Phrase-based Rāga Recognition using Vector Space Modeling

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Shanghai, China, 2016

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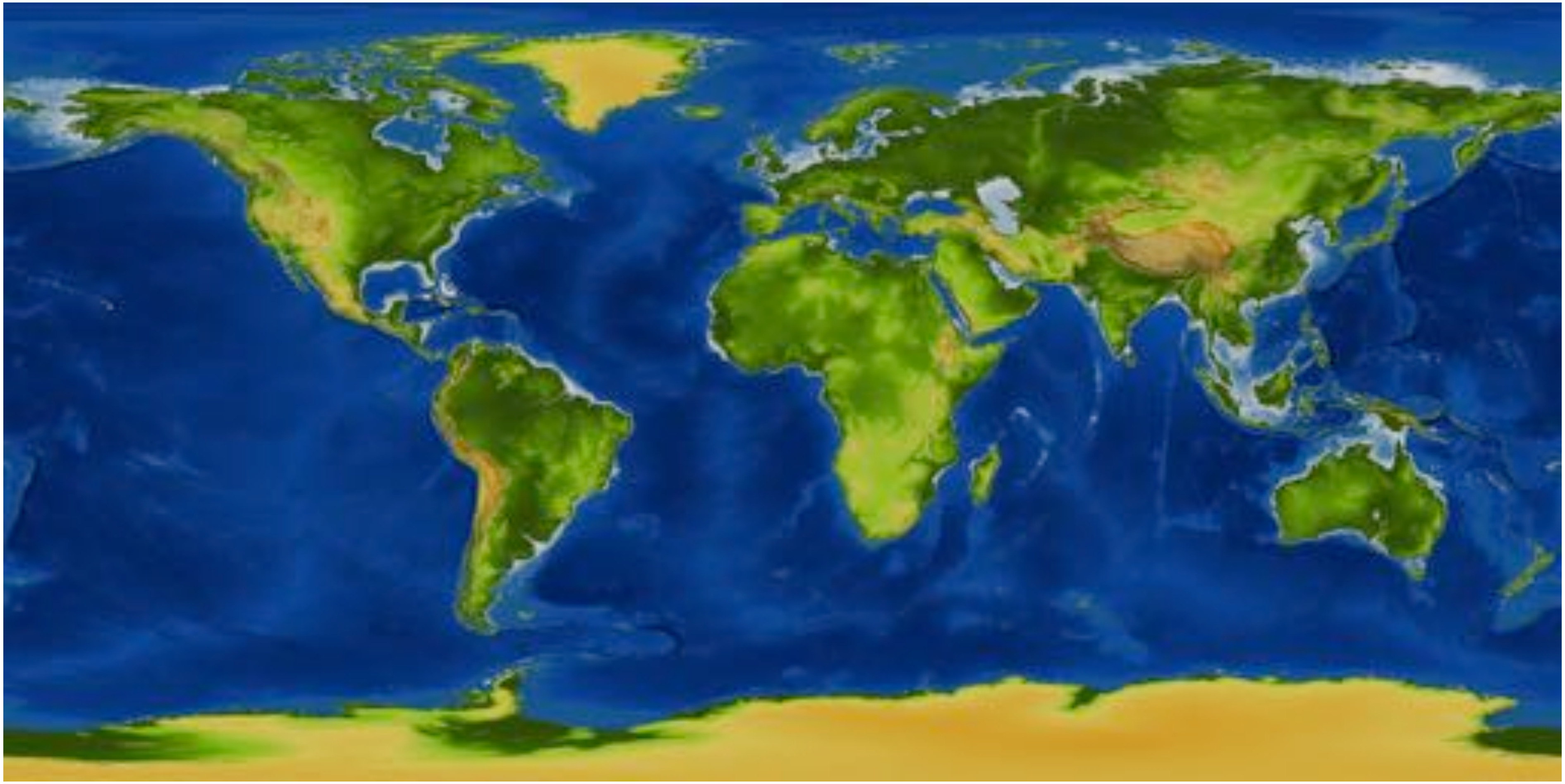
Indian Art Music



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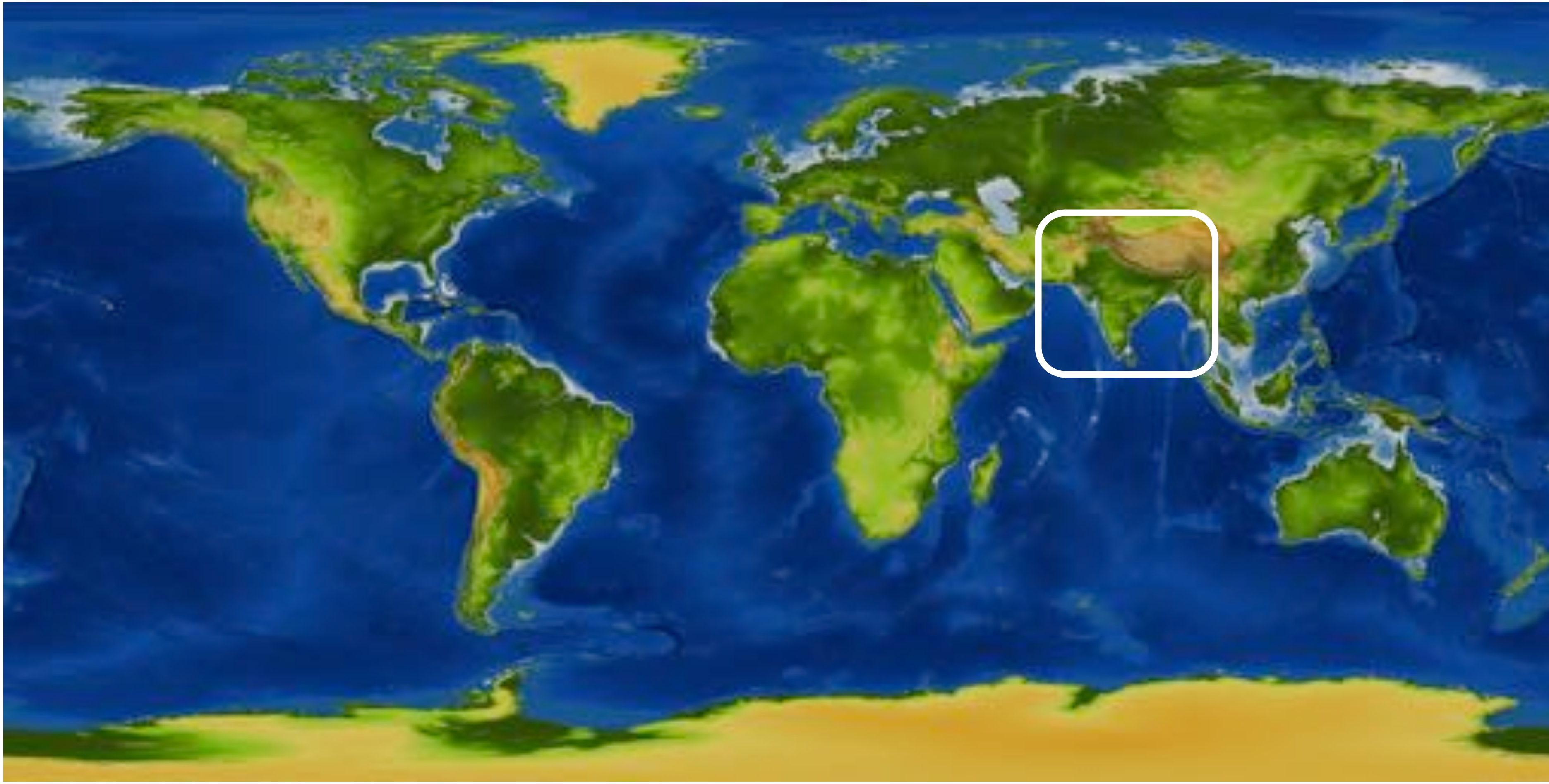
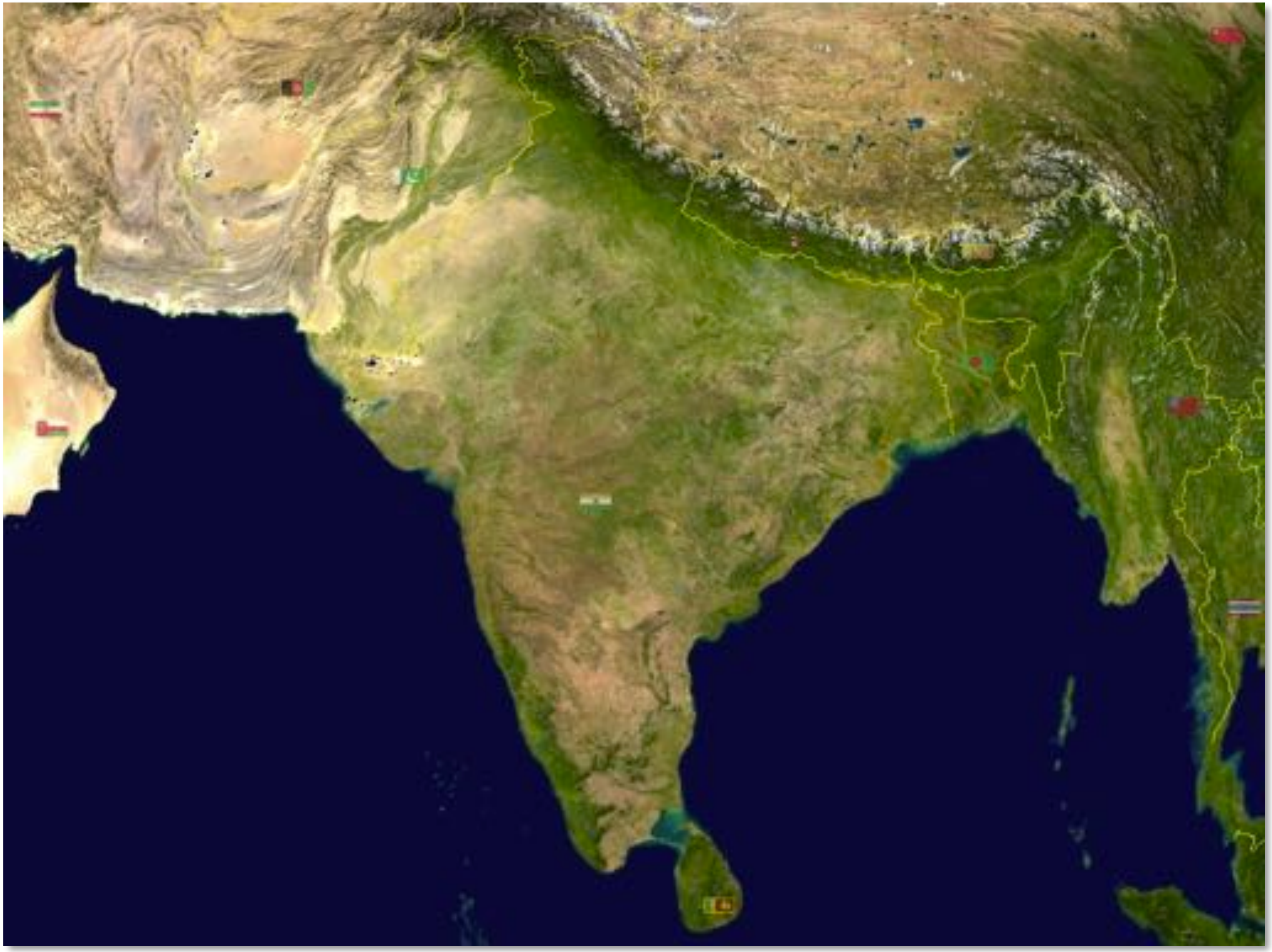
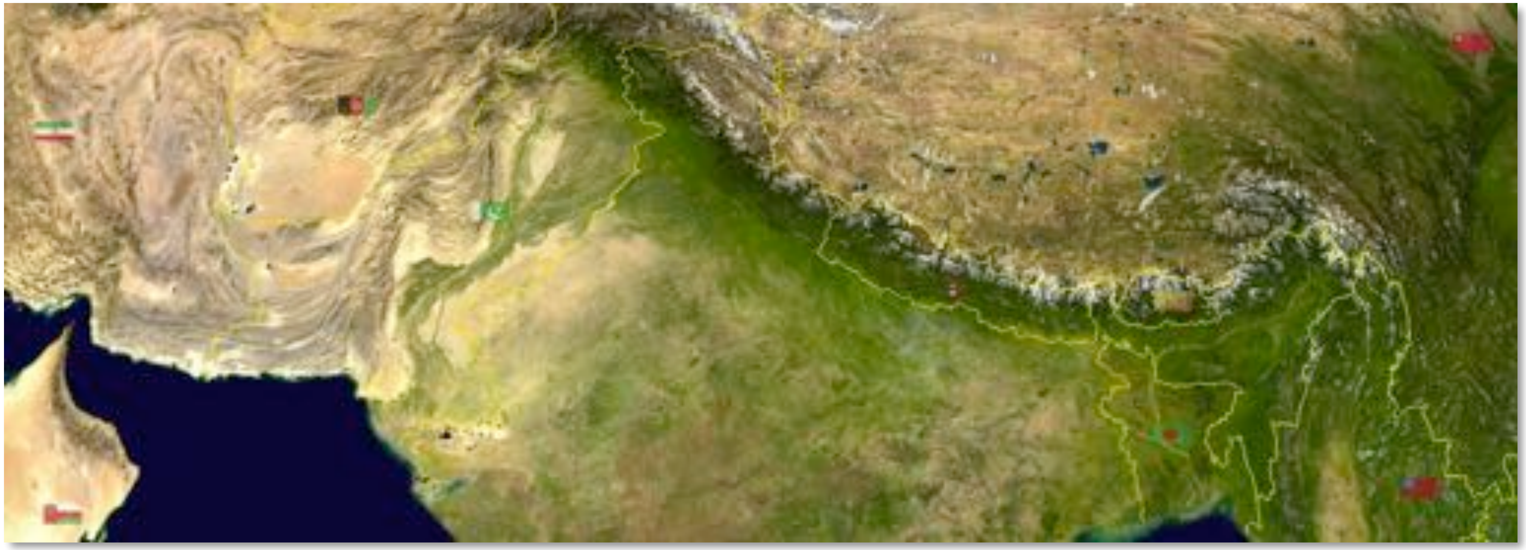


Indian subcontinent: India, Pakistan, Bangladesh, Srilanka, Nepal and Bhutan

Indian Art Music



Indian Art Music: Hindustani music



Indian Art Music: Carnatic music

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Rāga: melodic framework

- Grammar for improvisation and composition

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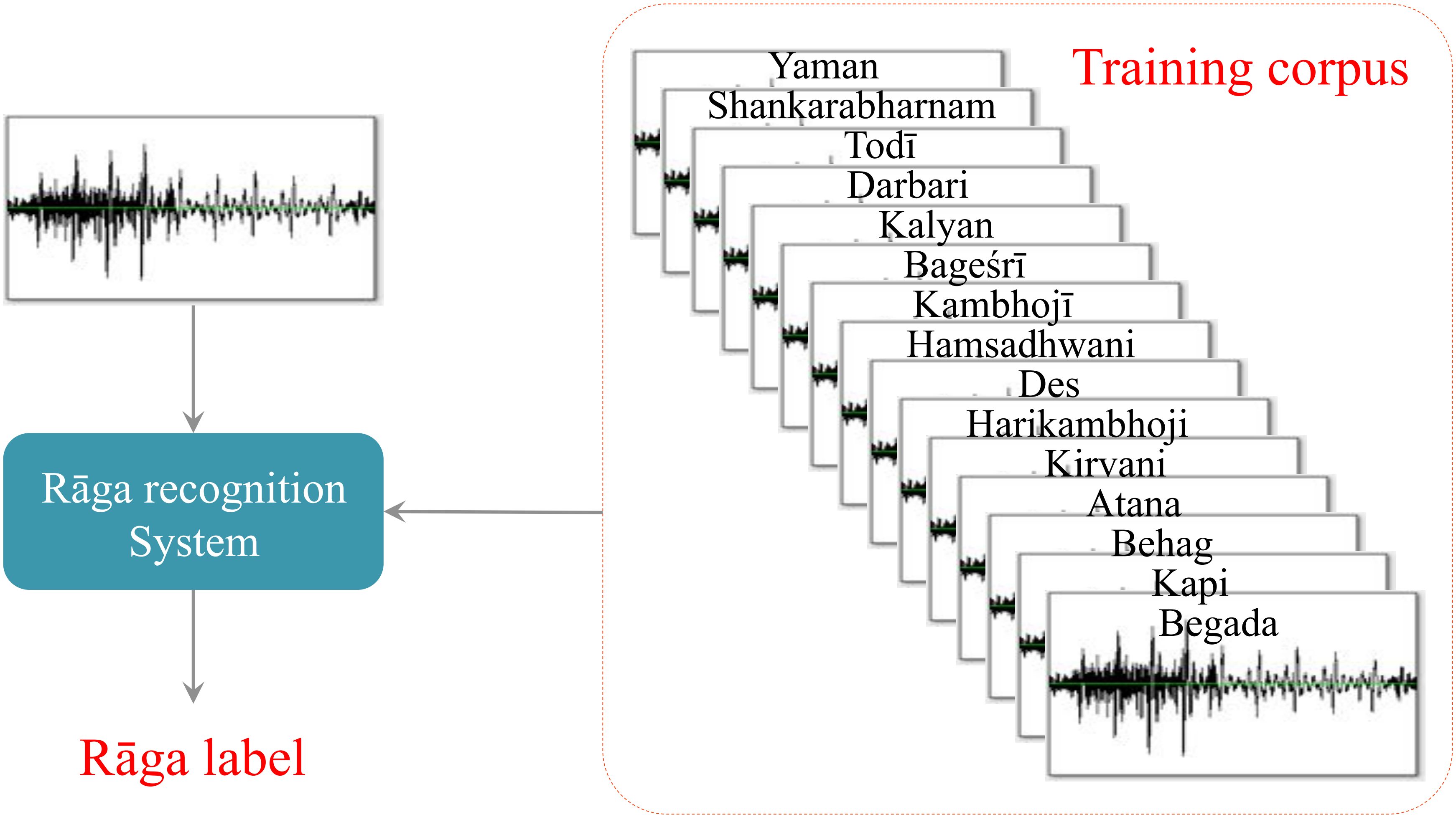
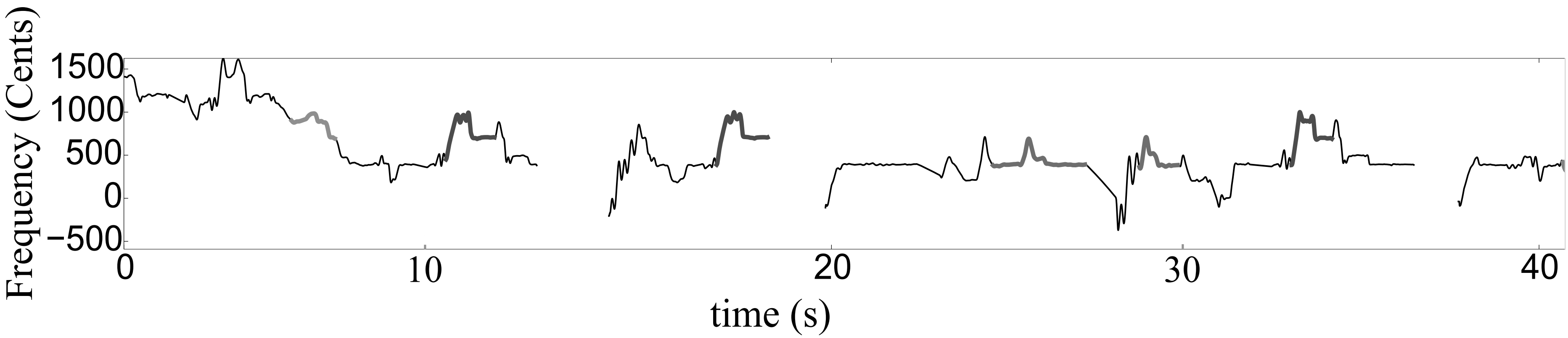
Automatic Rāga Recognition



Rāga Characterization: Svaras



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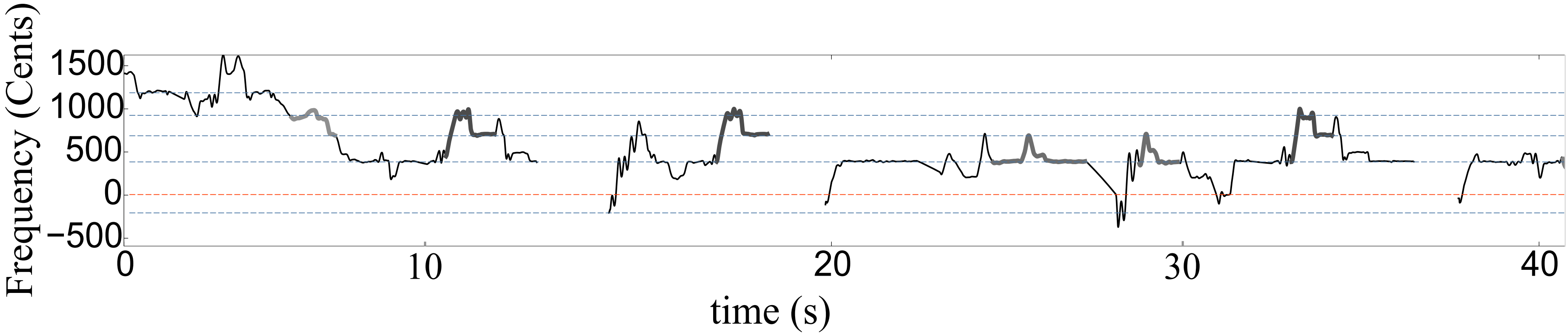

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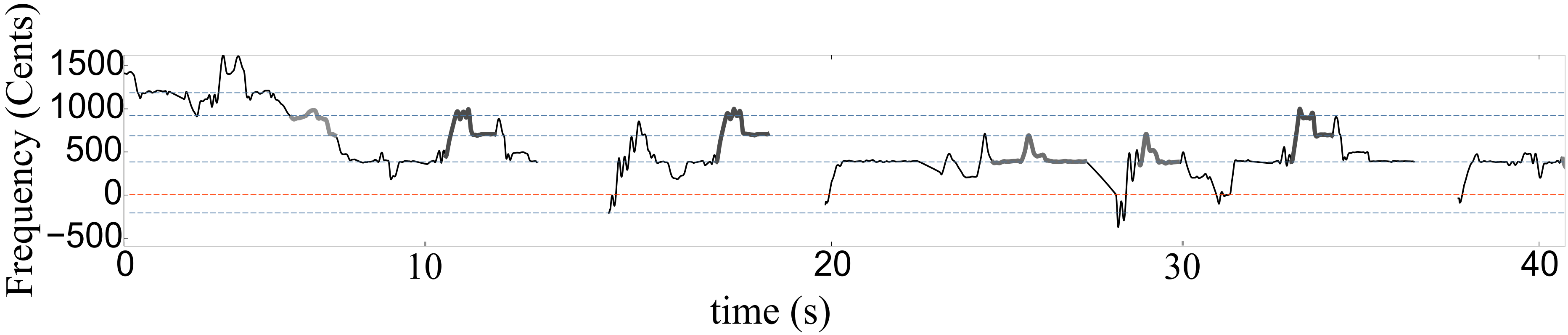

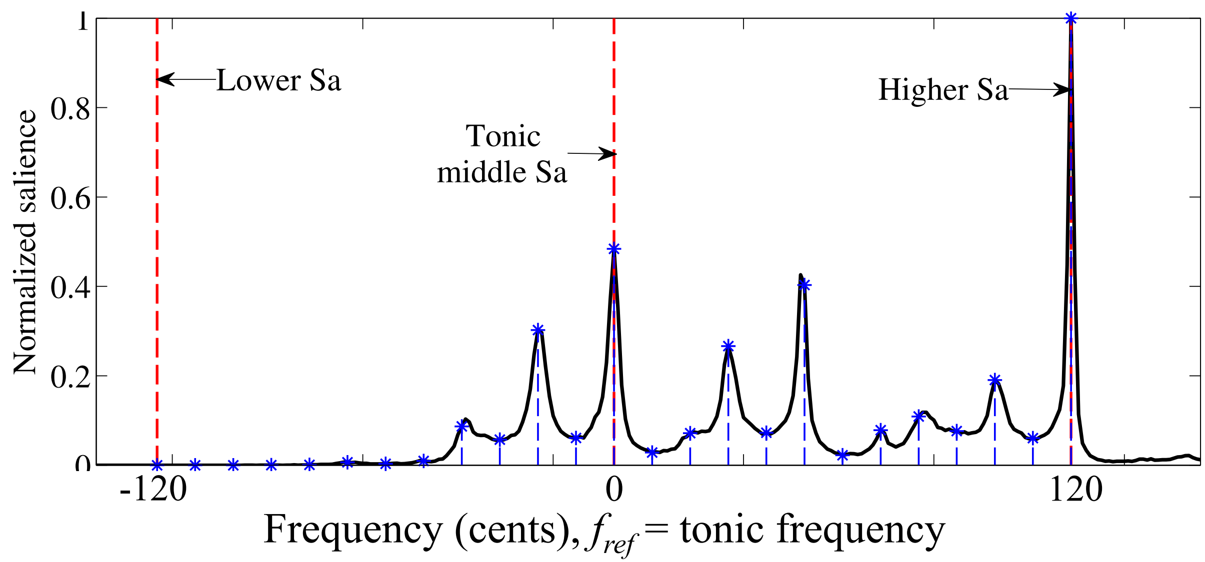

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- G. K. Koduri, S. Gulati, P. Rao, and X. Serra, "Rāga recognition based on pitch distribution methods," Journal of New Music Research, vol. 41, no. 4, pp. 337–350, 2012.

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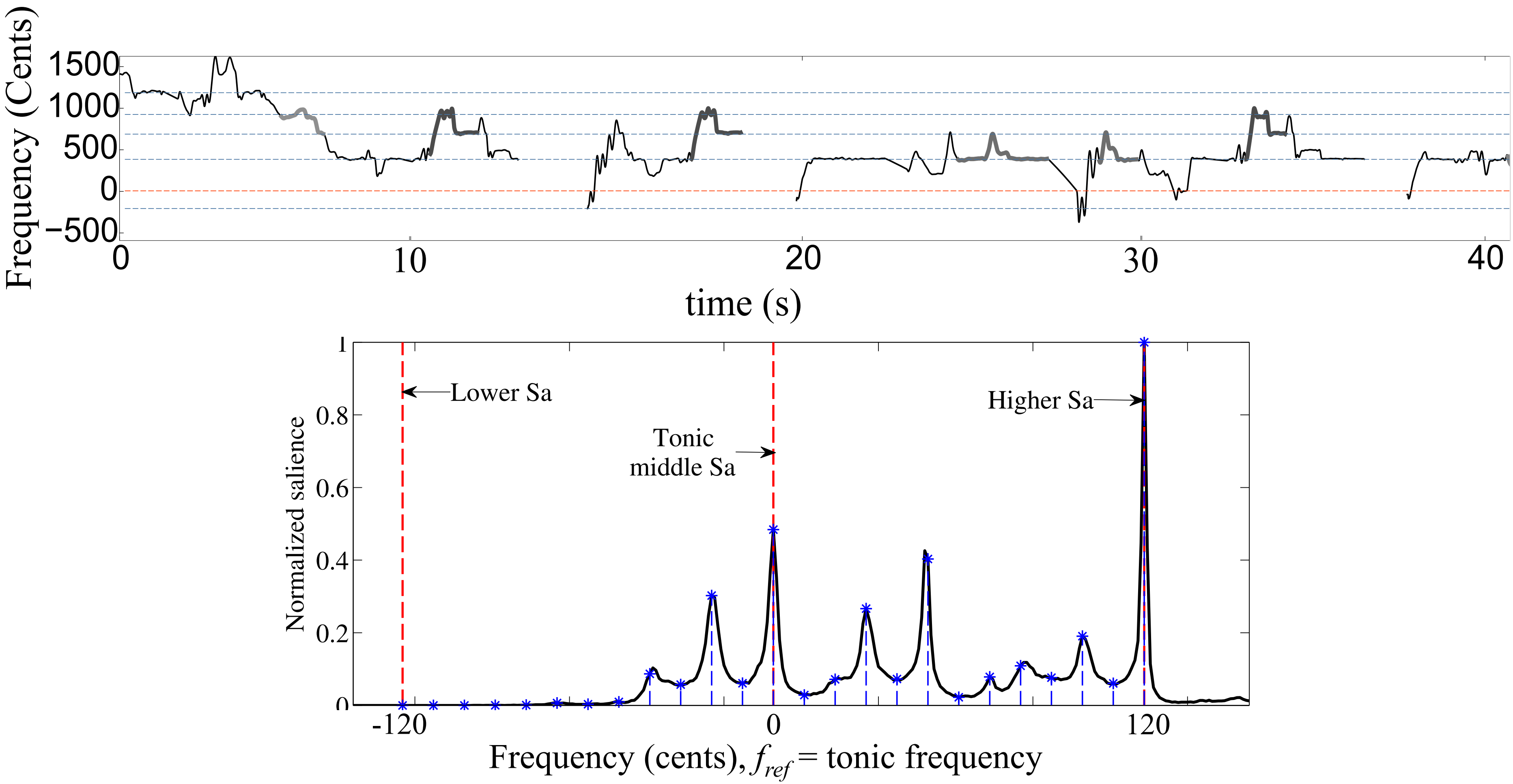
Rāga Characterization: Intonation



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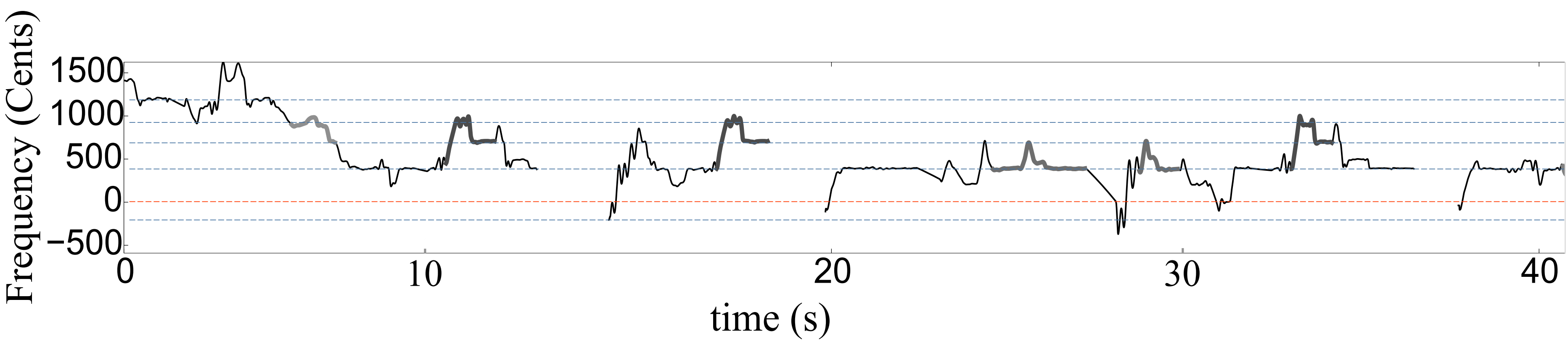
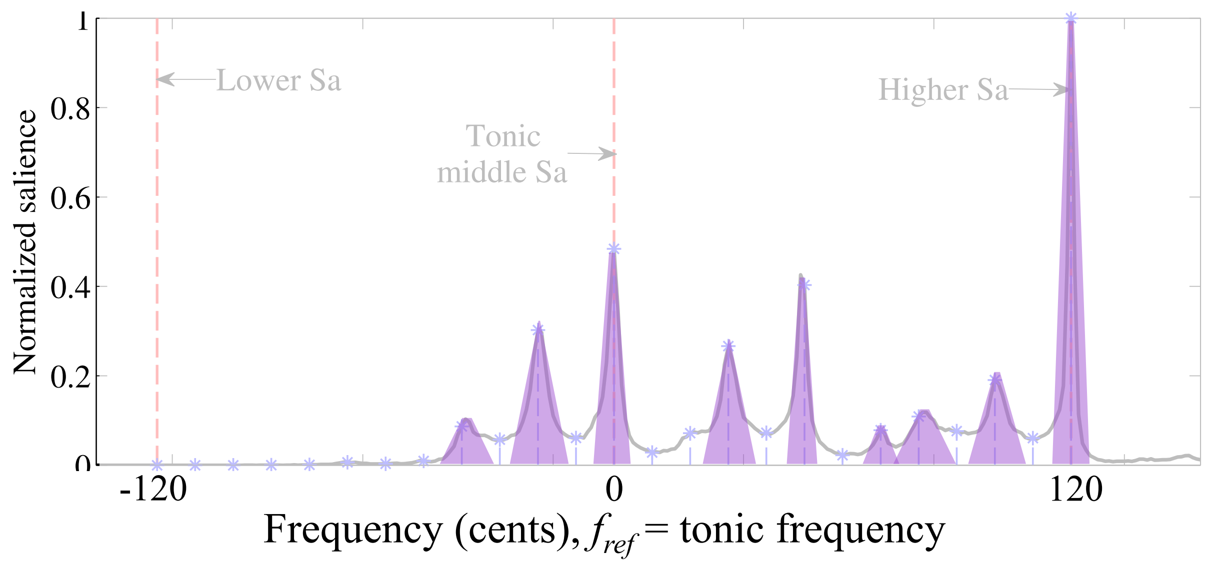
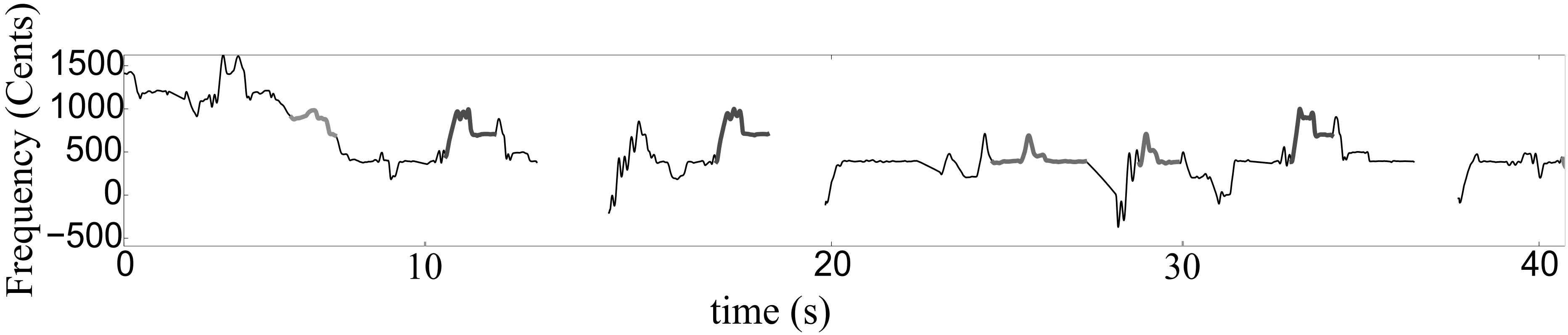
Rāga Characterization: Intonation





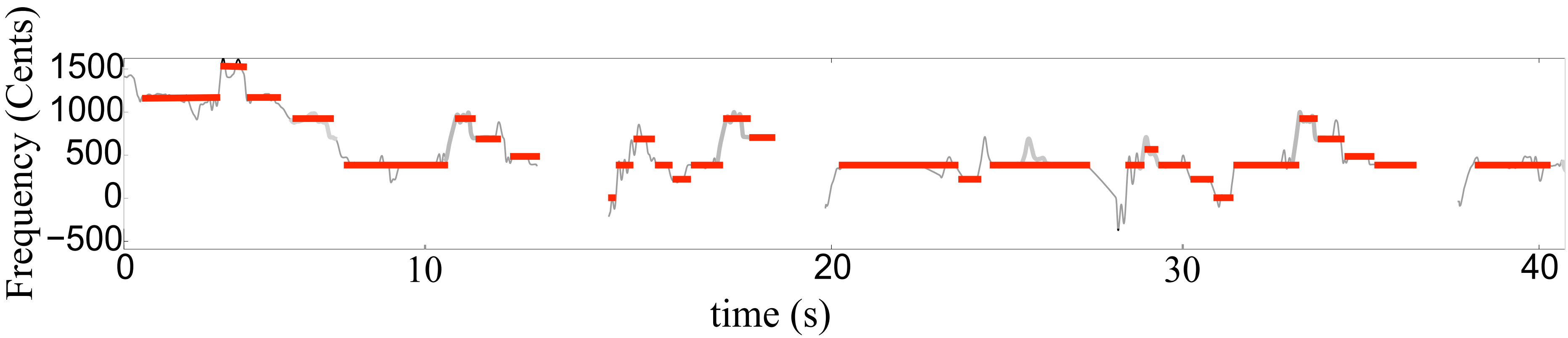
- G.K.Koduri,V.Ishwar,J.Serrà,andX.Serra,"Intonation analysis of rāgas in Carnatic music," Journal of New Music Research, vol. 43, no. 1, pp. 72–93, 2014.
- H. G. Ranjani, S. Arthi, and T. V. Sreenivas, "Carnatic music analysis: Shadja, swara identification and raga verification in alapana using stochastic models," in IEEE WASPAA, 2011, pp. 29–32.

Rāga Characterization: Ārōh-Avrōh



- Ascending-descending svara pattern; melodic progression

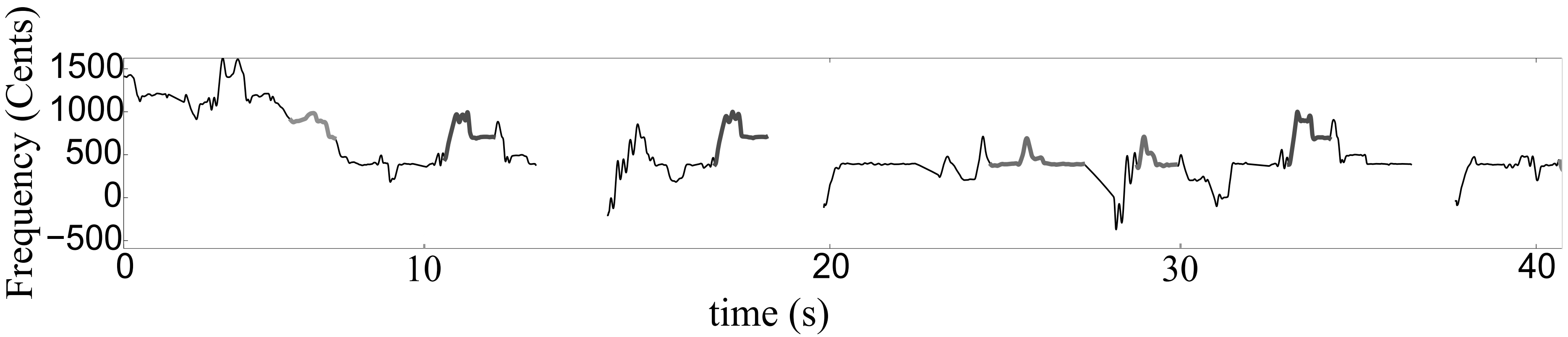
Rāga Characterization: Ārōh-Avrōh



Melodic Progression Templates
N-gram Distribution
Hidden Markov Model

- S. Shetty and K. K. Achary, "Raga mining of indian music by extracting arohana-avarohana pattern," Int. Journal of Recent Trends in Engineering, vol. 1, no. 1, pp. 362–366, 2009.
- V. Kumar, H Pandya, and C. V. Jawahar, "Identifying ragas in indian music," in 22nd Int. Conf. on Pattern Recognition (ICPR), 2014, pp. 767–772.
- P. V. Rajkumar, K. P. Saishankar, and M. John, "Identification of Carnatic raagas using hidden markov models," in IEEE 9th Int. Symposium on Applied Machine Intelligence and Informatics (SAMI), 2011, pp. 107–110.

Rāga Characterization: Melodic motifs



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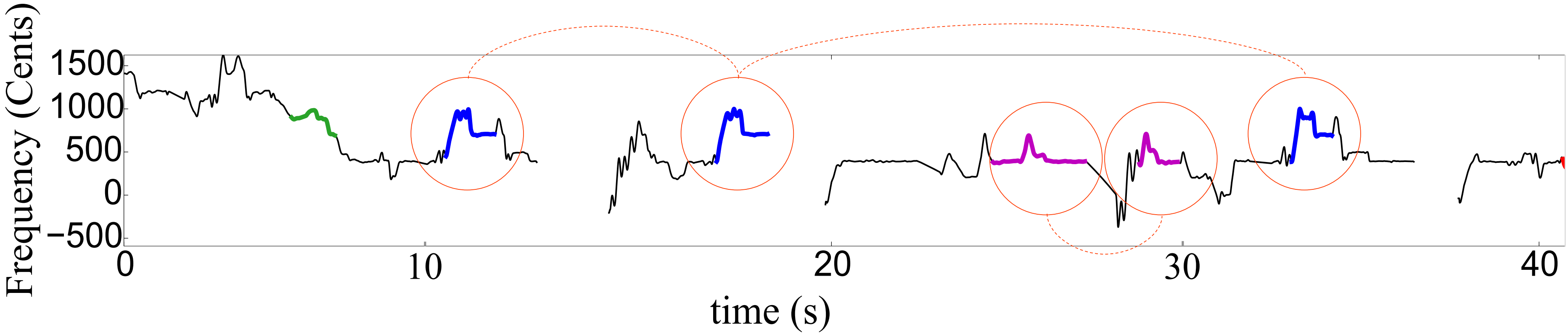
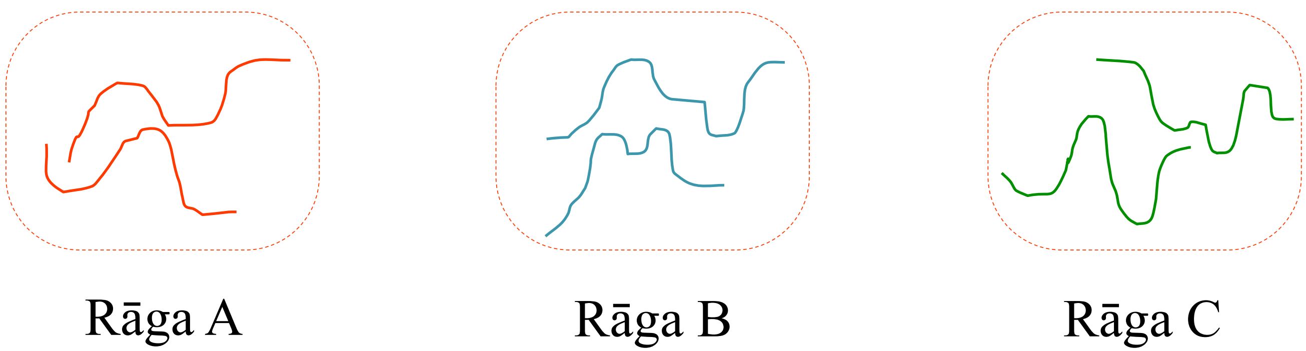
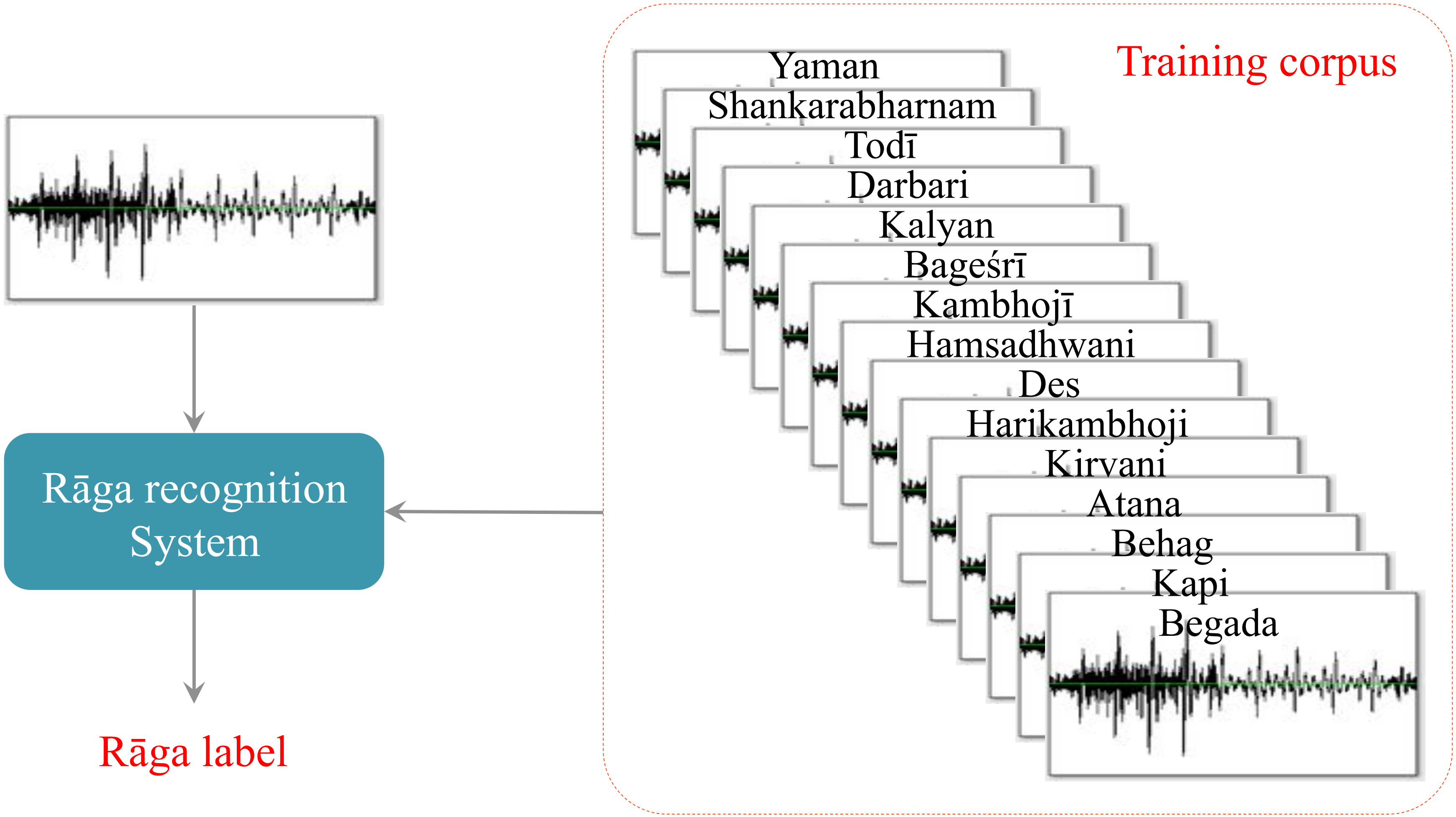




- R. Sridhar and T. V. Geetha, "Raga identification of carnatic music for music information retrieval," International Journal of Recent Trends in Engineering, vol. 1, no. 1, pp. 571–574, 2009.
- S. Dutta, S. PV Krishnaraj, and H. A. Murthy, "Raga verification in carnatic music using longest common segment set," in Int. Soc. for Music Information Retrieval Conf. (ISMIR), pp. 605-611,2015

Goal

- Automatic rāga recognition



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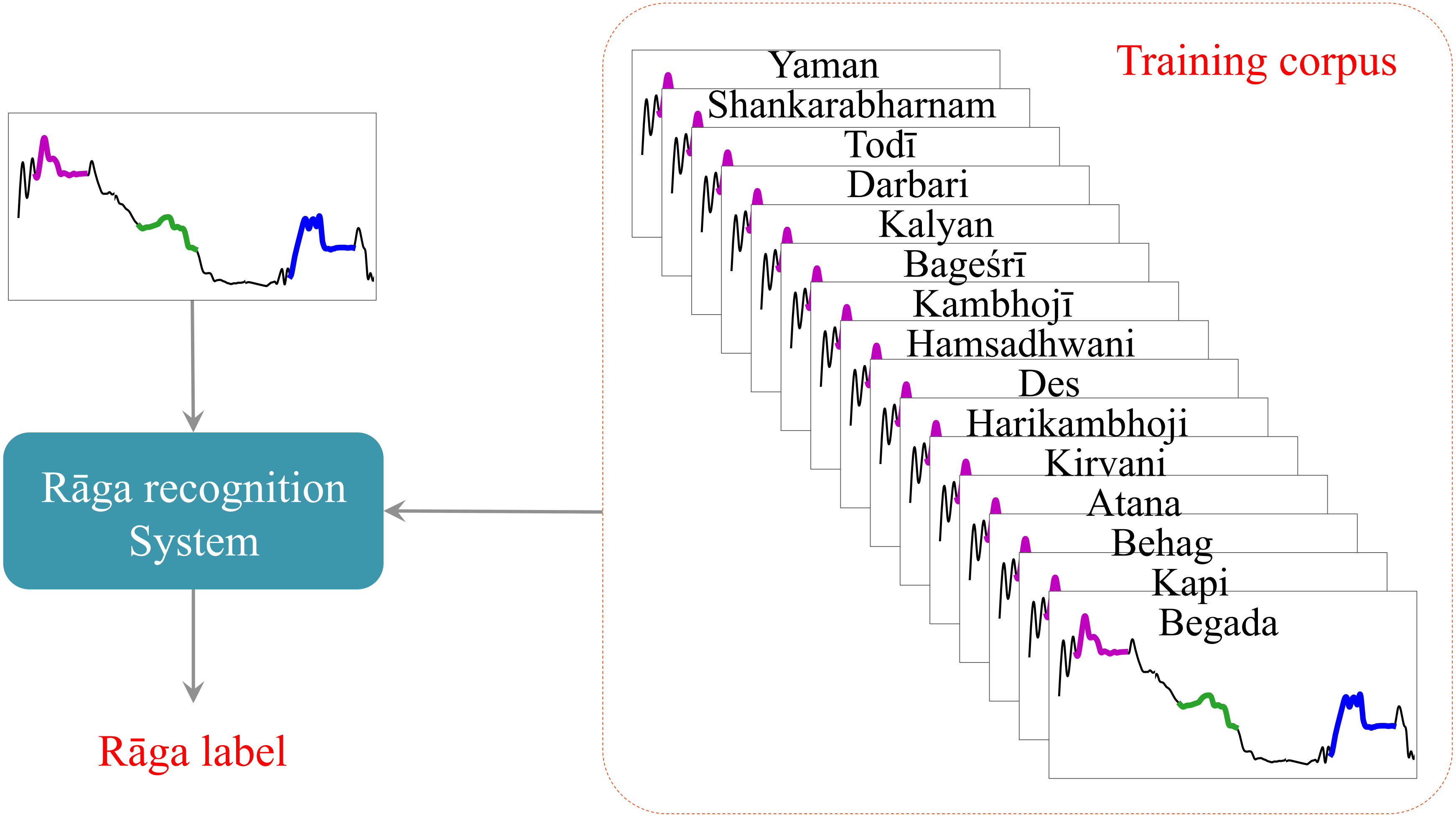
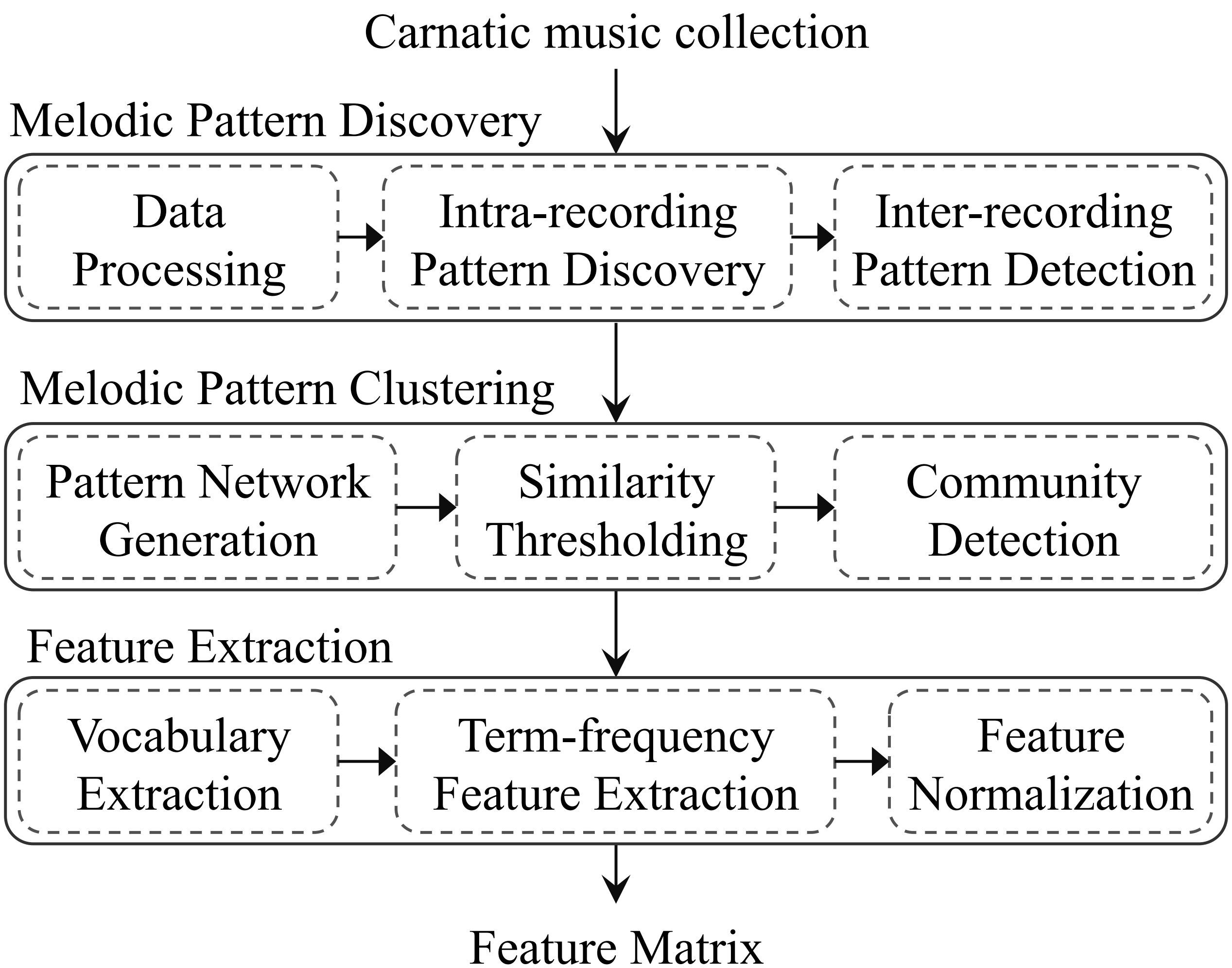


Block Diagram: Proposed Approach



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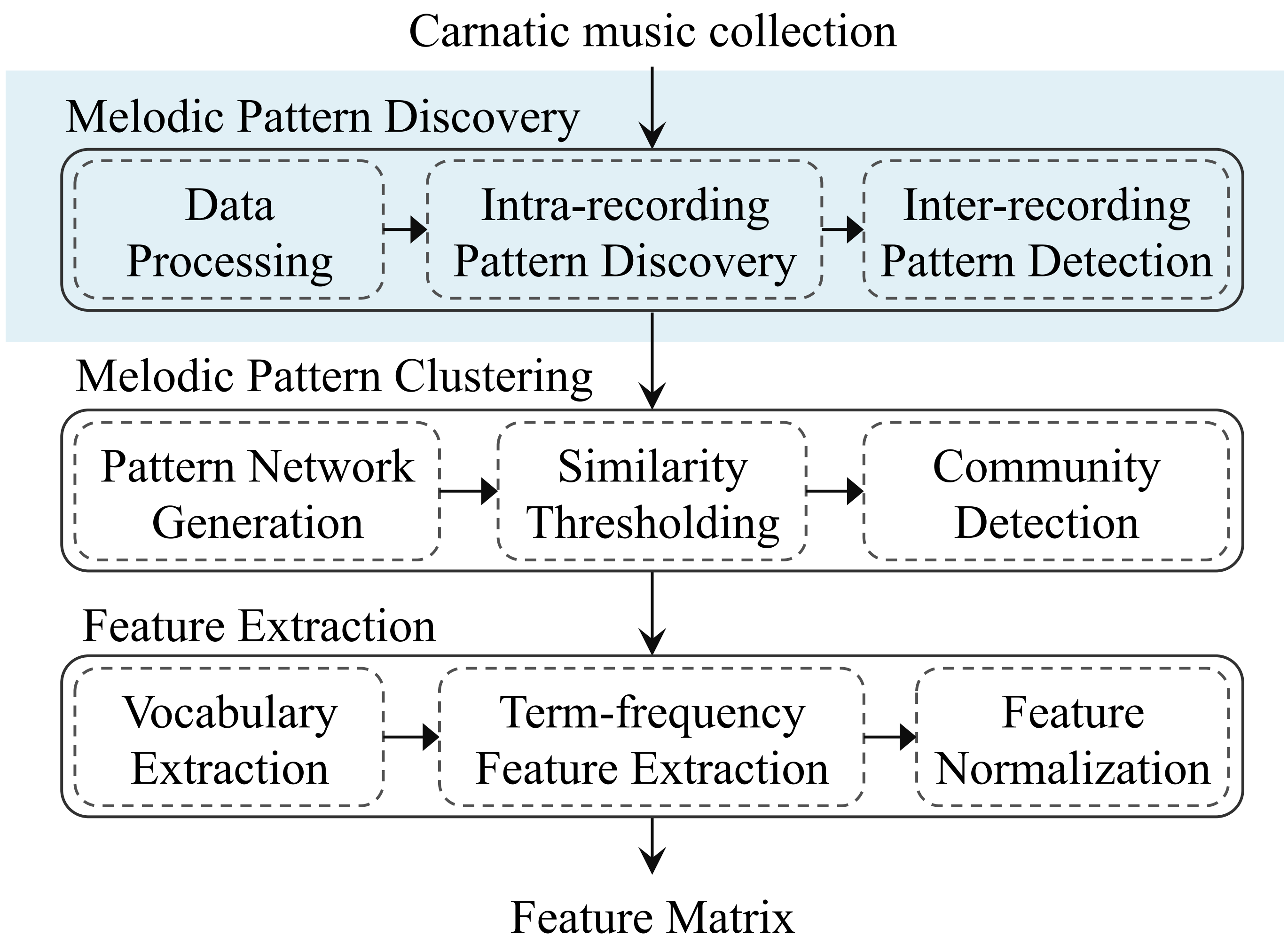
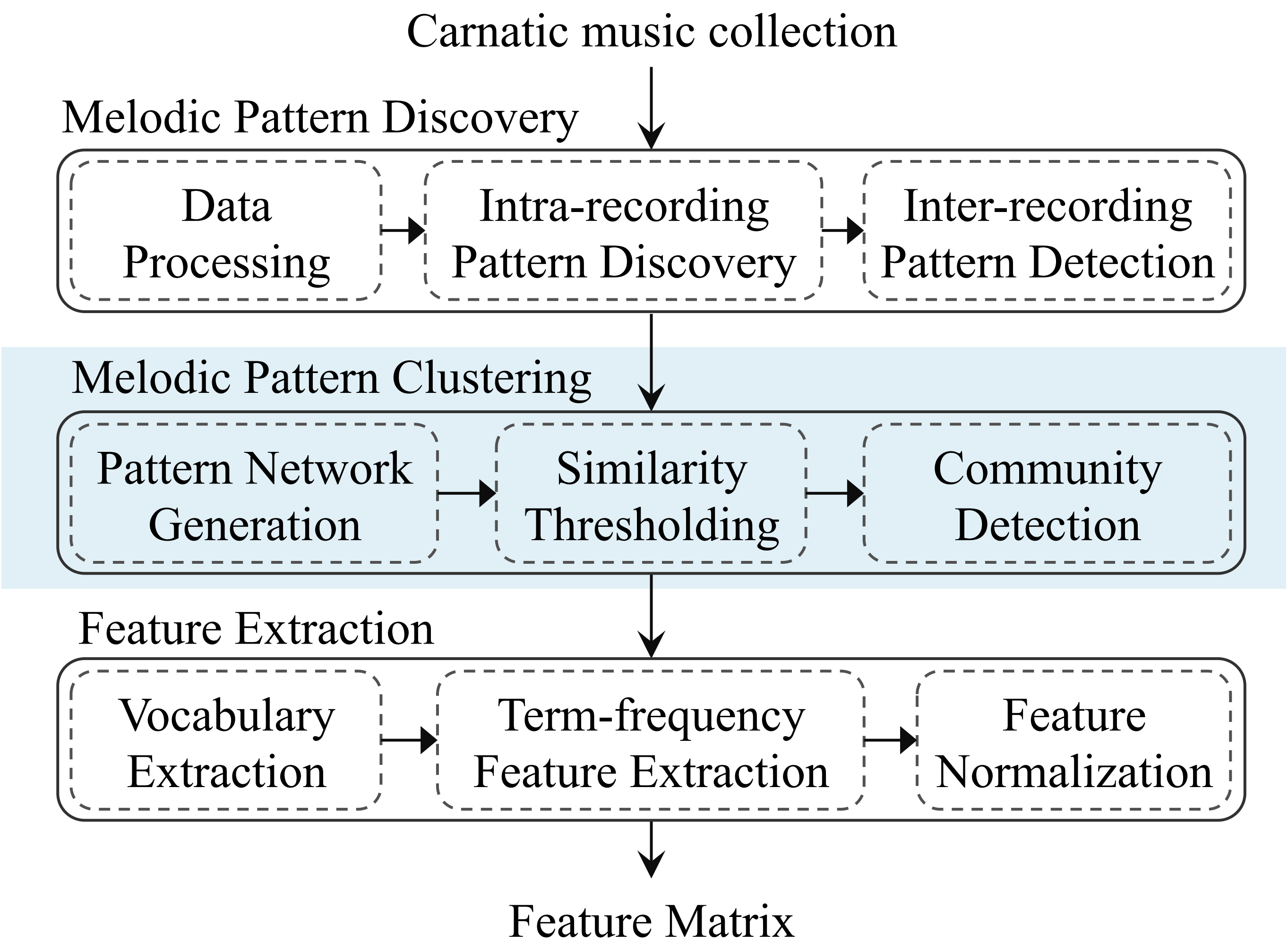
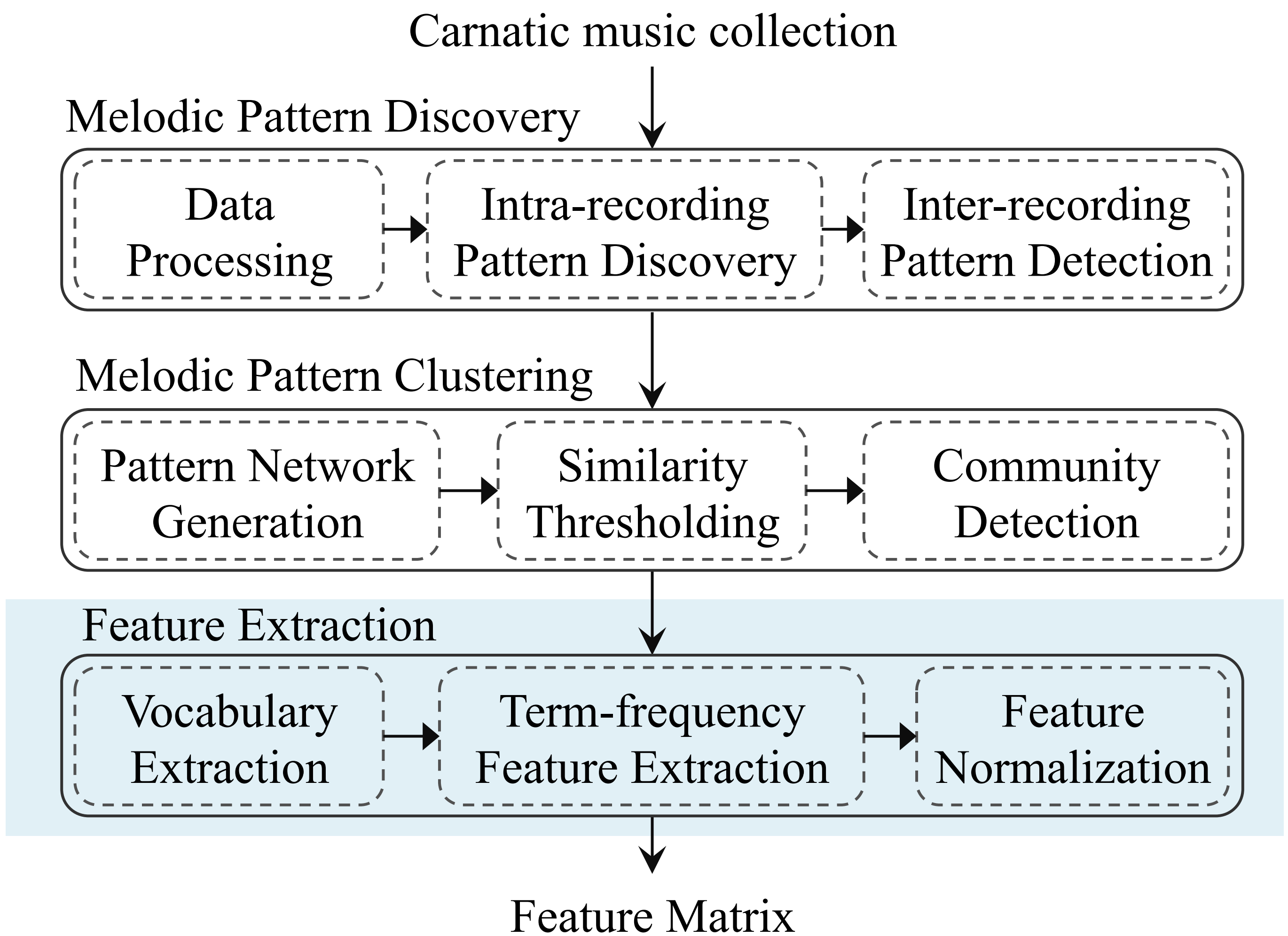
Block Diagram: Pattern Discovery



Block Diagram: Pattern Clustering



Block Diagram: Feature Extraction



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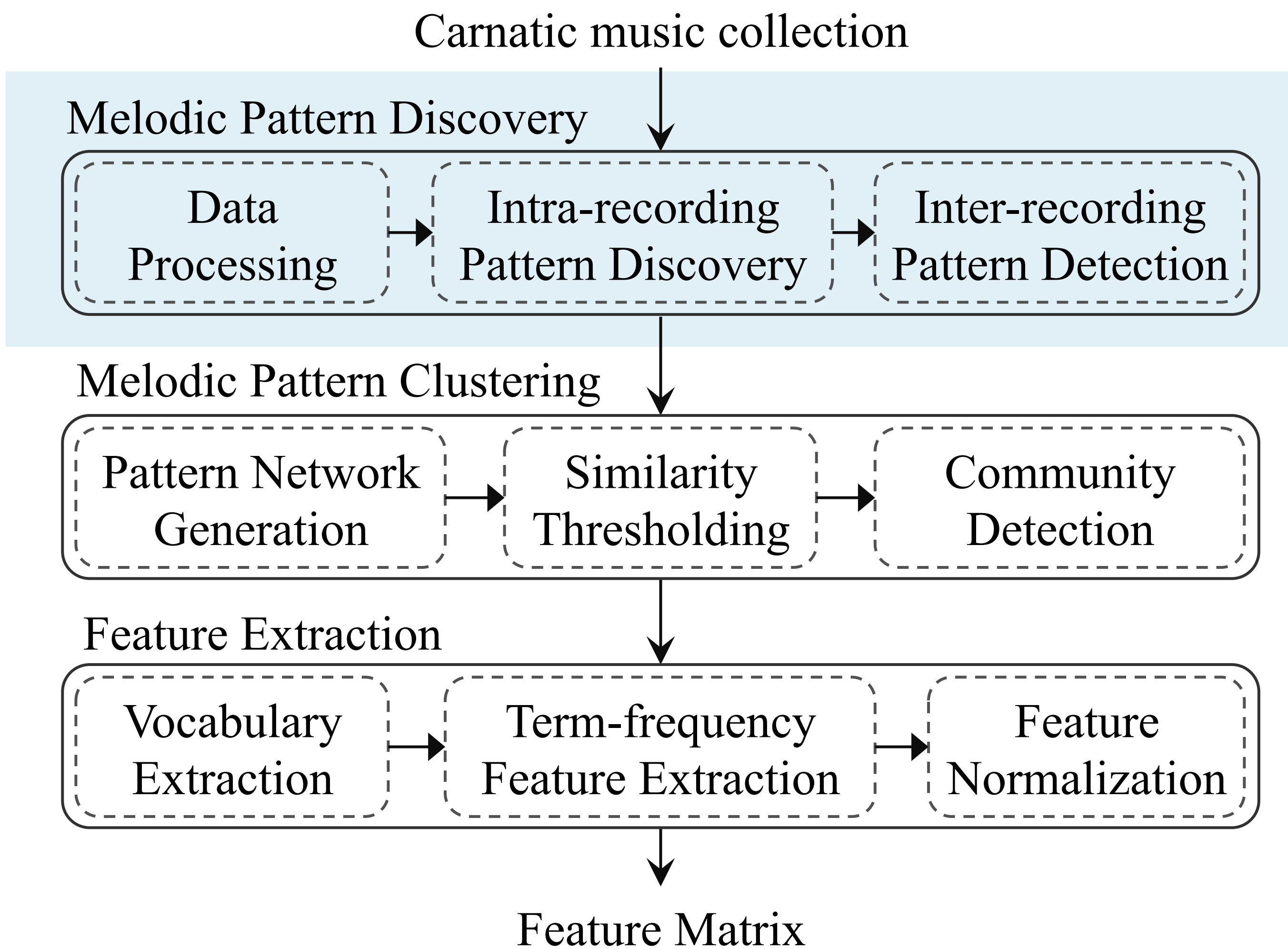

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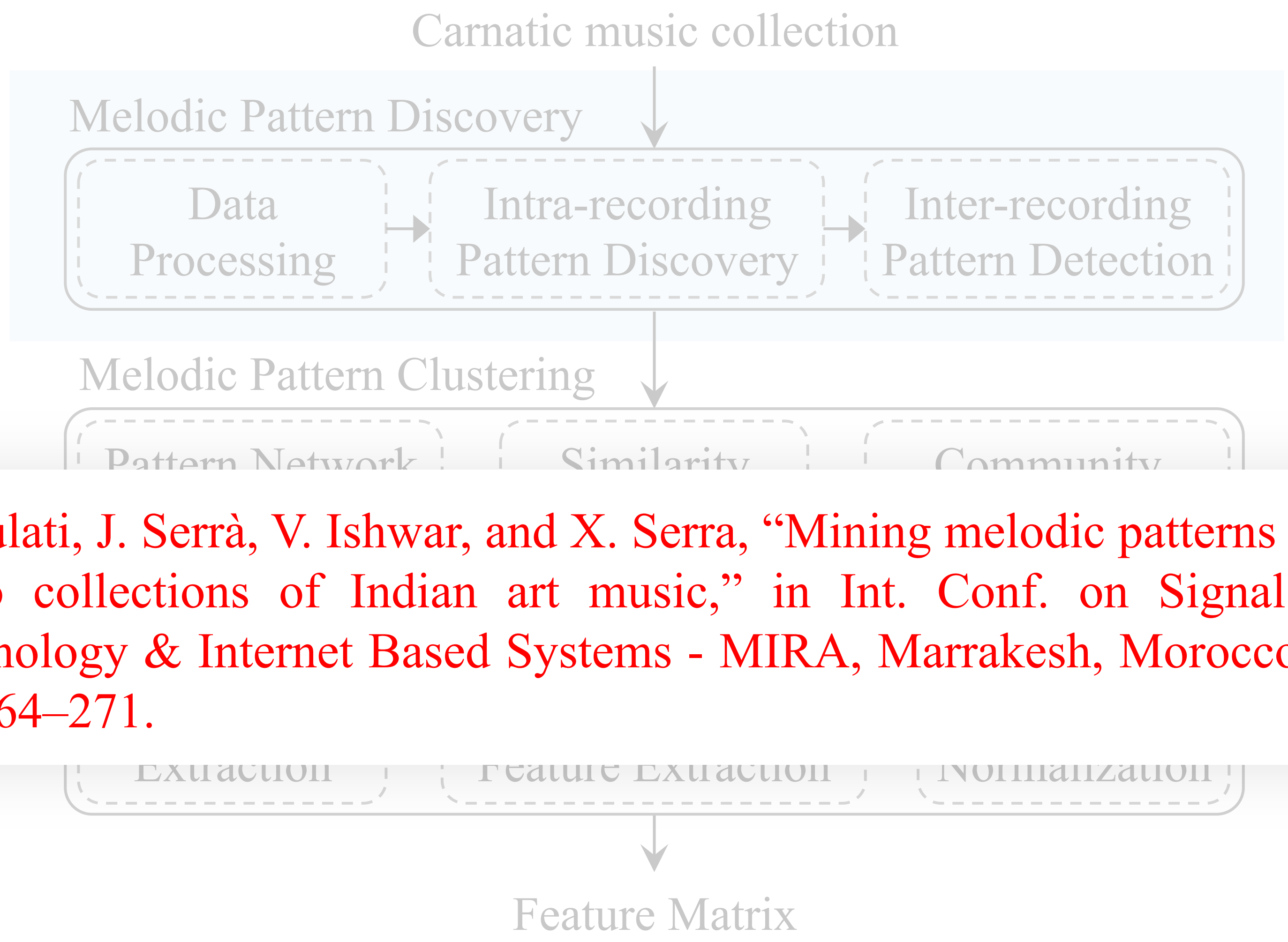

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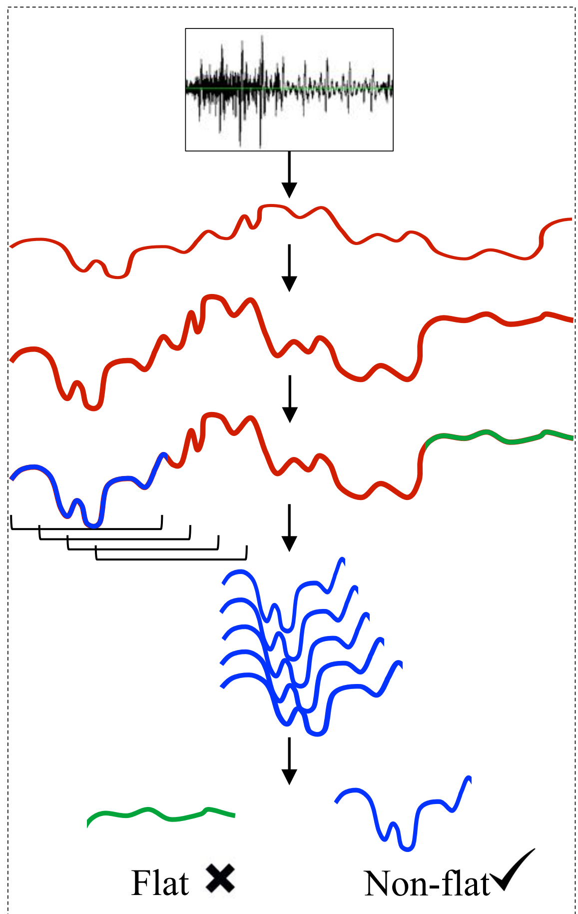
Proposed Approach: Pattern Discovery



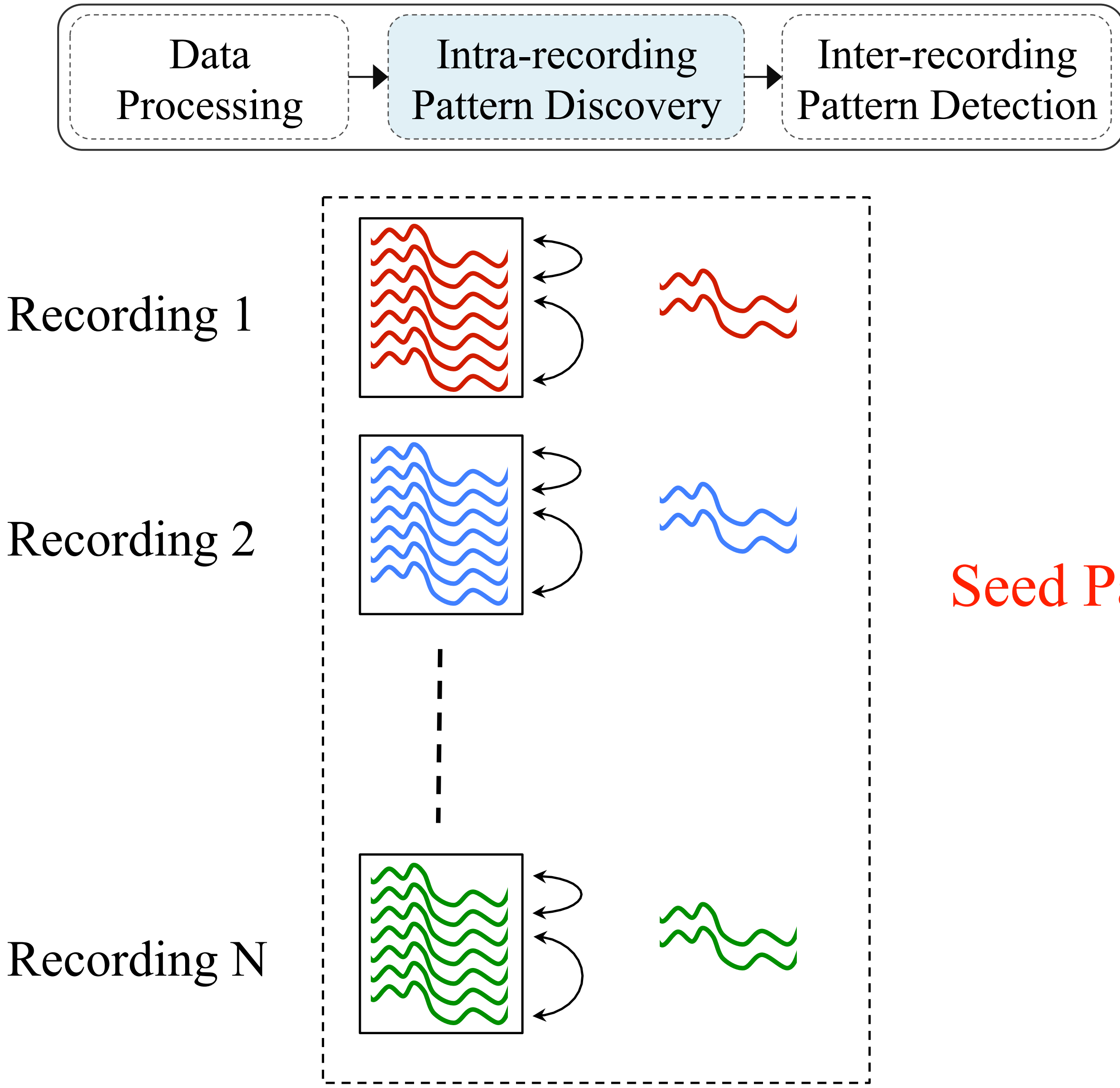
-Predominant pitch estimation

-Downsampling
-Hz to Cents
-Tonic normalization
-Brute-force segmentation

-Uniform Time-scaling

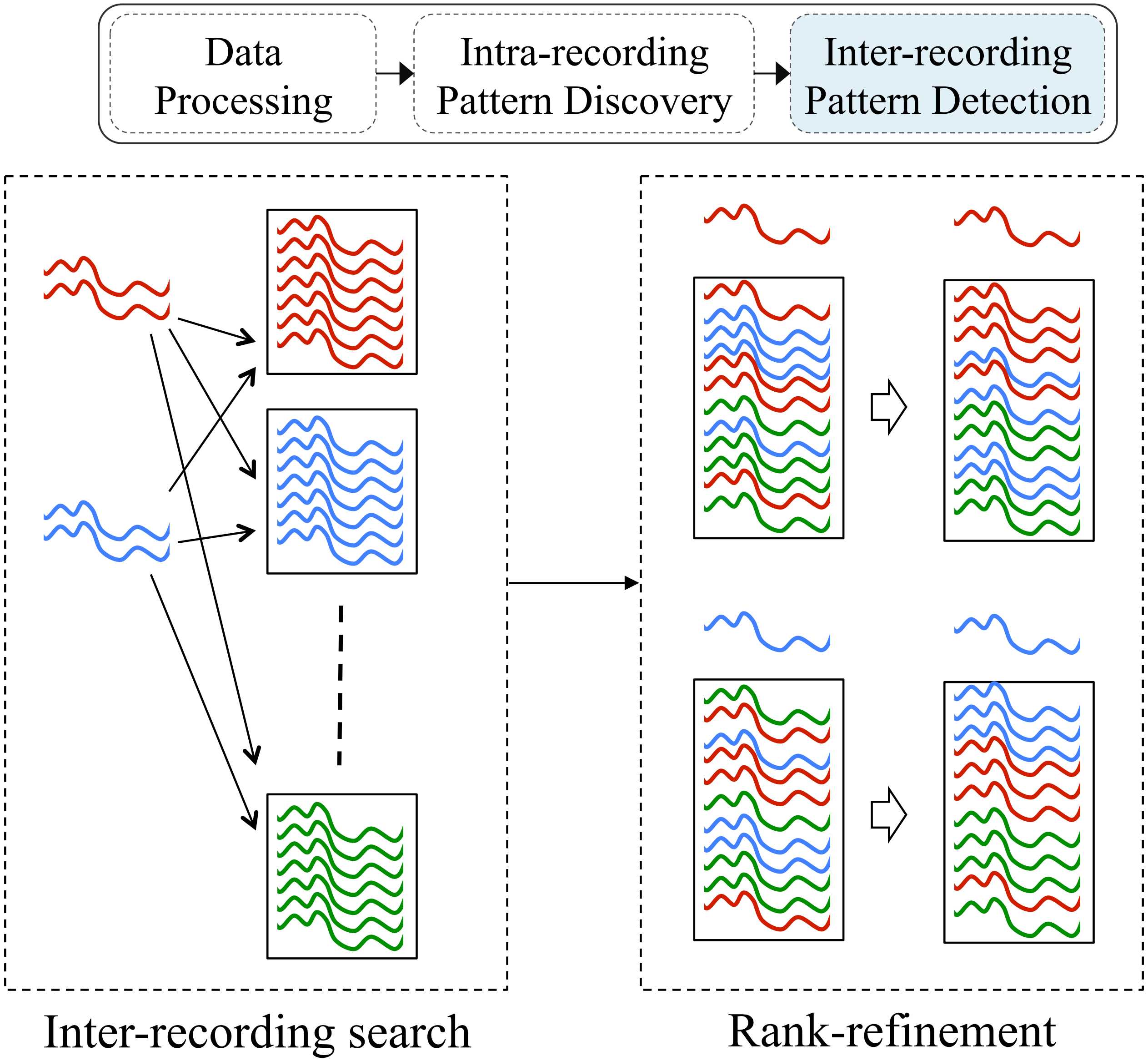
-Segment filtering

Proposed Approach: Pattern Discovery

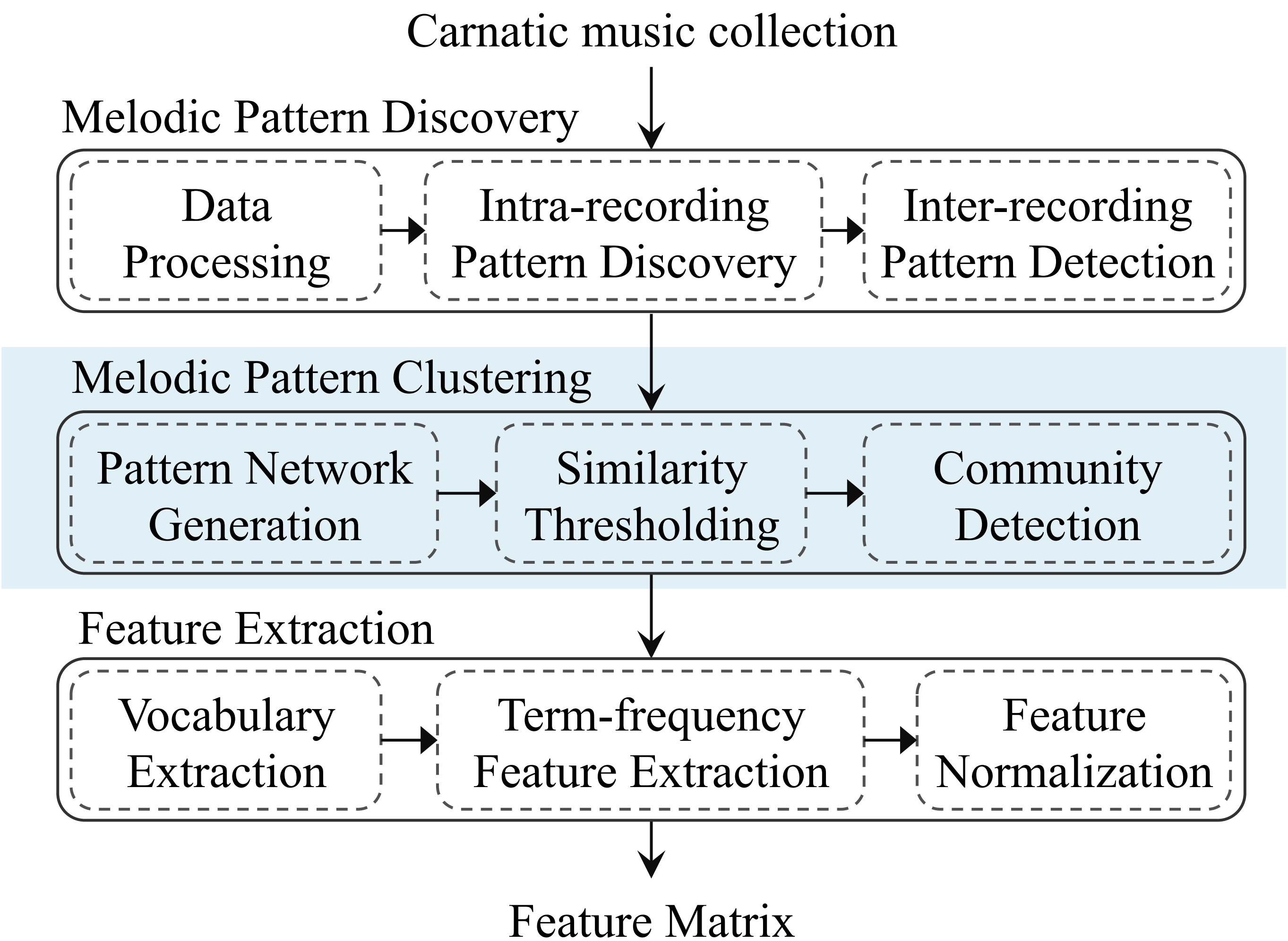


Seed Patterns

Proposed Approach: Pattern Discovery



Block Diagram: Pattern Clustering



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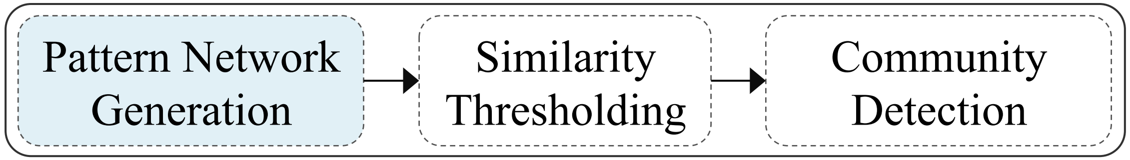
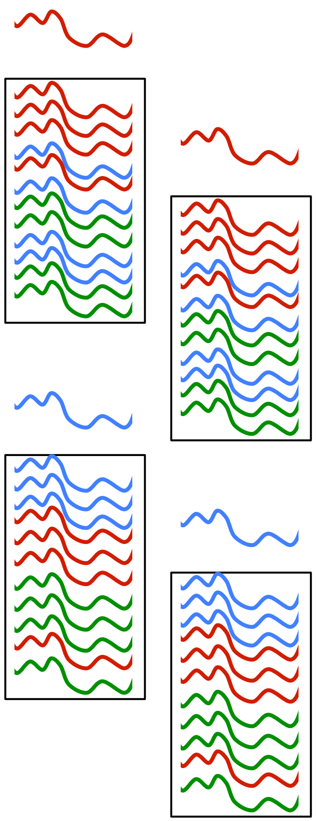
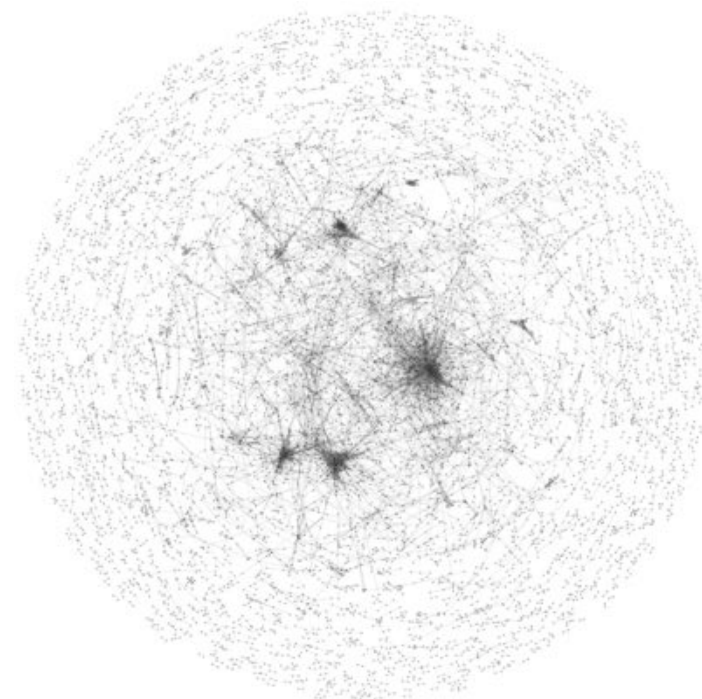




$$W_{ij} = e^{-D_{ij}/\overline{D}}$$

Undirectional



- M. EJ Newman, "The structure and function of complex networks," Society for Industrial and Applied Mathematics (SIAM) review, vol. 45, no. 2, pp. 167–256, 2003.

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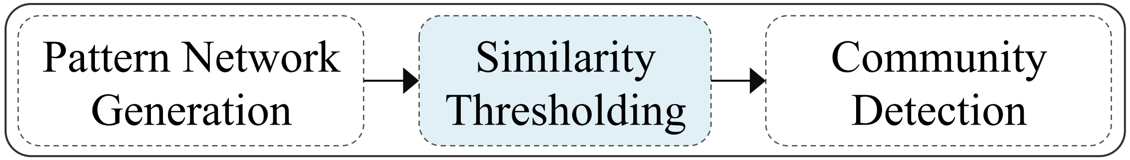

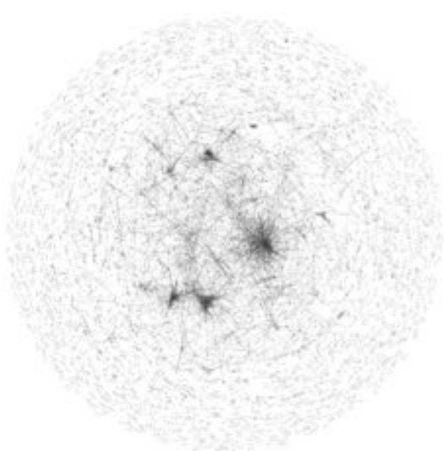

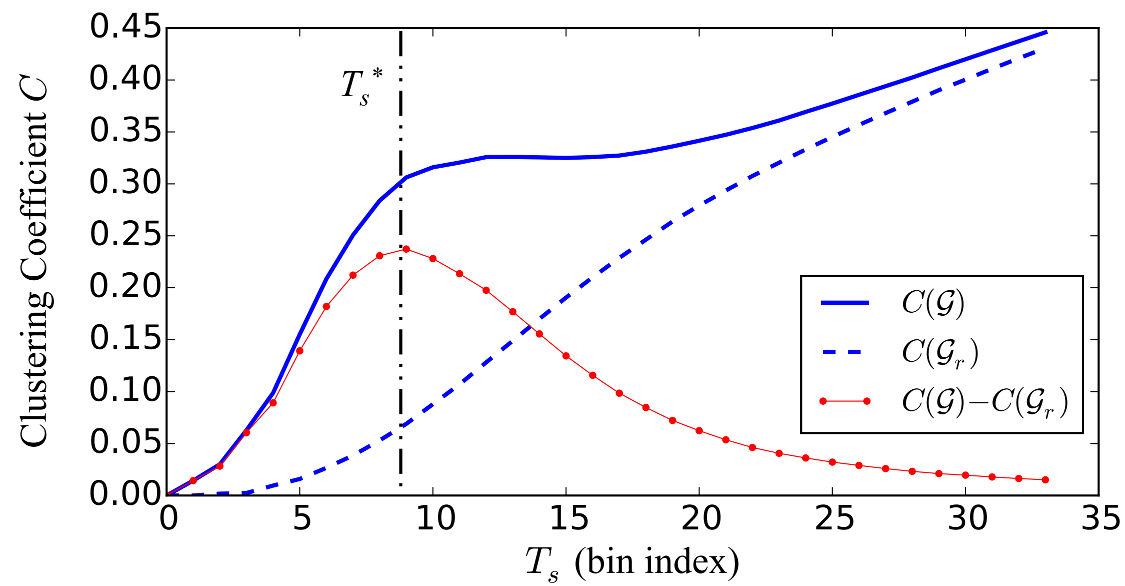

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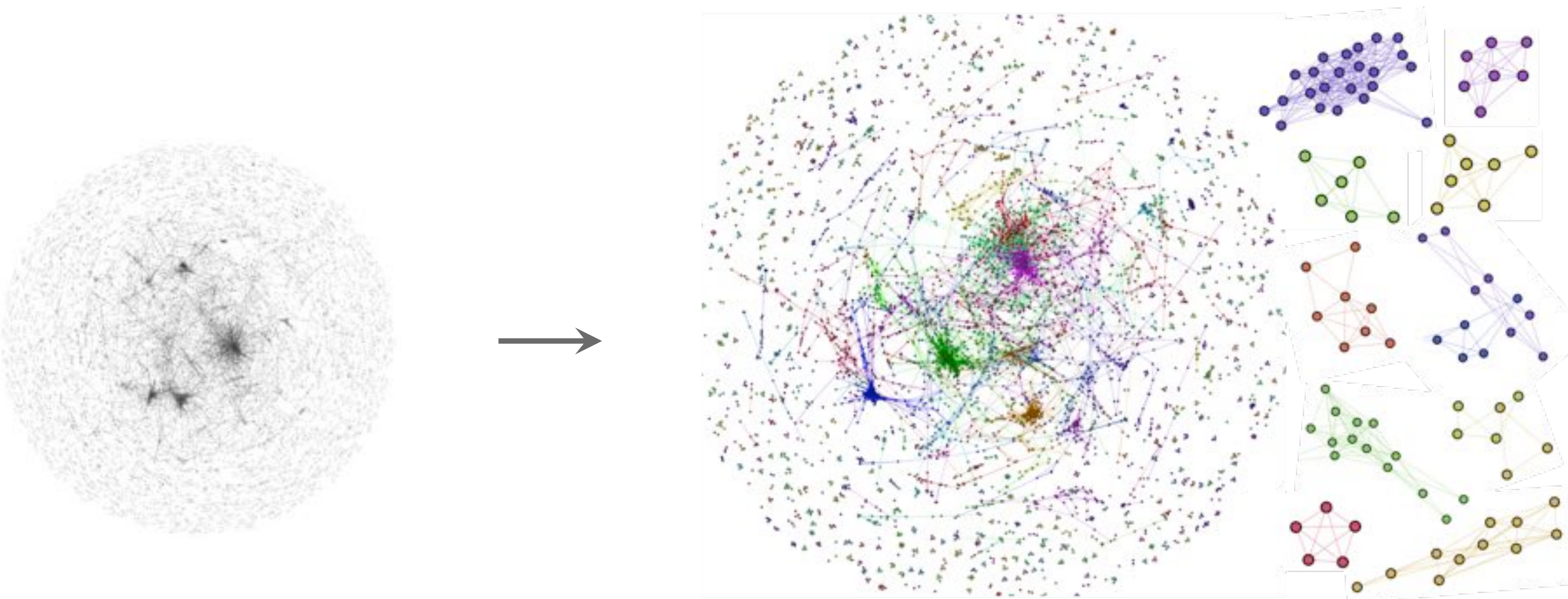
Proposed Approach: Pattern Clustering

Pattern Network Generation → Similarity Thresholding → Community Detection



- V. D. Blondel, J. L. Guillaume, R. Lambiotte, and E. Lefebvre, "Fast unfolding of communities in large networks," Journal of Statistical Mechanics: Theory and Experiment, vol. 2008, no. 10, pp. P10008, 2008.
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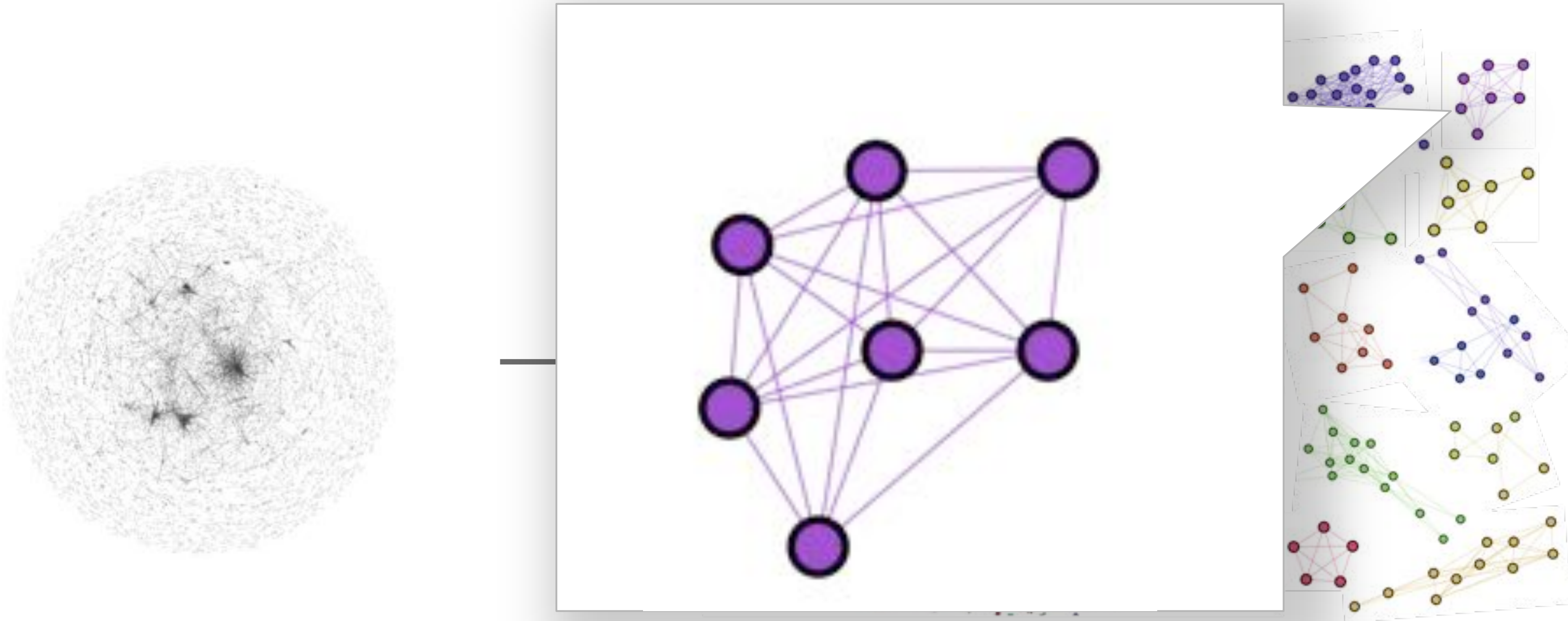

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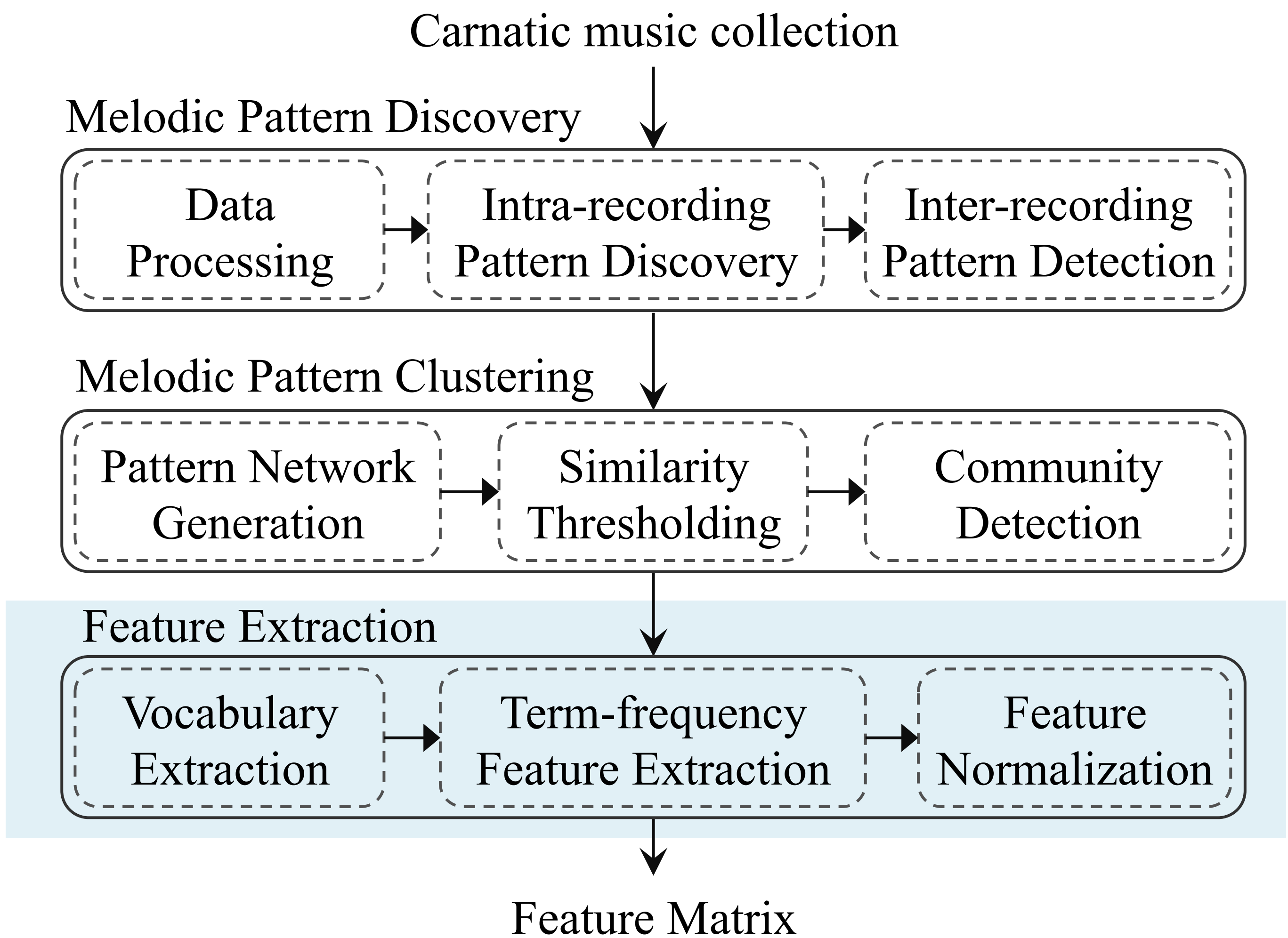

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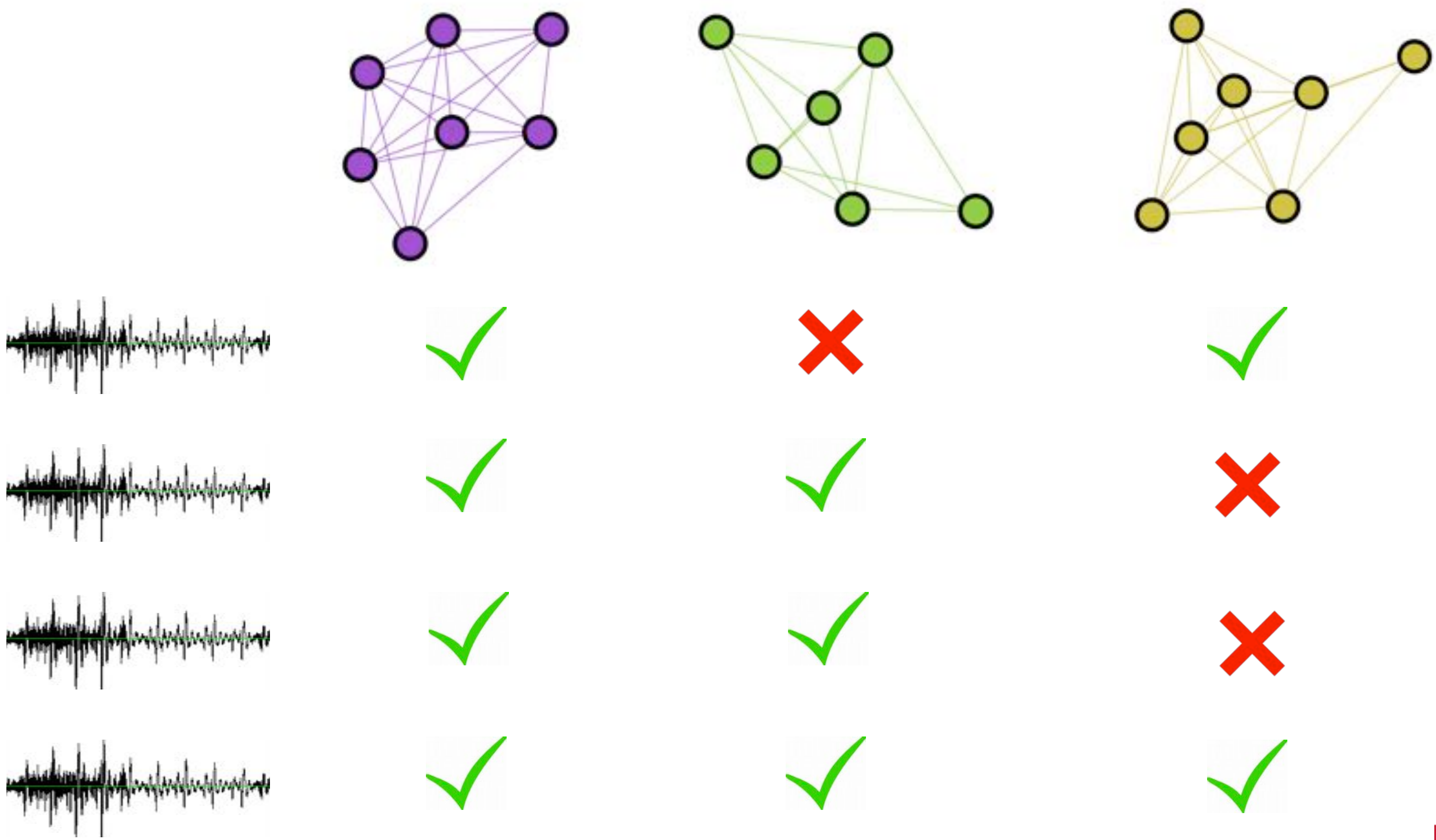


Proposed Approach: Feature Extraction

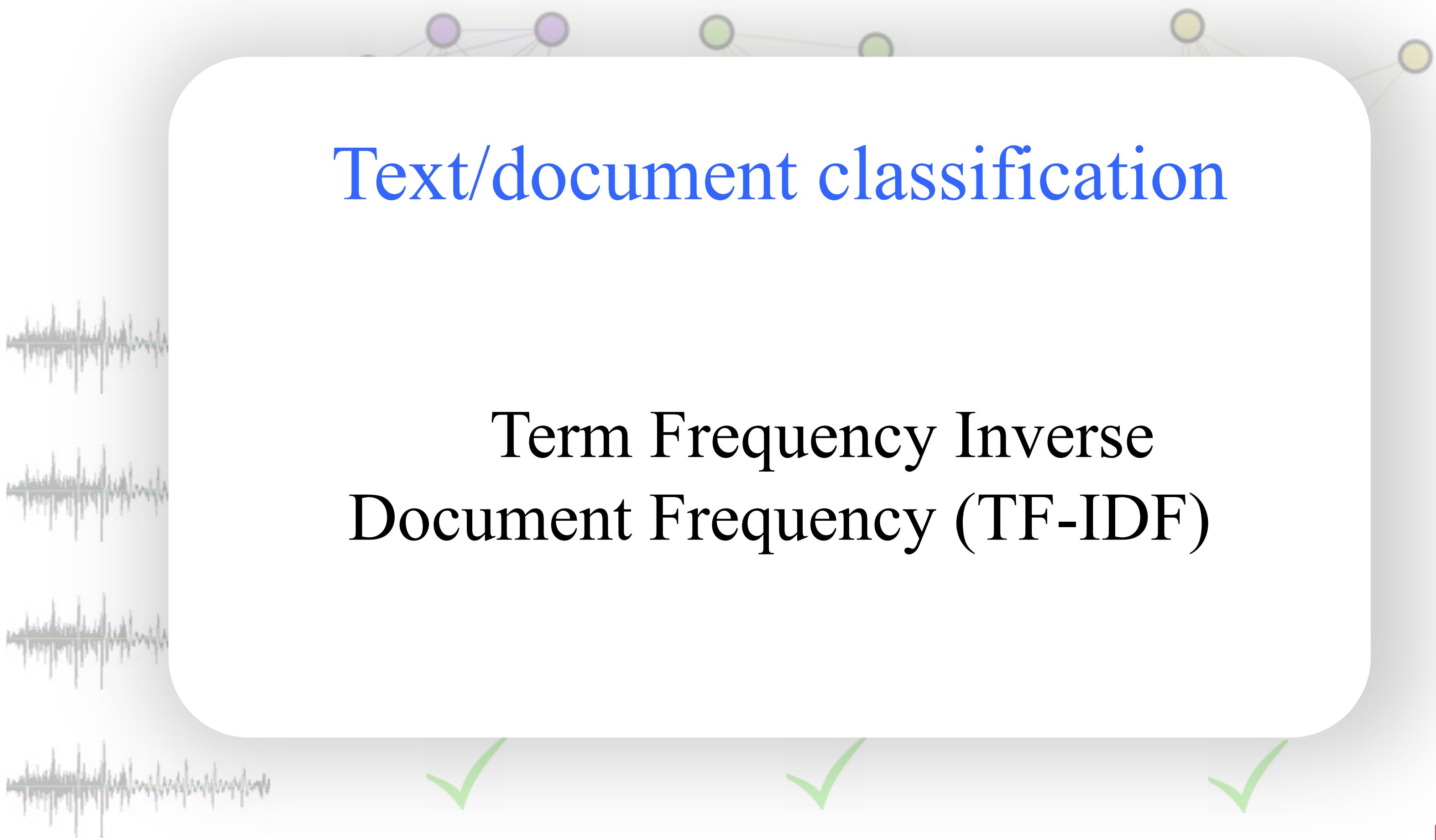
Text/document classification

Phrases ⟷ Words

Rāga ⟷ Topic

Recordings ⟷ Documents

Proposed Approach: Feature Extraction

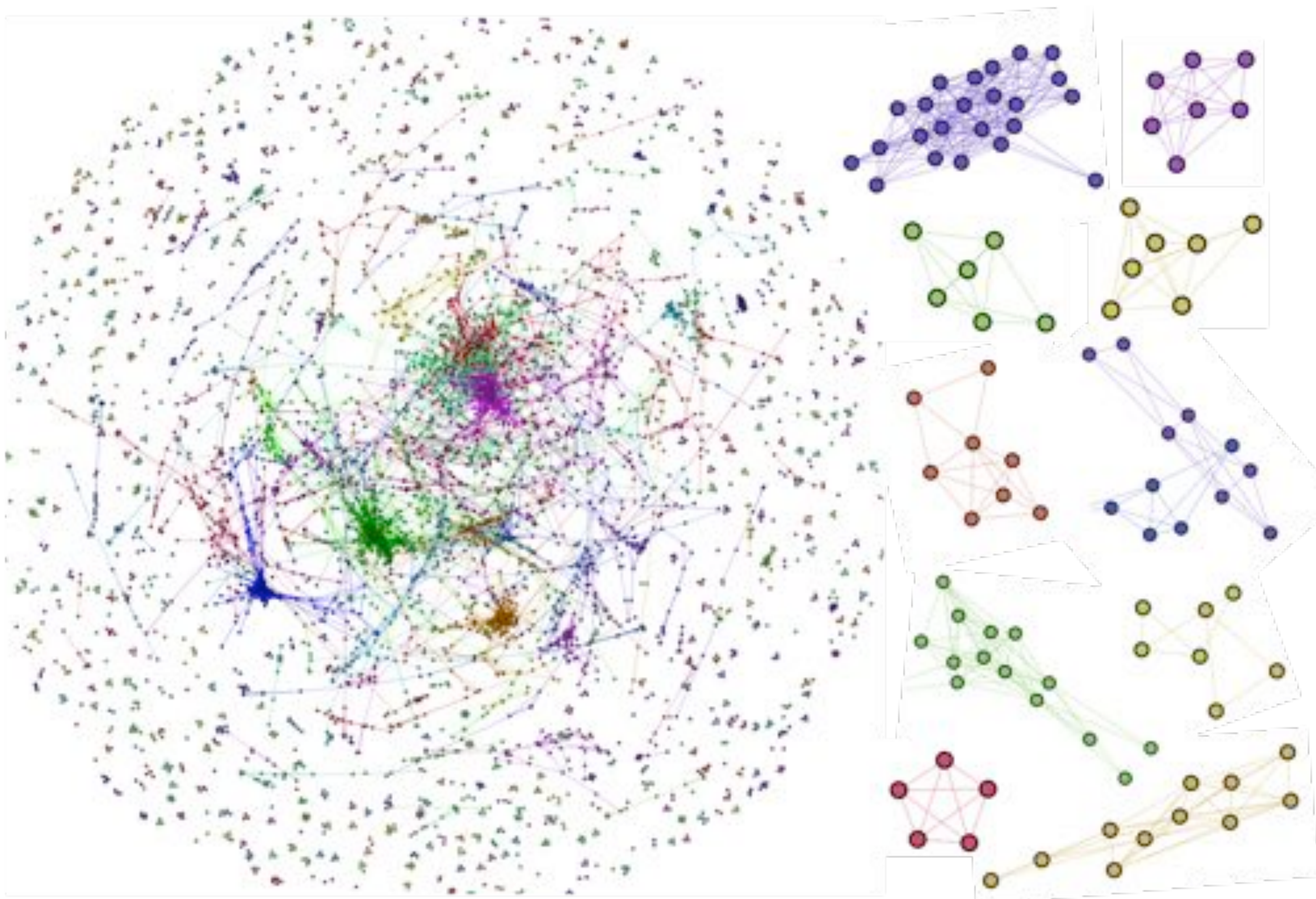


Text/document classification

Term Frequency Inverse Document Frequency (TF-IDF)

Proposed Approach: Feature Extraction

Vocabulary Extraction → Term-frequency Feature Extraction → Feature Normalization



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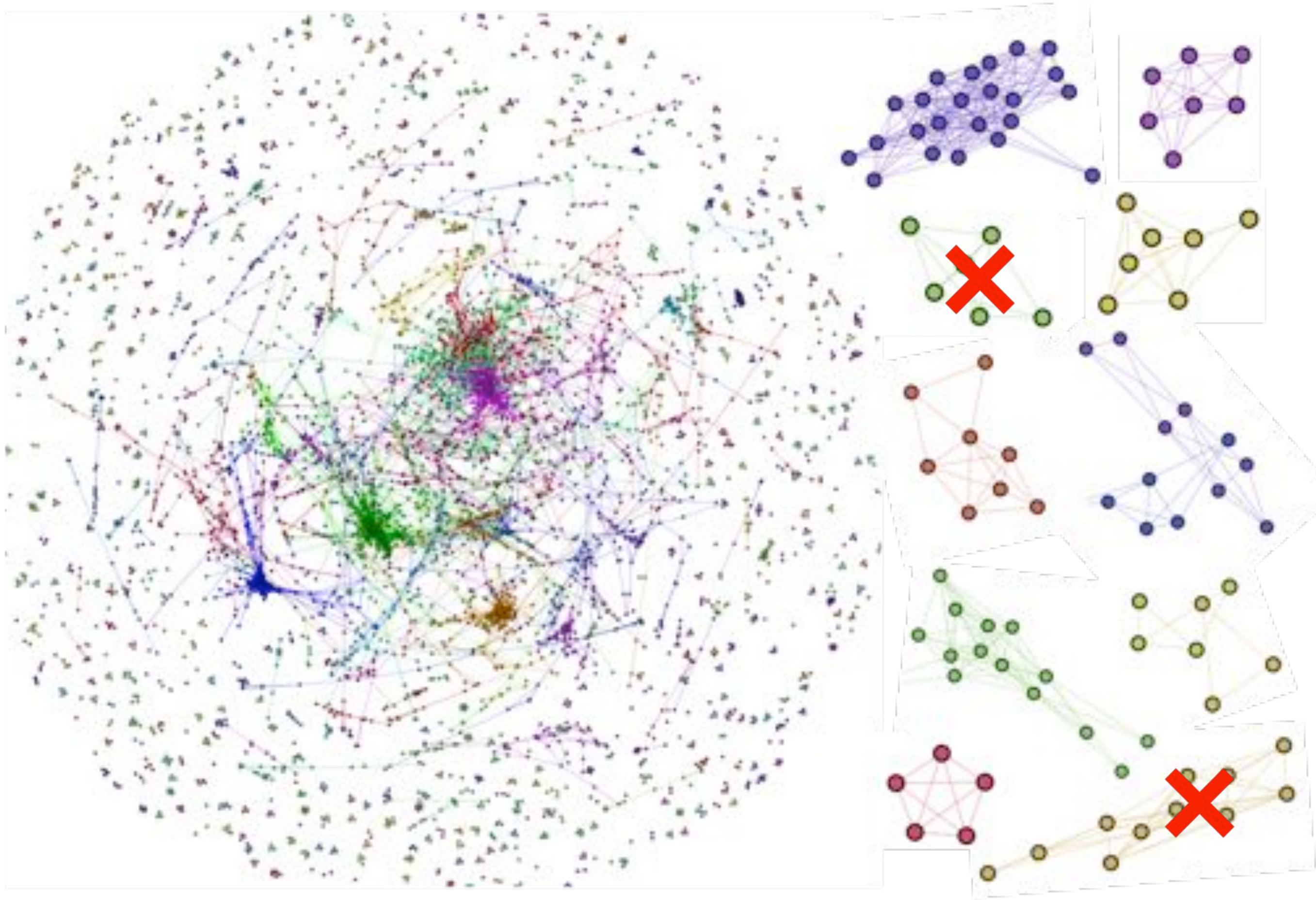

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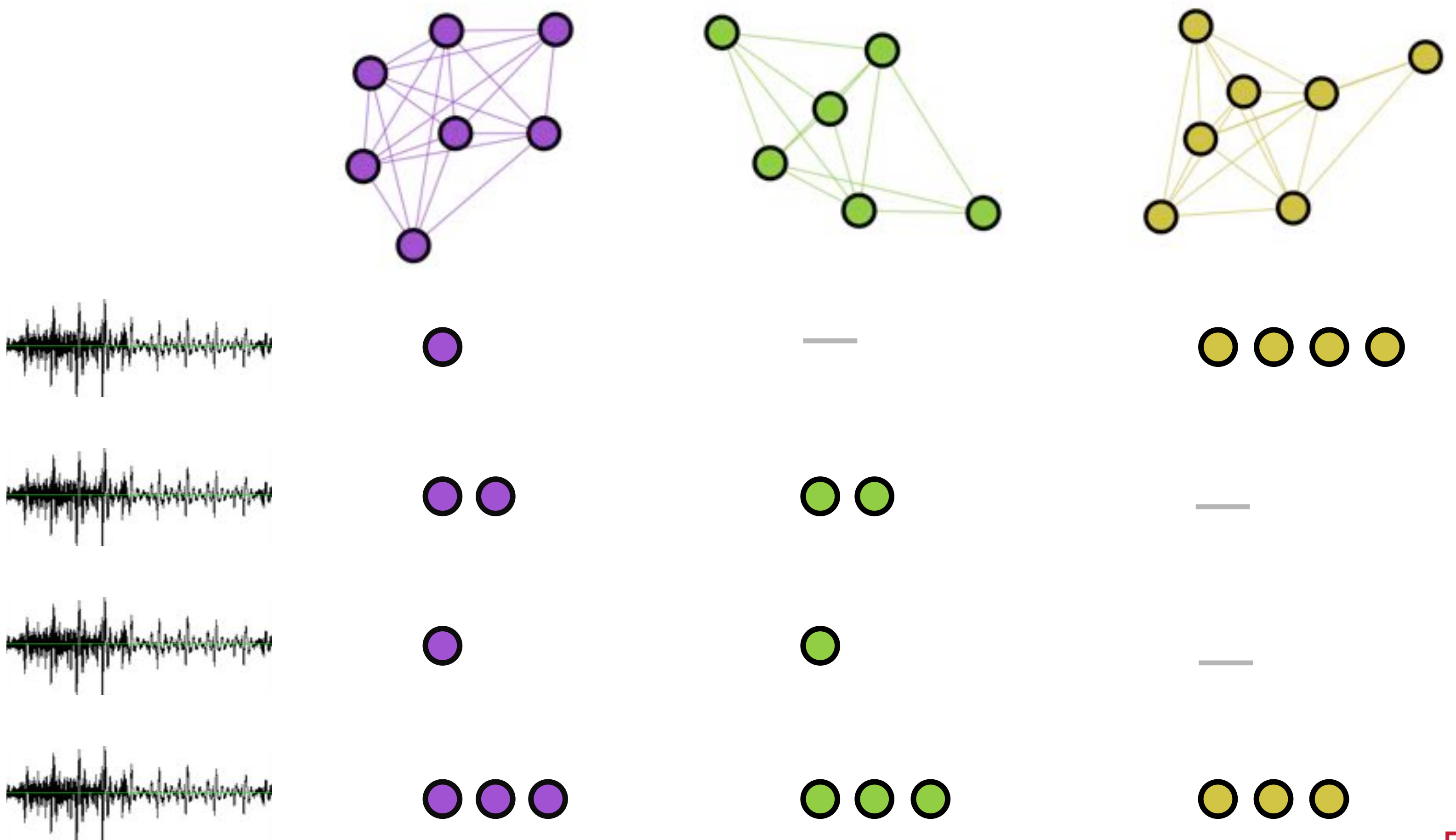

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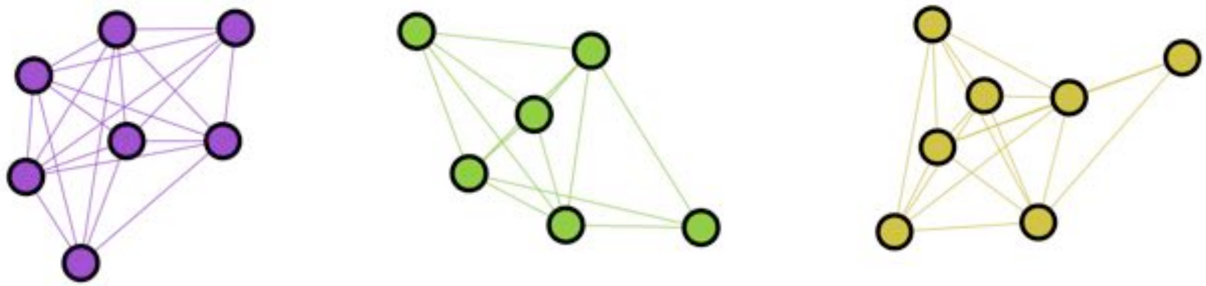

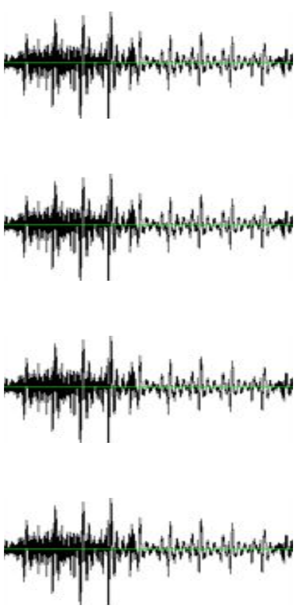

1	0	4
2	2	0
1	1	0
3	3	3

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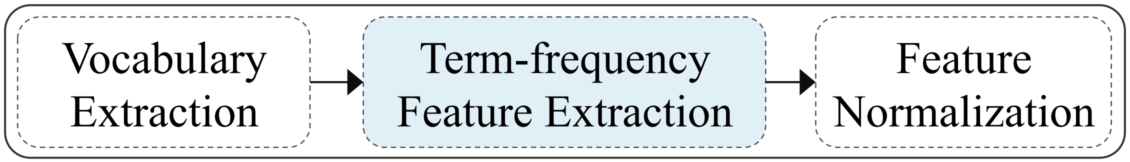
Proposed Approach: Feature Extraction



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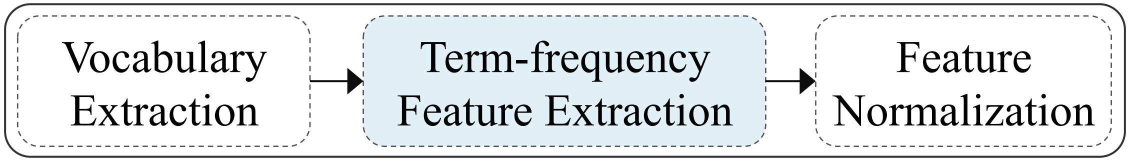
Vocabulary Extraction → Term-frequency Feature Extraction → Feature Normalization

$$F_1(p, r) = \begin{cases} 1, & \text{if} \quad f(p, r) > 0 \\ 0, & \text{otherwise} \end{cases}$$

Proposed Approach: Feature Extraction



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- $$F_2(p, r) = f(p, r)$$

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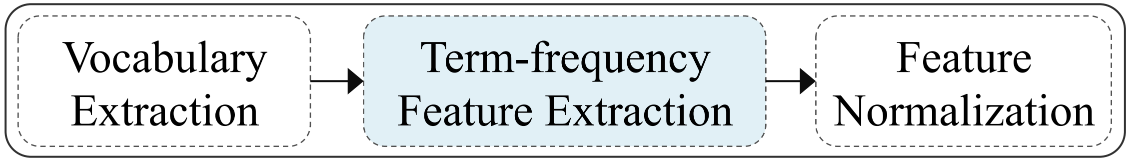

- $$\mathrm{F}_1(p, r) = \begin{cases} 1, & \text{if} \quad f(p, r) > 0 \\ 0, & \text{otherwise} \end{cases}$$

- $$\mathrm{F}_2(p, r) = f(p, r)$$

- $$\mathrm{F}_3(p, r) = f(p, r) \times \mathrm{irf}(p, R)$$

$$\mathrm{irf}(p, R) = \log\left(\frac{N}{|\{r \in R : p \in r\}|}\right)$$

Evaluation: Music Collection

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- Corpus: CompMusic Carnatic music
  - Commercial released music (~325) CDs
  - Metadata available in Musicbrainz

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- Datasets: subsets of corpus
  - DB40rāga
    - 480 audio recordings, 124 hours of music
    - 40 diverse set of rāgas
    - 310 compositions, 62 unique artists
  - DB10rāga
    - 10 rāga subset of DB40rāga

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MusicBrainz

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MusicBrainz

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Evaluation: Classification methodology

- Experimental setup
  - Stratified 12-fold cross validation (balanced)
  - Repeat experiment 20 times
  - Evaluation measure: mean classification accuracy

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- Experimental setup
  - Stratified 12-fold cross validation (balanced)
  - Repeat experiment 20 times
  - Evaluation measure: mean classification accuracy
- Classifiers
  - Multinomial, Gaussian and Bernoulli naive Bayes (NBM, NBG and NBB)
  - SVM with a linear and RBF-kernel, and with a SGD learning (SVML, SVMR and SGD)
  - logistic regression (LR) and random forest (RF)

Evaluation: Classification methodology

- Statistical significance
  - Mann-Whitney U test ($p < 0.01$)
  - Multiple comparisons: Holm Bonferroni method

- H. B. Mann and D. R. Whitney, “On a test of whether one of two random variables is stochastically larger than the other,” The annals of mathematical statistics, vol. 18, no. 1, pp. 50–60, 1947.
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Evaluation: Classification methodology

- Statistical significance
  - Mann-Whitney U test ($p < 0.01$)
  - Multiple comparisons: Holm Bonferroni method
- Comparison with the state-of-the-art
  - S_1: Pitch-class-distribution (PCD)-based method (PCD_{120}, PCD_{full})
  - S_2: Parameterized (PCD)-based method (PCD_{param})

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Results

db	Mtd	Ftr	NBM	NBB	LR	SVML	1NN
DB10rāga	M	F_1	90.6	74	84.1	81.2	-
		F_2	**91.7**	73.8	84.8	81.2	-
		F_3	90.5	74.5	84.3	80.7	-
	S_1	PCD_{120}	-	-	-	-	82.2
		PCD_{full}	-	-	-	-	**89.5**
	S_2	PD_{param}	37.9	11.2	**70.1**	65.7	-
DB40rāga	M	F_1	69.6	61.3	55.9	54.6	-
		F_2	**69.6**	61.7	55.7	54.3	-
		F_3	69.5	61.5	55.9	54.5	-
	S_1	PCD_{120}	-	-	-	-	66.4
		PCD_{full}	-	-	-	-	**74.1**
	S_2	PD_{param}	20.8	2.6	**51.4**	44.2	-

Results

db	Mtd	Ftr	NBM	NBB	LR	SVML	1NN
DB10rāga	M	F_1	90.6	74	84.1	81.2	-
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		F_3	90.5	74.5	84.3	80.7	-
	S_1	PCD_{120}	-	-	-	-	82.2
		PCD_{full}	-	-	-	-	**89.5**
	S_2	PD_{param}	37.9	11.2	**70.1**	65.7	-
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		F_3	69.5	61.5	55.9	54.5	-
	S_1	PCD_{120}	-	-	-	-	66.4
		PCD_{full}	-	-	-	-	**74.1**
	S_2	PD_{param}	20.8	2.6	**51.4**	44.2	-

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		PCD_{full}	-	-	-	-	**74.1**
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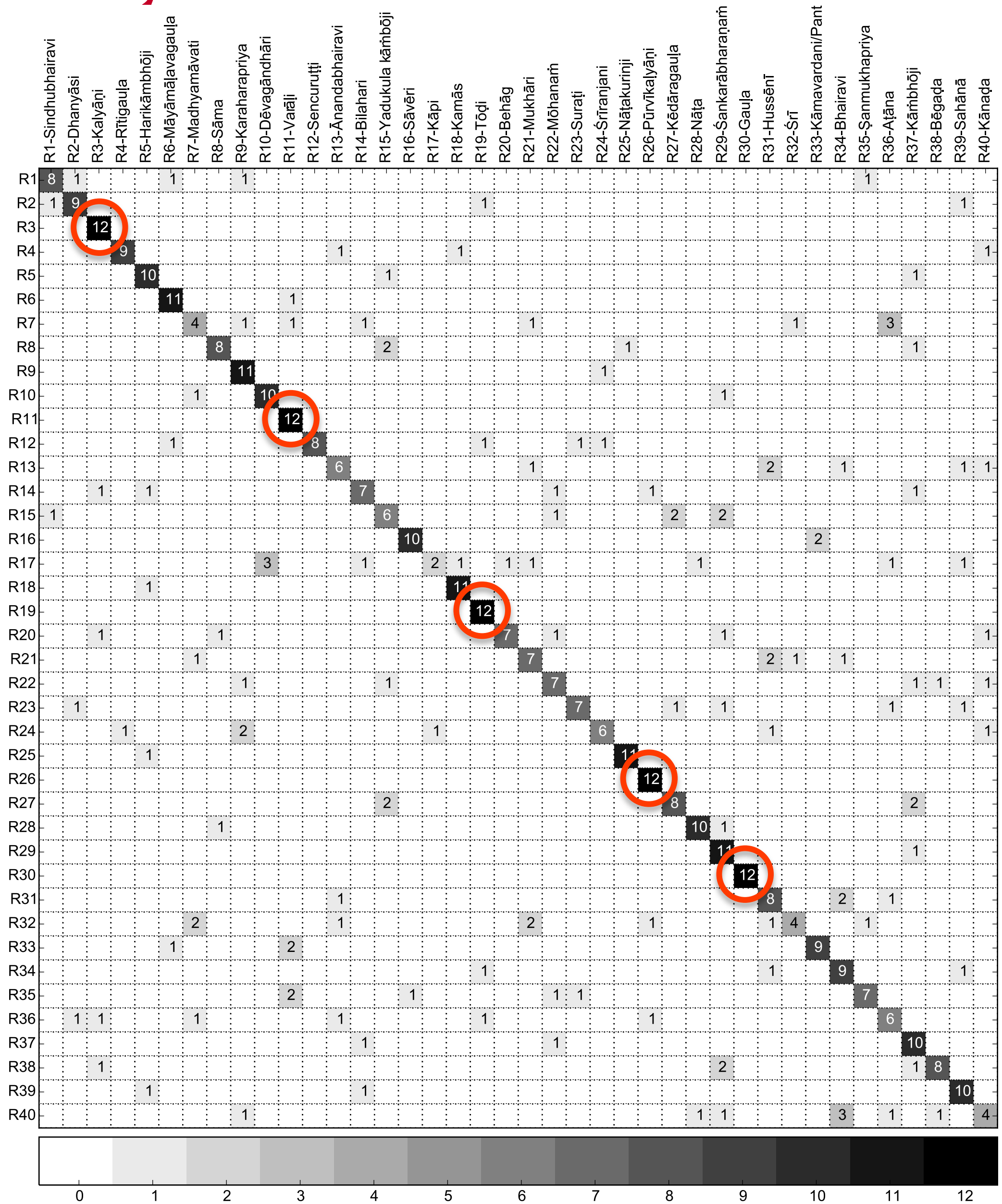
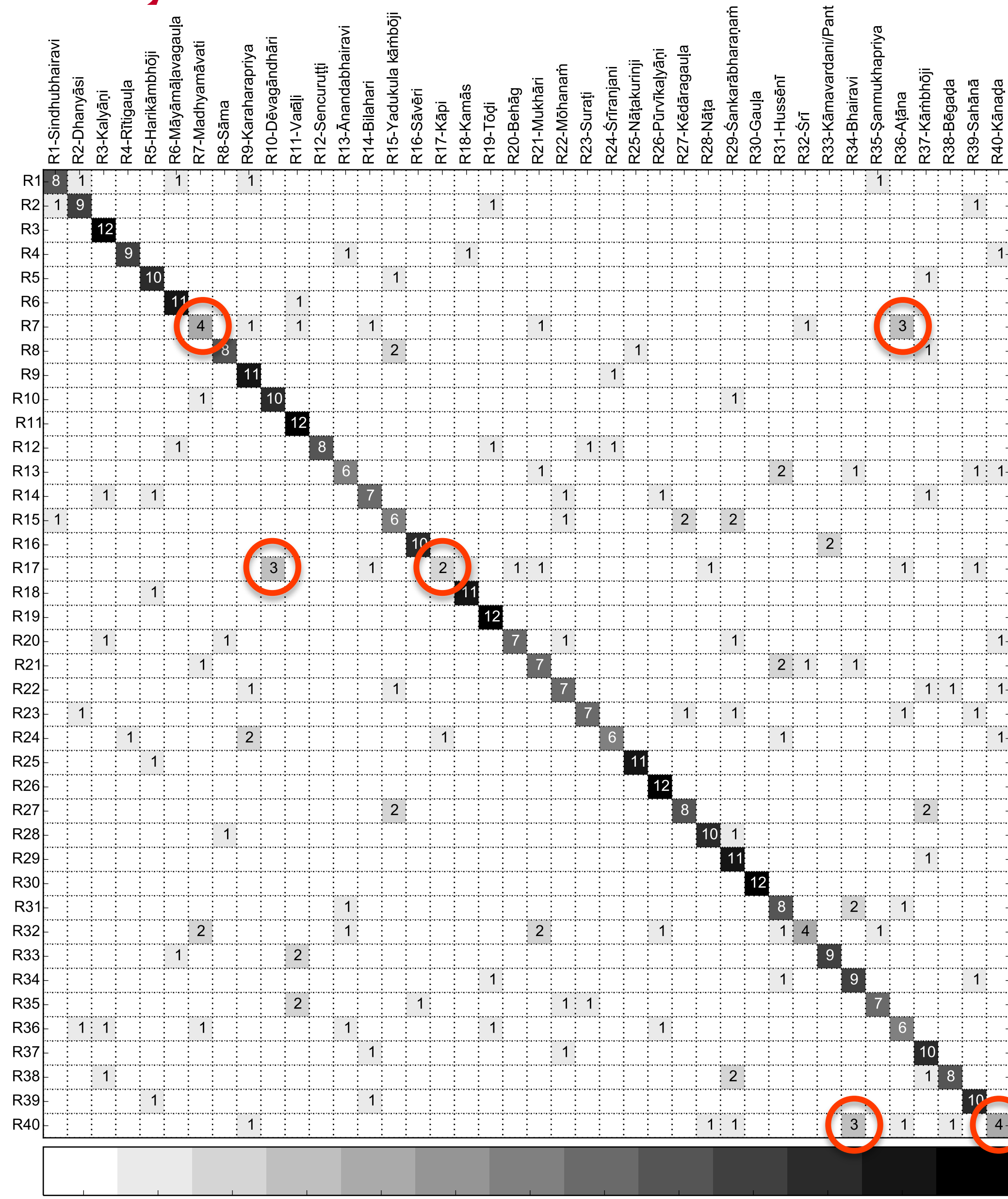
		PCD_{full}	-	-	-	-	**74.1**
	S_2	PD_{param}	20.8	2.6	**51.4**	44.2	-

Error Analysis



Kalyāṇi
Varāḷi
Tōḍi
Pūrvikalyāṇi

Error Analysis



Allied rāgas

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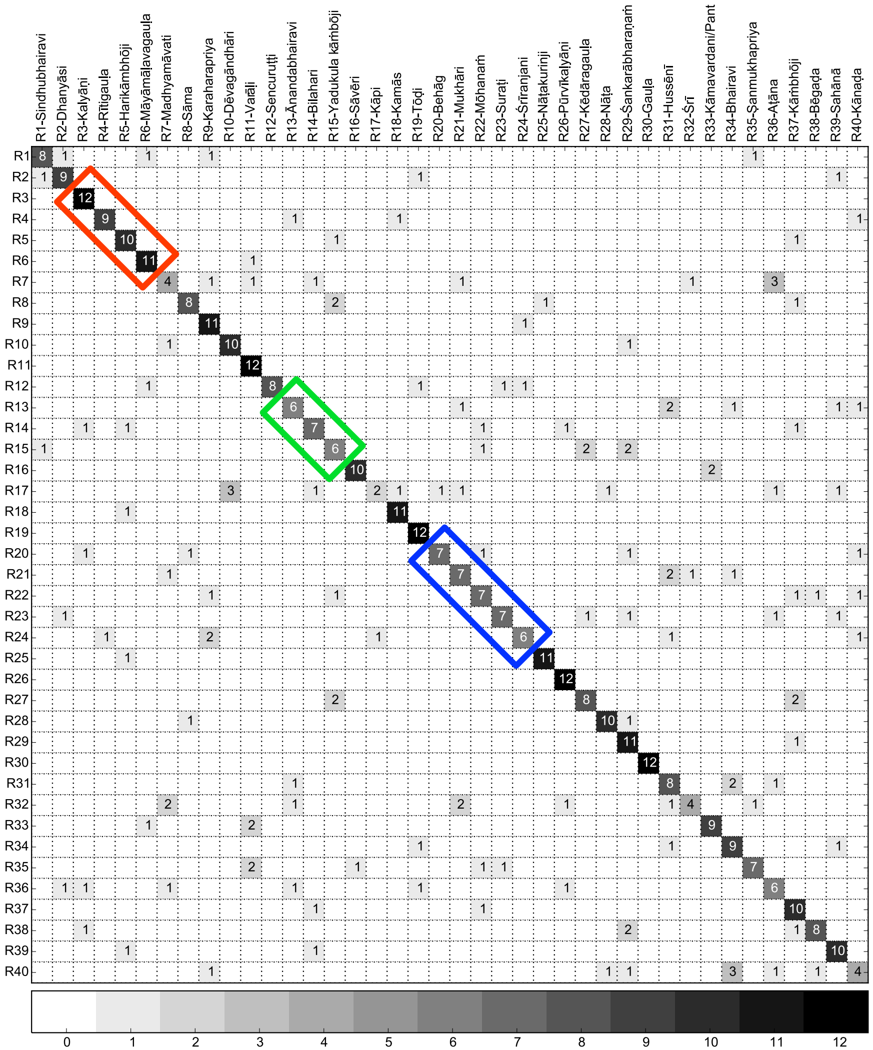
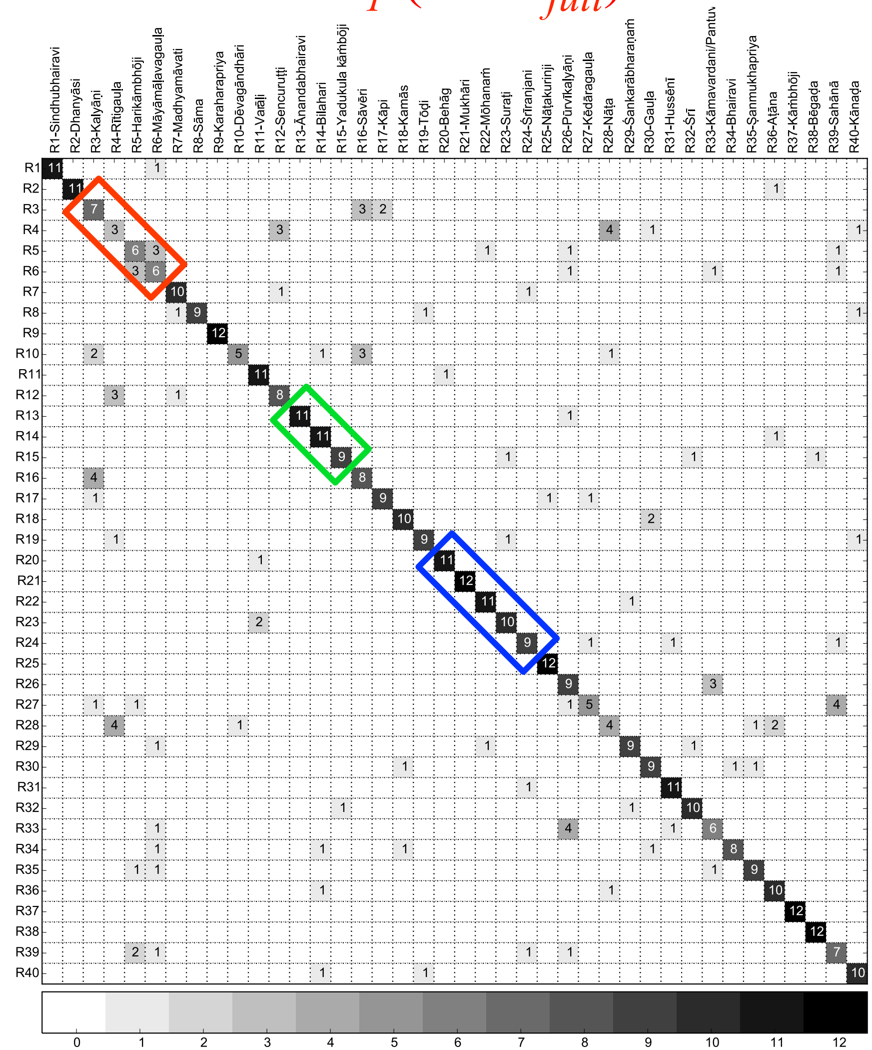
Error Analysis: complementary with S_1

M (F_1)



S_1 (PCD_{full})



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- Phrase-based rāga recognition using VSM is a successful strategy
- Mere presence/absence of melodic phrases enough to recognize rāga
- Multinomial Naive Bayes classifier outperforms the rest
- Topological properties of network - similarity threshold
- Complementary errors in prediction compared to PCD-based methods (Future Work)

Resources

- Rāga dataset:
  - http://compmusic.upf.edu/node/278
- Demo:
  - http://dunya.compmusic.upf.edu/pattern_network/
- CompMusic:
  - http://compmusic.upf.edu/
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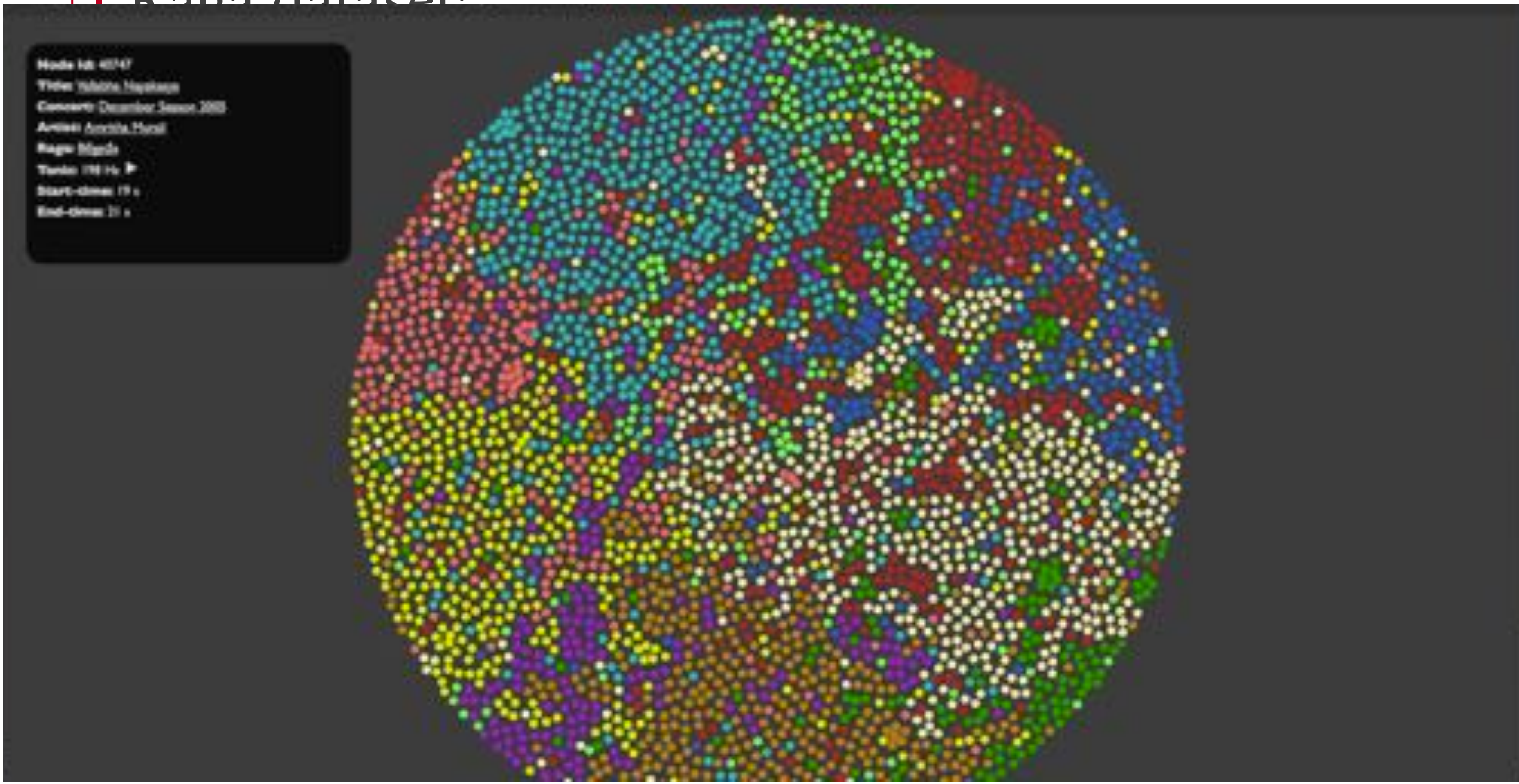

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Phrase-based Rāga Recognition using Vector Space Modeling

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