S
4	Mayamalavagaula	116	SR1G3M1PD1N3S	SN3D1PM1G3R1S
5	Natabhairavi	113	SR2G2M1PD1N2S	SN2D1PM1G2R2S

Table – 6
Top 5 ragas based on Betweenness centrality, Eigen Vector Centrality and Closeness centrality

Rank	Raaga Name	Centrality	Arohanam	Avarohanam
Betweenness (for Network III)				
1	Vakulaabharanam	0.0183	SR1G3M1PD1N2S	SN2D1PM1G3R1S
2	Mayamalavagaula	0.0177	SR1G3M1PD1N3S	SN3D1PM1G3R1S
3	Harikaambhoji	0.0174	SR2G3M1PD2N2S	SN2D2PM1G3R2S
4	Shankarabharanam	0.0168	SR2G3M1PD2N3S	SN3D2PM1G3R2S
5	Natabhairavi	0.0161	SR2G2M1PD1N2S	SN2D1PM1G2R2S
Eigen Vector (for Network III)				
1	Harikaambhoji	0.164	SR2G3M1PD2N2S	SN2D2PM1G3R2S
2	Kapinarayani	0.150	SR2M1PD2N2S	SN2D2PM1G3R2S
3	Kharaharapriya	0.148	SR2G2M1PD2N2S	SN2D2PM1G2R2S
4	Mahaguhabharanam	0.140	SR2G3M1PD2N2S	SN2D2PM1R2S
4	Sudhashiran	0.140	SG3M1PD2N2S	SN2D2PM1G3R2S
Closeness (for Network III)				
1	Cakuli	0.2413	SG3M1PD2N3S	SN3D2PM1G3R1S
2	Visnabharanam	0.2409	SR2G3M1PN3S	SN3D2PM1G3R2S
3	Shivagandhari	0.2407	SG3M1PD2N3S	SN3D2PM1G3R2S
4	Sarasaangi	0.2404	SR2G3M1PD1N3S	SN3D1PM1G3R2S
5	Kedaranata	0.2403	SR2G3M1PD1N3S	SN3PM1G3R2S

IV. DISCUSSION

It is interesting to observe that ragas *Harikaambhoji, Kharaharapriya, Shankarabharanam, Mayamalavagaula* and *Natabhairavi* emerges as the most significant ragas in the network since these ragas are also popular from a Karnatik compositions / *kritis* stand point. All these five ragas are also Melakartha ragas (Iyer, 2018). Each of the five ragas has a significant importance in the Karnatik music learning. For instance, *Mayamalavagaula* (Iyer, 2018) is technically the first raga that a student will extensively rely on to train the brain in learning fundamental frequency, note frequency positioning, rendering notes in various speeds / tempo and to gather basic understanding of phrases. The appearance of raga *Mayamalavagaula* among top 5 ragas based on degrees illustrates its significance and why it emerged as the preferred raga to start with the learning. A natural transition from *Mayamalavagaula* is to *Shankarabharanam*, another raga in top five list, *(this raga corresponds to a natural scale if the low Sa is mapped to note C in piano)* since it would be easier to train the brain on fixing the note positions of *Shankarabharanam* by virtue of training on *Mayamalavagaula.* This ease of transition is attributed primarily to the two-note difference between these ragas (note R1changes to R2 and D1 changes to D2). *Harikaambhoji* would be a good choice to transition from since the difference is in one note (N3 changes to N2) in comparison with *Shankarabharanam*. *Kharaharapriya*, another name in the top five list, is a good choice to transition from *Harikaambhoji* since the transition again involves only one note (G3 changes to G2) which would be easier for the brain to adapt to and learn. Based on the analysis, it can be observed that *Harikaambhoji raga* is on the top of the list, and can certainly hypothesize that there won't be any impact on learning if started with *Harikaambhoji* instead of *Mayamalavagaula* since *Harikaambhoji* has better connectivity with all other ragas and may assist in learning different ragas faster as compared to the current method. However, there are specific reasons for choosing *Mayamalavagaula* as a raga to start with Karnatik music learning predominantly due to the positioning of notes/swaras in the raga ((FAN, 2011)). Based on the analysis, a guideline can be derived to learn Karnatik ragas where one can follow the order: *Harikaambhoji* → *Kharaharapriya* → *Shankarabharanam* →

Mayamalavagaula → *Natabhairavi.* It's also observed that these ragas demonstrate high closeness centrality and is typically driven by the occurrence of sequence "G3M1PD2N3" in those ragas

V. CONCLUSION

On analyzing the Karnatik learning method, the commonly followed pattern of learning raga is similar to one explained above. This inference offers a significant reliability to envisioning ragas as a network and analyzing them can unearth several interesting insights. Studying this network further, especially from a community analysis perspective, can assist in deriving additional meaningful assessments about ragas and its coexistence. We also propose to further study ragas mentioned in Table 5: Top 5 ragas based on degree distribution, from the perspective of invoking emotion in listeners so as to establish a generic framework to illustrate raga to emotion mapping. In addition, we recommend to conduct a comparative study to determine effect of starting Karnatik music with learning *Harikaambhoji as* compared to starting with *Mayamalavagaula,* as done traditionally.

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