Supplementary Material accompanying TISMIR submitted paper titled “Identifying Melodic Motifs and Stable Notes from Gestural Information in Indian Vocal Performances”

This document contains extra figures and tables as well as illustrative snippets of the videos from our dataset, all organised by the section number they correspond to in the main paper.

Contents

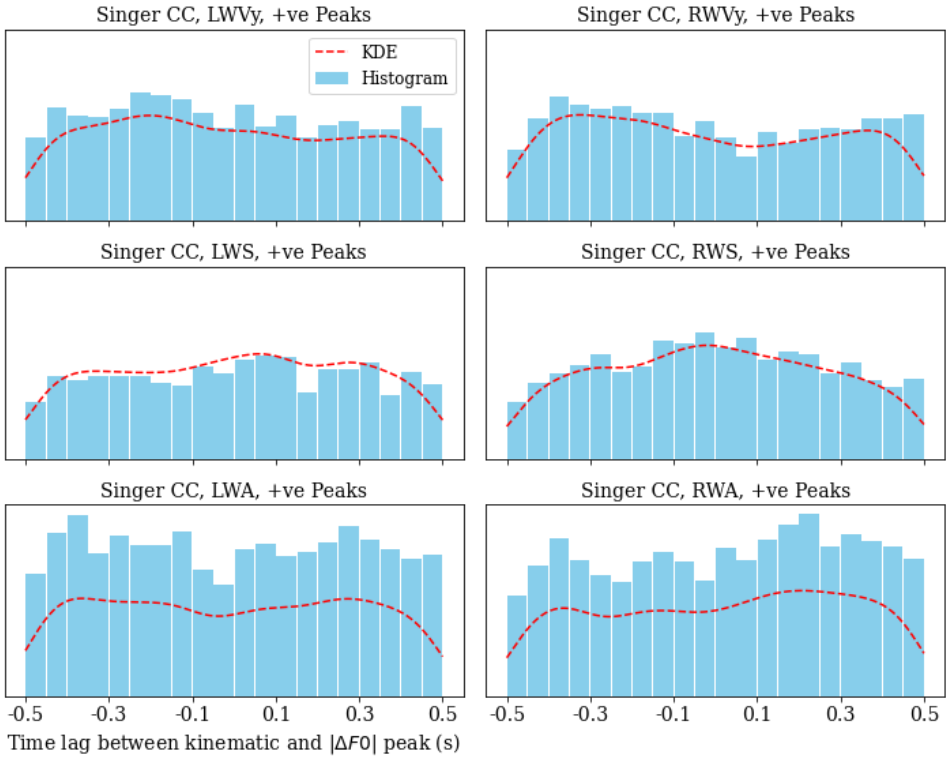
Section 4S: Relating F0 with Kinematic Changes

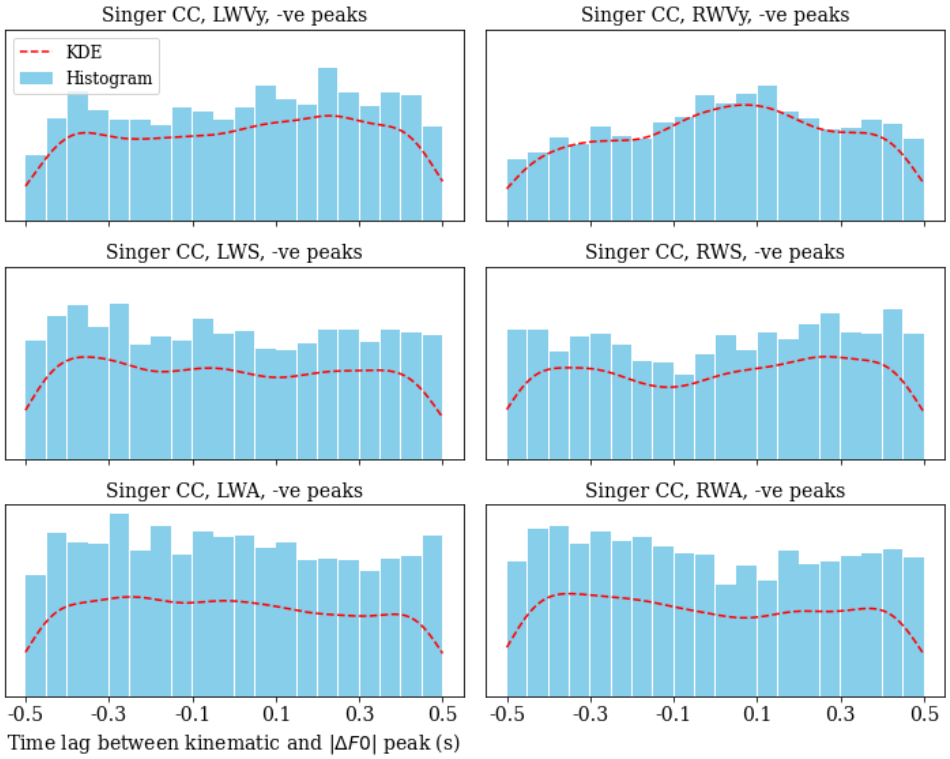
4S.2 Temporal Coupling Study

The following figures present distributions for the time offset values (in seconds) observed between kinematic peaks and corresponding |ΔF0| peaks, within the 1s windows centered at kinematic peaks. The plots are provided for singers AG and CC since they show the highest values for magnitude coupling in the main paper's Table 2.

Negative time lags indicate the |ΔF0| peak leading the kinematic peak, while positive lags indicate the |ΔF0| peak lagging the kinematic peak. Positive and negative kinematic peaks are studied separately for each of height (Vy), and acceleration; peaks and valleys are separated for speed parameter. We observe a nearly uniform distribution in every case indicating the absence of a consistent lag or lead.

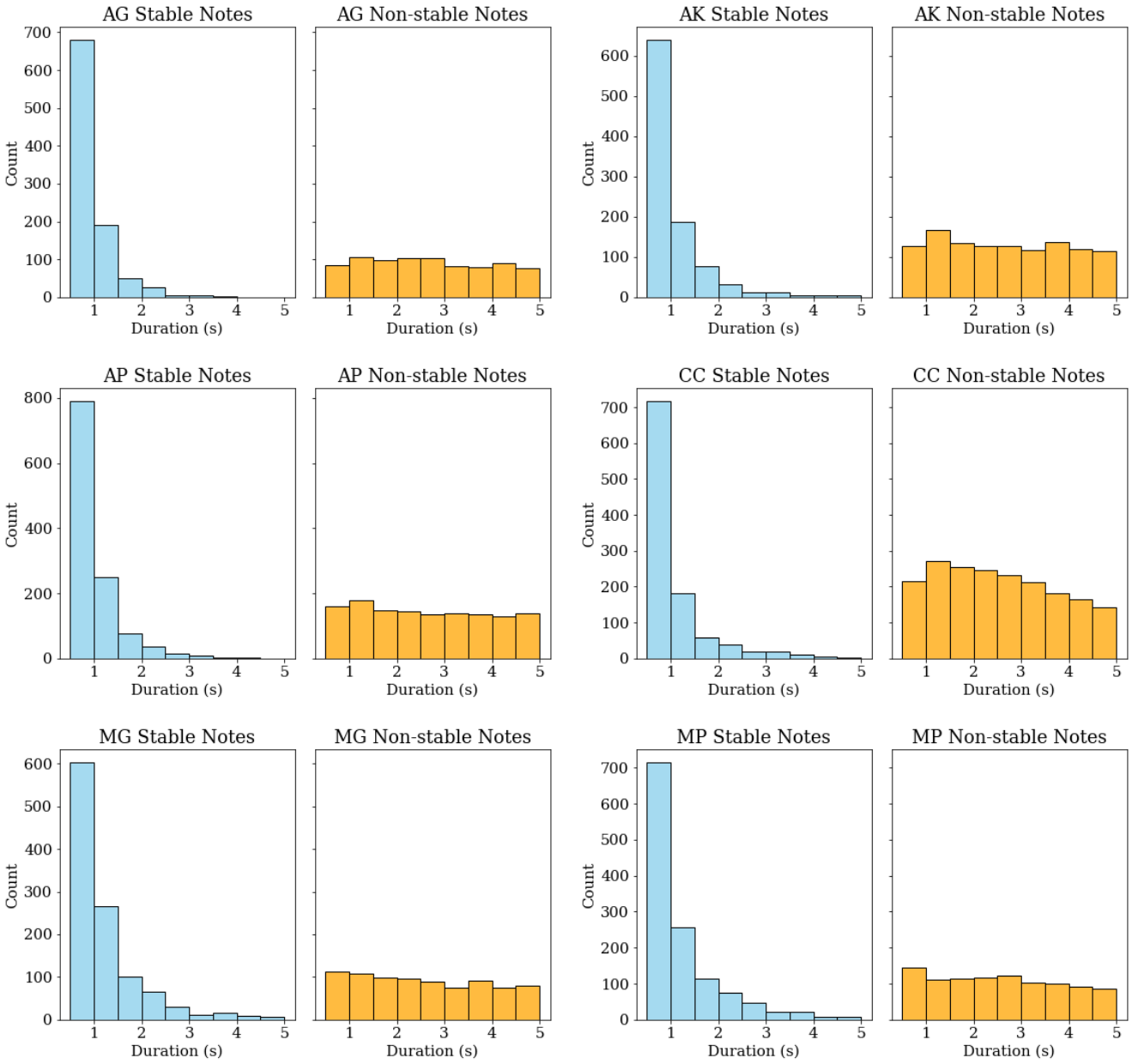

Singer AG, LWVy, +ve Peaks
KDE
Histogram
Singer AG, RWVy, +ve Peaks
Singer AG, LWS, +ve Peaks
Singer AG, RWS, +ve Peaks
Singer AG, LWA, +ve Peaks
Singer AG, RWA, +ve Peaks
-0.5 -0.3 -0.1 0.1 0.3 0.5
Time lag between kinematic and |ΔF0| peak (s)
Singer AG, LWVy, -ve Peaks
KDE
Histogram
Singer AG, RWVy, -ve Peaks
Singer AG, LWS, -ve Peaks
Singer AG, RWS, -ve Peaks
Singer AG, LWA, -ve Peaks
Singer AG, RWA, -ve Peaks
-0.5 -0.3 -0.1 0.1 0.3 0.5
Time lag between kinematic and |ΔF0| peak (s)

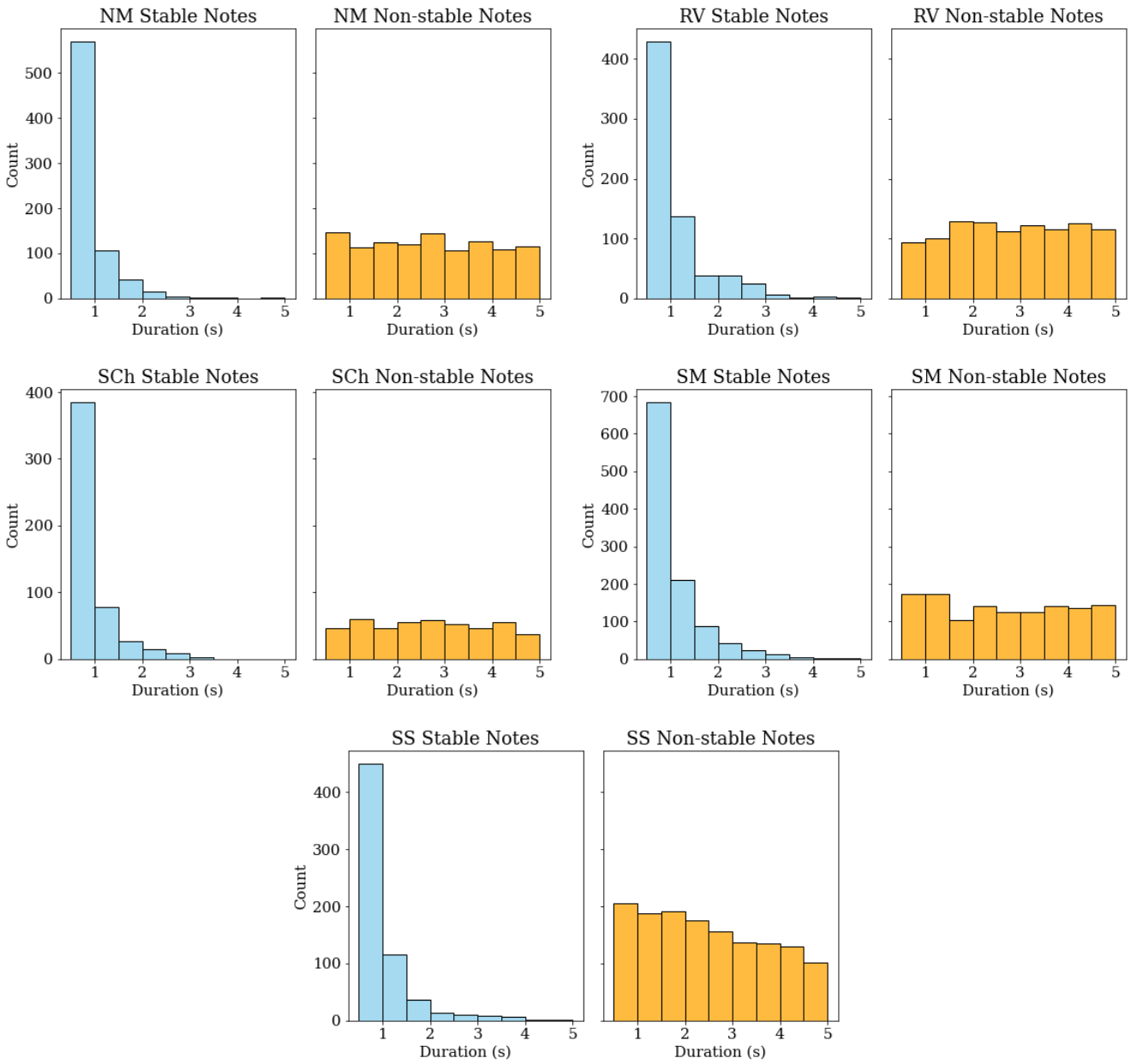

Singer CC, LWVy, +ve Peaks
KDE
Histogram
Singer CC, RWVy, +ve Peaks
Singer CC, LWS, +ve Peaks
Singer CC, RWS, +ve Peaks
Singer CC, LWA, +ve Peaks
Singer CC, RWA, +ve Peaks
-0.5
-0.3
-0.1
0.1
0.3
0.5
Time lag between kinematic and |ΔF0| peak (s)


Singer CC, LWVy, -ve peaks
KDE
Histogram
Singer CC, RWVy, -ve peaks
Singer CC, LWS, -ve peaks
Singer CC, RWS, -ve peaks
Singer CC, LWA, -ve peaks
Singer CC, RWA, -ve peaks
-0.5
-0.3
-0.1
0.1
0.3
0.5
Time lag between kinematic and |ΔF0| peak (s)

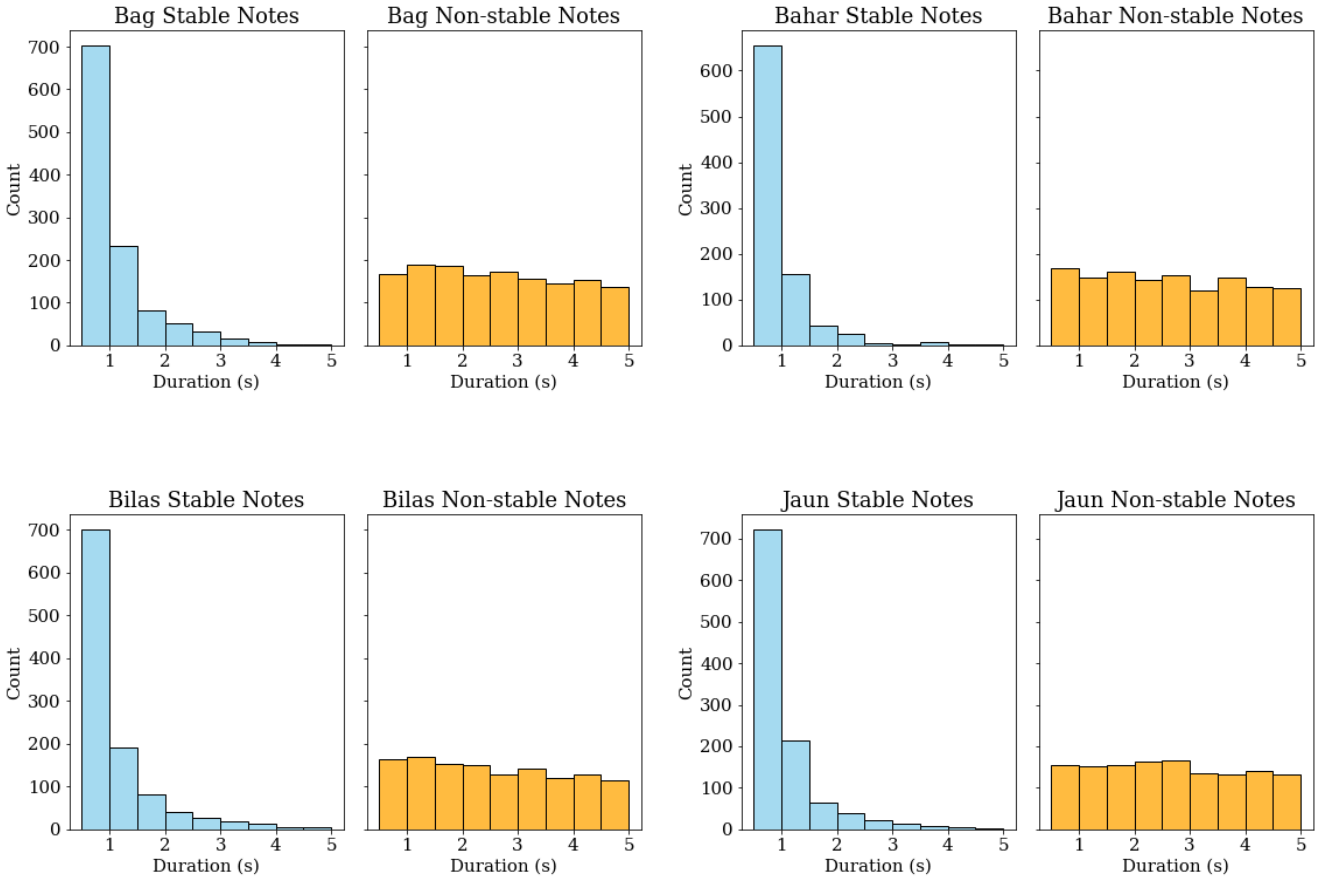
Section 5S: F0 segmentation methods

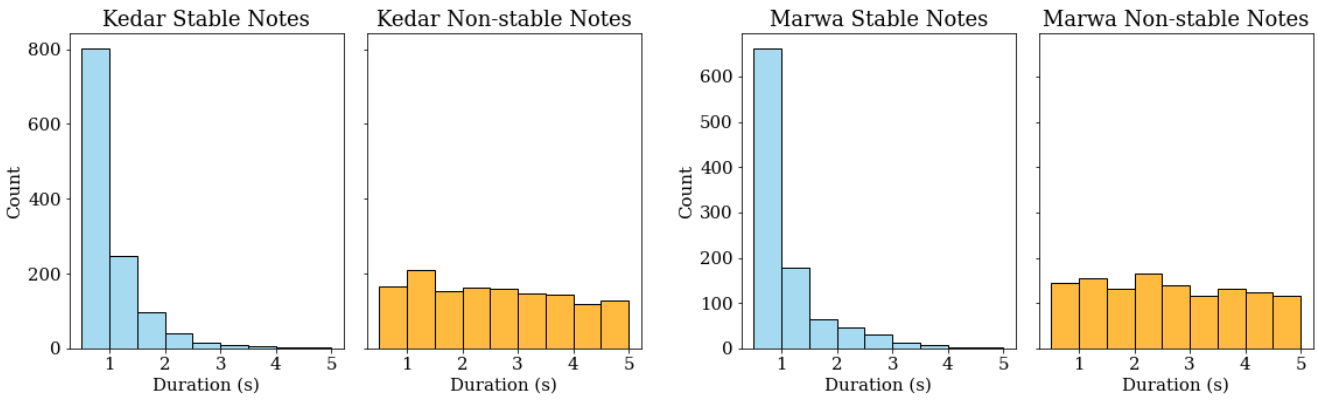
5S.1: Singerwise distribution of stable note and non-stable segment durations across ragas. All singers follow the trend of a distribution that is skewed towards lower durations for stable note segments.



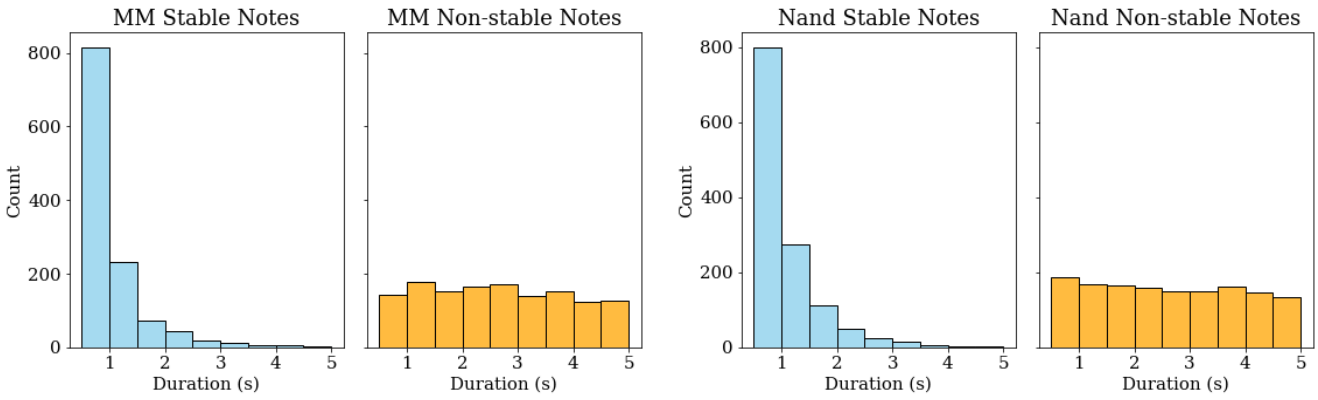

NM Stable Notes
NM Non-stable Notes
RV Stable Notes
RV Non-stable Notes
SCh Stable Notes
SCh Non-stable Notes
SM Stable Notes
SM Non-stable Notes
SS Stable Notes
SS Non-stable Notes
Count
Duration (s)

5S.2: Ragawise distribution of stable note and non-stable segment durations across singers. All ragas follow the trend of a distribution that is skewed towards lower durations for stable note segments.

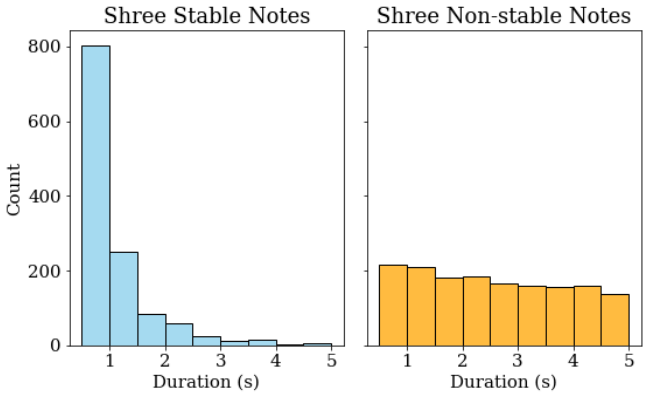



Kedar Stable Notes
Kedar Non-stable Notes
Count
Duration (s)

Marwa Stable Notes
Marwa Non-stable Notes
Count
Duration (s)

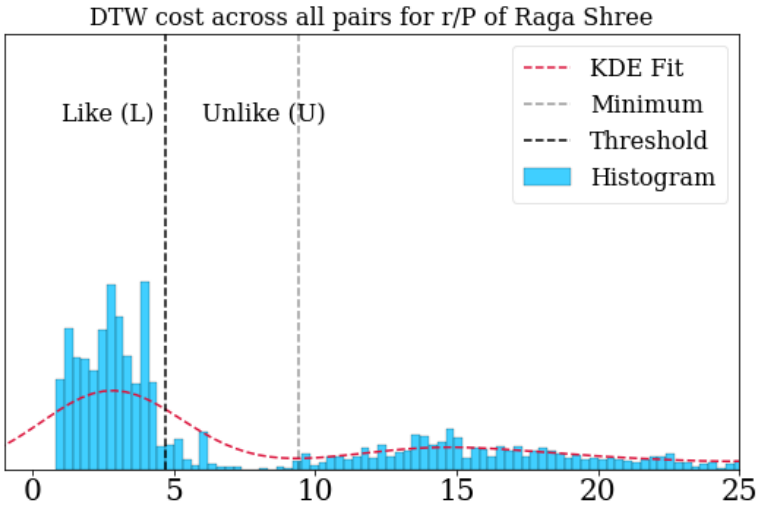

MM Stable Notes
MM Non-stable Notes
Count
Duration (s)

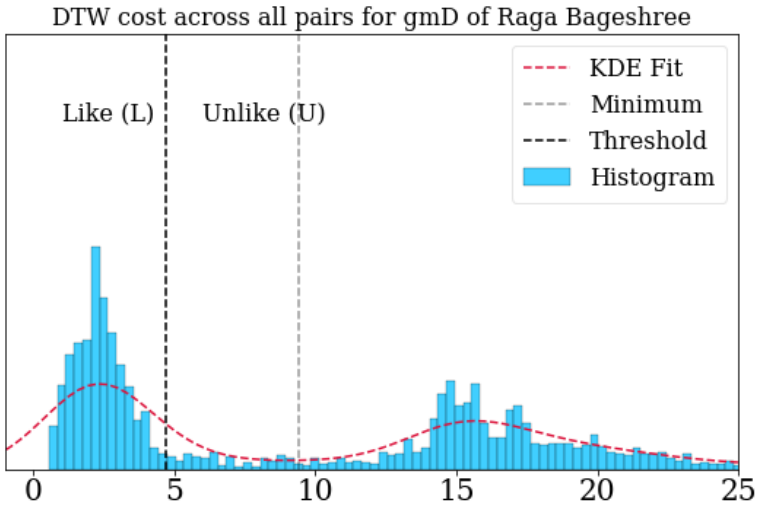
Nand Stable Notes
Nand Non-stable Notes
Count
Duration (s)

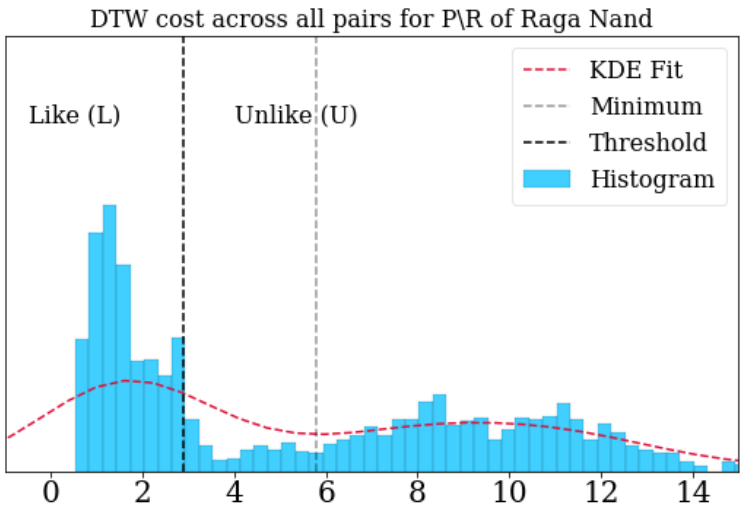

Shree Stable Notes
Shree Non-stable Notes
Count
Duration (s)

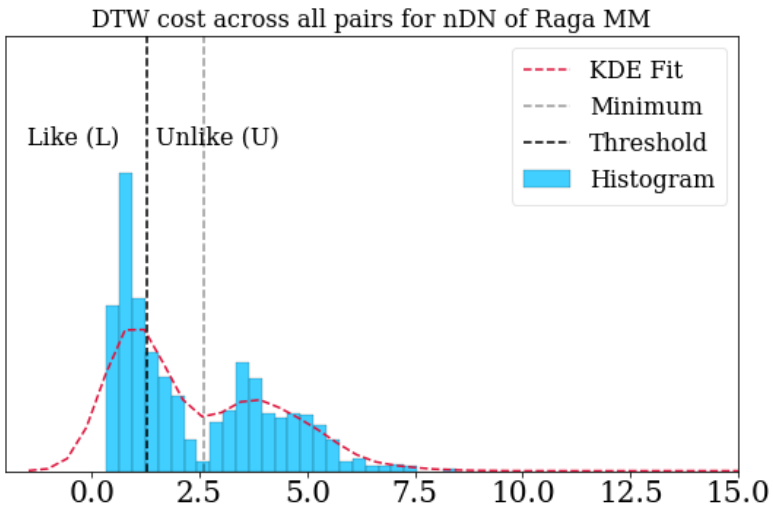
5S.3 Histograms and KDE Plots for each raga phrase

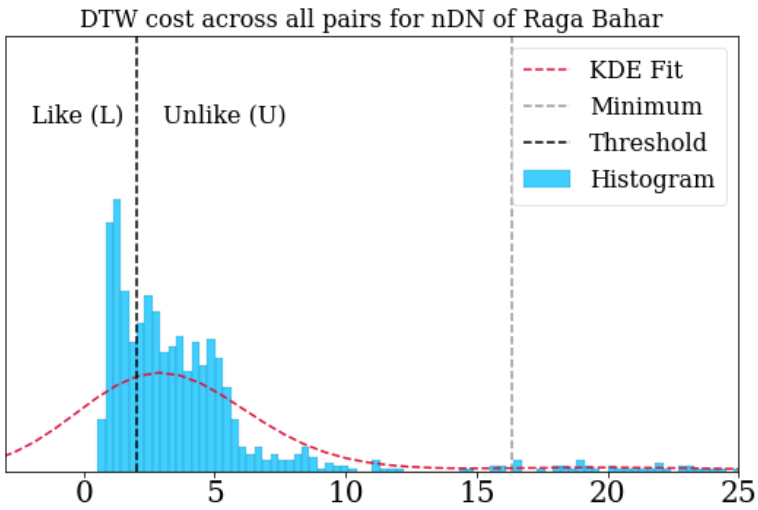
The following plots show the histogram for the DTW cost obtained from the audio-based subsequence alignment. (Figure 9 of the paper shows the distribution computed for the raga Nand P\R phrase.) The KDE fit is superposed on each distribution. The KDE is bimodal and the threshold to label L and U is set at a half of DTW cost at the valley between the peaks in all cases. Only for nDN (Bahar), we do not get a bimodal distribution so the threshold is set manually at one-eighth the location of the minimum. This threshold ensures that the data is roughly balanced between Like and Unlike segments and that the like segments are indeed melodically similar to the pakad templates based on informal checks by an expert listener.






DTW cost across all pairs for P\R of Raga Nand
KDE Fit
Minimum
Threshold
Histogram
Like (L)
Unlike (U)
0
2
4
6
8
10
12
14


DTW cost across all pairs for nDN of Raga MM
KDE Fit
Minimum
Threshold
Histogram
Like (L)
Unlike (U)
0.0
2.5
5.0
7.5
10.0
12.5
15.0


DTW cost across all pairs for nDN of Raga Bahar
KDE Fit
Minimum
Threshold
Histogram
Like (L)
Unlike (U)
0
5
10
15
20
25

Section 7S: Gesture-Based Classification Experiments

7S.1 Stable Note: Example of Singer Meher Paralikar

Link to Video Folder

The video snippets illustrate the characterization of stable and non-stable notes using gestures. If hand movements correspond to the singer's gestures we would expect that stable notes would be accompanied by relatively stationary hands, and melodic movements by moving hands. These clips illustrate that as a generalisation, this is what we find. However, unsurprisingly perhaps this correspondence does not always hold, and we can observe moments when a steady pitch is accompanied by hand movements (e.g. Video-2_MP_Alap1_Shree_137s_157s, 4-5 secs). Also worth noting is the fact that in these cases the singer's left hand is held steady at abdomen, chest or shoulder height; his right hand, resting on his knee, is not involved in the gesture and does not help to distinguish stable notes. This may explain why Position information is useful in classifying Stable Notes.

Video-1: 20 s snippet from MP_Alap1_Bag (middle octave notes)

Video-2: 20 s snippet from MP_Alap1_Shree (higher octave notes)

7S.2 Stable Note: Snippets showing misclassified segments

Link to Video Folder

The video snippets show one case from either class that was misclassified by the SVM model. The first one shows a non-stable note classified as stable. Singer Sawani Shikhare (SS) moves her hands uniformly with very limited wrist motion, as a result of which the note is classified as stable. In the second snippet, we can see a stable note that is classified as non-stable, which may be because of the fact that there is some motion of the hands even when the note is stable. This is quite a common phenomenon in Hindustani vocal music: the singer holds a stable note while continuing to move the hand, as if signifying that the stable note is being stretched out.

Video-1: Non-stable note classified as stable (from SS_Alap1_Shree)

Video-2: Stable note classified as non-stable (from SS_Alap1_Shree)

7S.3 Raga Phrase Detection Experiment

7S.3.1 Phrase r/P from Raga Shree

Link to Video Folder

The videos show some examples of phrase r/P from singers Apoorva Gokhale (AG) and Sudokshina Chatterjee (SCh). We see a similarity in the gesturing style wherein the right wrist is involved in an upward motion during the glide.

We also see two instances of r/P by CC where the realisations differ significantly in the speed of rendering but display considerable similarity in the form of the hand movement.

The use of such hand-raising gestures to accompany this melodic movement, and the ways in which it is linked to the meanings ascribed to the raga, are discussed in detail in Leante (2009).

7S.3.2 Phrase nDN from Raga Bahar

Link to Video Folder

The videos show the phrase nDN from raga Bahar sung by singer Nishad Matange (NM). The first one is a pakad template while the next one is an alap instance. The gestures seem to be different in the two cases, which might be the reason for low performance in phrase nDN. The gestures have something in common - a high degree of mobility and an oscillatory movement from n down to D, then back up to N - but the movements occur in a different plane and with different hand positions, presumably making it difficult for a classifier to pick up the similarity.

7S.3.3 Phrase gmD from Raga Bageshree

Link to Video Folder

The examples from the pakad (query templates) show some variability: for AK and AG there is a clear gestural analogue to the rising pitch, SCh shows more lateral movement (out, to right of screen), and SM's movement is much more limited. Two examples from AG's alap evidence the same feature seen in her pakad: recognition of this motif was in fact particularly good for this singer. (Both the singing and the hand movement seem to be more fluent in the alap version, where the middle note Ma is not clearly articulated, but there is enough similarity to allow successful detection.)

7S3.4 Prase P\R from Raga Nand

Link to Video Folder

This falling motif demonstrates the fact that we cannot expect consistent pitch height to hand height correlations, even in this dataset where gestures are assumed to refer to melody rather than rhythm or inter-performer communication. The clip of MP shows one possible gesture, in which the focus seems to shift from the singer's right hand to his left, the latter occupying a slightly lower spatial position. We have two examples from CC. One of these (56.5 - 59 s) is a near prototypical downward movement with the right hand falling while also moving inward. The other CC example, in contrast, illustrates a manual gesture which actually *rises* while the pitch falls. A possible interpretation of the latter case is that following a large fall from the 5th to the 2nd degree of the scale, the raised hand is marking the melody's resistance to a further fall to the tonic Sa, although this is only conjecture. What is clear is that singing-accompanying gesture is complex and multidimensional. Gestures accompanying this P\R motif seem to be more varied than those accompanying the Shree r/P described above, accounting for the lower detection accuracy.

7S.4 Results for Singer-specific Gesture based phrase detection

In the following tables, we report the F1-scores after stratified 10-fold cross-validation for the raga-phrase detection framework for each phrase. Bold values indicate results that are statistically significant when compared to a chance classifier which predicts 'Like' with probability equal to the percentage of like segments ($p < 0.05$). In some of the cases, the singer did not sing the particular phrase in the pakad, or the alap instances were too few in number (less than 15 in total). In such cases, the singer's data was not considered in the experiment and the tables contain a blank '-' for them. Also, for ragas MM and Bahar, the overall number of segments was low because of which we decided to do a 3-fold cross validation rather than a 10-fold cross validation, since the implementation requires at least 1 example from each class in the testing data in every fold.

Raga Shree, Phrase r/P

	AG	**AK**	**AP**	**CC**	**MG**	**MP**	**NM**	**RV**	**SCh**	**SM**	**SS**
Count	31	38	41	52	28	27	30	47	36	36	49
% Like	71	57.9	43.9	30.8	50	48.1	56.7	61.7	38.9	61.1	42.9
DTW-D (1)	83	71.2	0	11.8	80.0	48.3	74.4	**76.3**	81.5	75.9	0
DTW-I (1)	88.	73.3	0	40.0	59.3	23.5	73.7	**76.3**	63.6	75.9	0
DTW-LR (2)	76	71.2	48	43.5	76.9	43.5	72.2	**76.3**	**92.3**	75	58.8
DTW-Ind (36)	81	**78.0**	**77.8**	**85**	**82.8**	**69.6**	**82.4**	74.6	85.7	74.4	**66.7**
DTW-Ind-W (18)	**87.0**	60.5	**77.8**	78.6	75.9	64	74.3	73.3	89.7	**78.3**	42.9

Raga Bageshree, Phrase gmD

	AG	**AK**	**AP**	**CC**	**MG**	**MP**	**NM**	**RV**	**SCh**	**SM**	**SS**
Count	30	28	34	35	19	23	28	32	24	36	42
% Like	60	60.7	47.1	31.4	68.4	60.8	46.4	56.3	58.3	50	57.1
DTW-D (1)	**87.2**	**77.3**	0	28.6	86.7	75.7	0	61.9	73.7	58.3	**72.7**
DTW-I (1)	75	75.6	0	26.7	77.4	75.7	0	**68.1**	73.7	41.2	**72.7**
DTW-LR (2)	**87.2**	76.2	55.2	60	77.4	70.6	34.8	**68.1**	**81.3**	62.5	70.8
DTW-Ind (36)	**87.2**	64.7	71.0	60.9	**88.9**	**83.9**	**72**	64.7	71.4	**73.7**	64
DTW-Ind-W (18)	78.9	60.6	**74.1**	**66.7**	84.6	78.6	60.9	66.7	72.2	66.7	65.3

Raga Nand, Phrase P\R

R	**AG**	**AK**	**AP**	**CC**	**MG**	**MP**	**NM**	**RV**	**SCh**	**SM**	**SS**

P\R Count	23	33	22	27	25	21	35	37	-	32	40
P\R % Like	78.3	42.4	40.9	25.9	48	47.6	42.8	43.2	-	53.1	42.5
P\R DTW-D (1)	**87.8**	0	0	54.5	14.3	**62.5**	0	0	-	69.4	9.5
P\R DTW-I (1)	**87.8**	0	46.2	61.5	37.5	16.7	47.6	64	-	72.3	0
P\R DTW-LR (2)	**87.8**	**66.7**	46.2	61.5	66.7	40	30	56	-	75.0	38.5
P\R DTW-Ind (36)	80	60	**55.6**	**72.7**	**72.7**	52.6	**64.5**	**66.7**	-	**80.0**	54.5
P\R DTW-Ind-W (18)	87.2	62.5	50	54.5	72	60	60	56.2	-	76.5	**60.6**

Raga MM, Phrase nDN (3-fold CV)

	AG	**AK**	**AP**	**CC**	**MG**	**MP**	**NM**	**RV**	**SCh**	**SM**	**SS**
nDN Count	19	16	-	16	-	-	18	-	-	-	21
nDN % Like	68.4	56.3	-	56.3	-	-	61.1	-	-	-	28.6
nDN DTW-D (1)	81.1	78.6	-	72.2	-	-	75.6	-	-	-	0
nDN DTW-I (1)	81.1	72.2	-	72.2	-	-	18	-	-	-	0
nDN DTW-LR (2)	73.3	**95.2**	-	86.9	-	-	69	-	-	-	48.9
nDN DTW-Ind (36)	89.6	77.8	-	64.1	-	-	76.7	-	-	-	13.3
nDN DTW-Ind (18)	90.7	84.1	-	82.1	-	-	78.6	-	-	-	26.7

Raga Bahar, Phrase nDN (3-fold CV)

	AG	**AK**	**AP**	**CC**	**MG**	**MP**	**NM**	**RV**	**SCh**	**SM**	**SS**
nDN Count	-	-	-	44	-	-	29	-	-	37	30
nDN %Like	-	-	-	38.6	-	-	62	-	-	56.8	36.7
nDN DTW-D (1)	-	-	-	61.8	-	-	75.1	-	-	71.7	11.1
nDN DTW-I (1)	-	-	-	25	-	-	75.5	-	-	71.7	52.4
nDN DTW-LR (2)	-	-	-	21.6	-	-	76.3	-	-	63.6	22.9
nDN DTW-Ind (36)	-	-	-	57.8	-	-	**81.1**	-	-	61	20.6
nDN DTW-Ind (18)	-	-	-	47	-	-	73.7	-	-	64.8	22.9