Tonic Identification System for Hindustani and Carnatic Music

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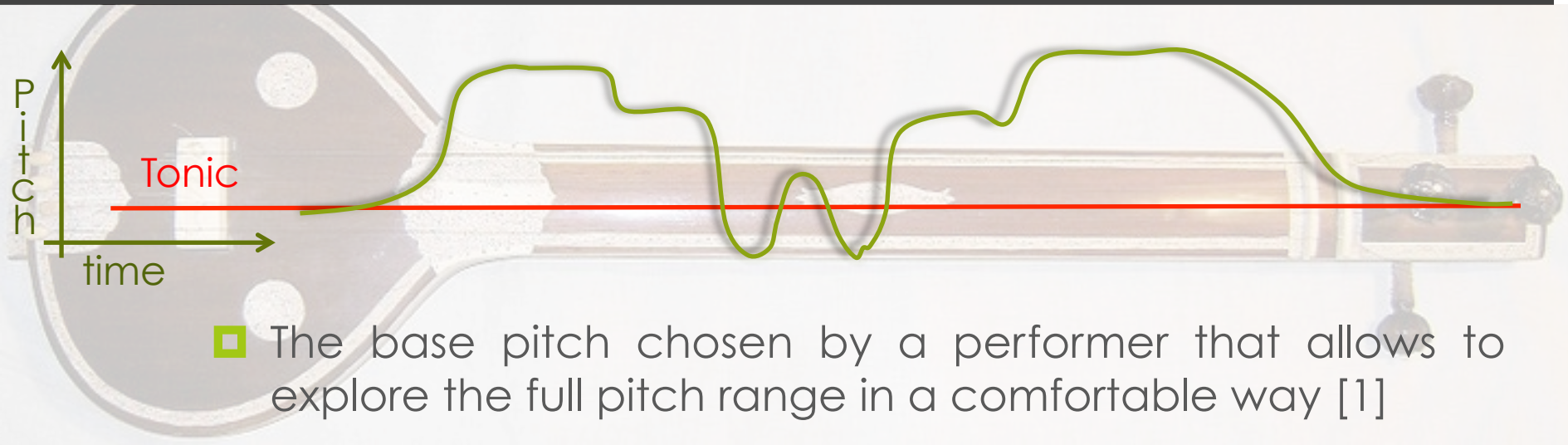
Introduction: Tonic in Indian art music



- The base pitch chosen by a performer that allows to explore the full pitch range in a comfortable way [1]
- Anchored as 'Sa' swar in a performance (mostly)
- All the other notes used in the raga exposition derive their meaning in relation to this pitch value
- All other accompanying instruments are tuned using this pitch as reference

Role of Drone Instrument

- Performer and audience needs to hear this pitch throughout the concert
- Reinforces the tonic and establishes all harmonic and melodic relationships

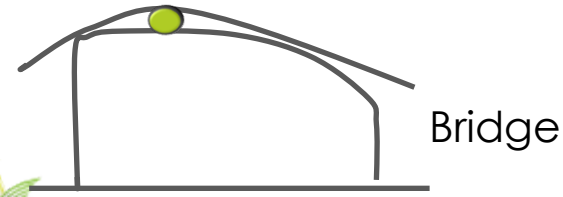
Sitar

Surpeti or Shrutibox

Electronic Tanpura

Tanpura

Introduction: Tonal structure of Tanpura



- Four strings
- Tunings
  - Sa-Sa'-Sa'-Pa
  - Sa-Sa'-Sa'-Ma
  - Sa-Sa'-Sa'-Ni
- Special bridge with thread inserted (Jvari)
  - Violate Helmholtz law [2]
- Rich overtones [1]

Introduction: Goals and Motivation

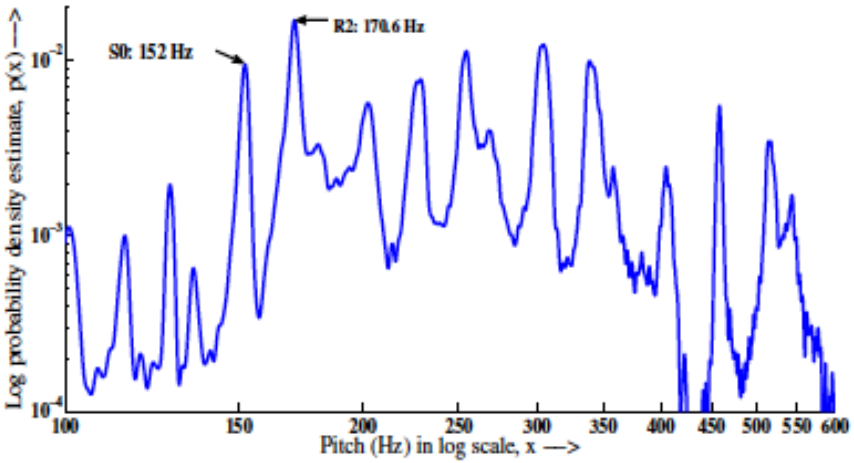
- Automatic labeling of the tonic in large databases of Indian art music
- Devise a system for identification of
  - Tonic pitch for vocal excerpts
  - Tonic pitch class profile for instrumental excerpts
- Use all the available data (audio + metadata) to achieve maximum accuracy
- Confidence measure for each output from the system

Introduction: Goals and Motivation

- Fundamental information
- Tonic identification: crucial input for:
  - Intonation analysis
  - Raga recognition
  - Melodic motivic analysis

Relevant work: Tonic Identification

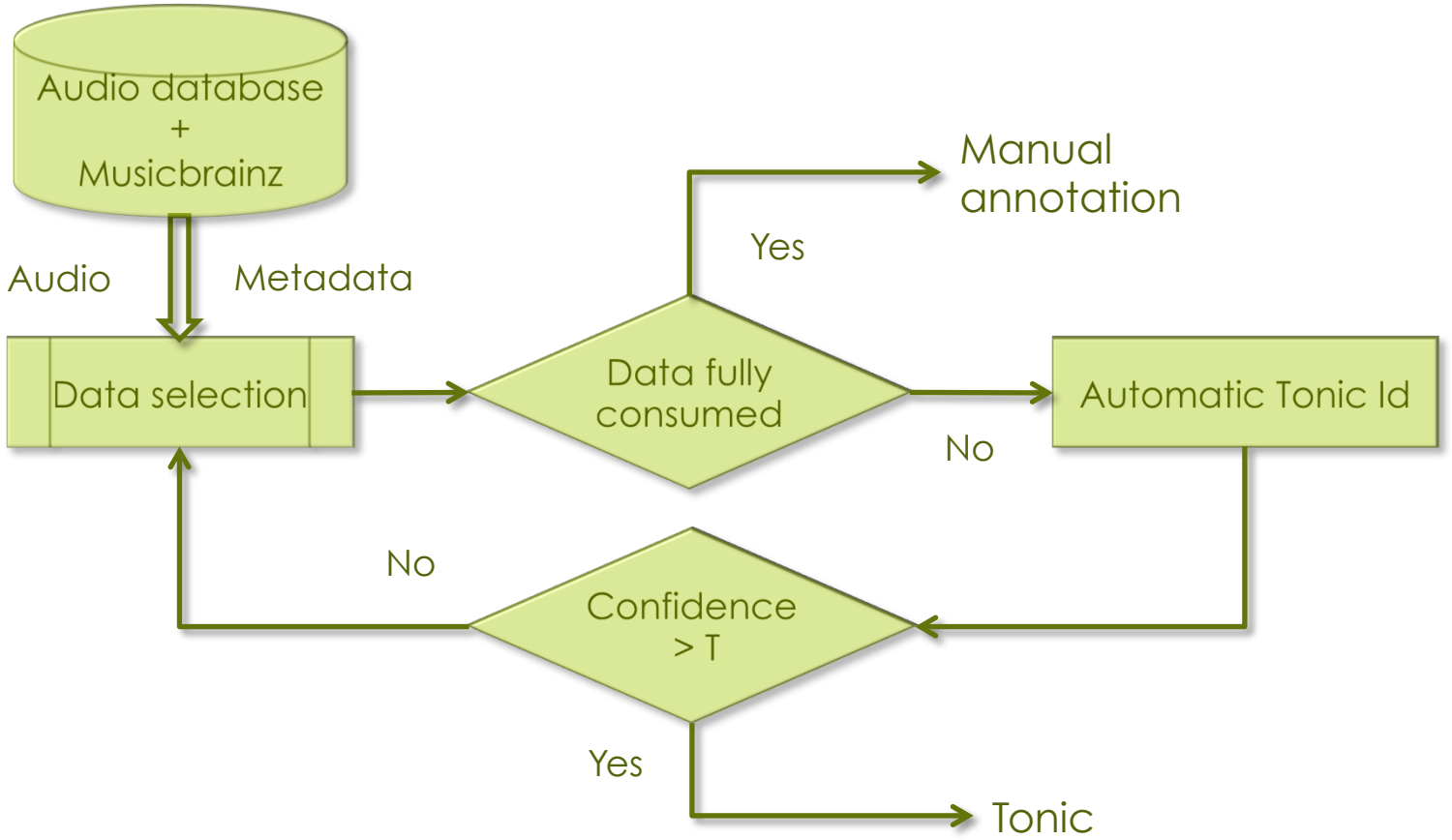
- Very little work done in the past
- Based on melody [4,5]
- Ranjani et al. take advantage of melodic characteristics of Carnatic music [4]



Relevant work: Summary

- Utilized only the melodic aspects
- Used monophonic pitch trackers for heterophonic data
- Limited diversity in database
  - Special raga categories, aalap sections, solo vocal recordings
- Unexplored aspects:
  - Utilizing background audio content comprising drone sound
  - Taking advantage of different types of available data, like audio and metadata
  - Evaluation on diverse database

Methodology: System Overview

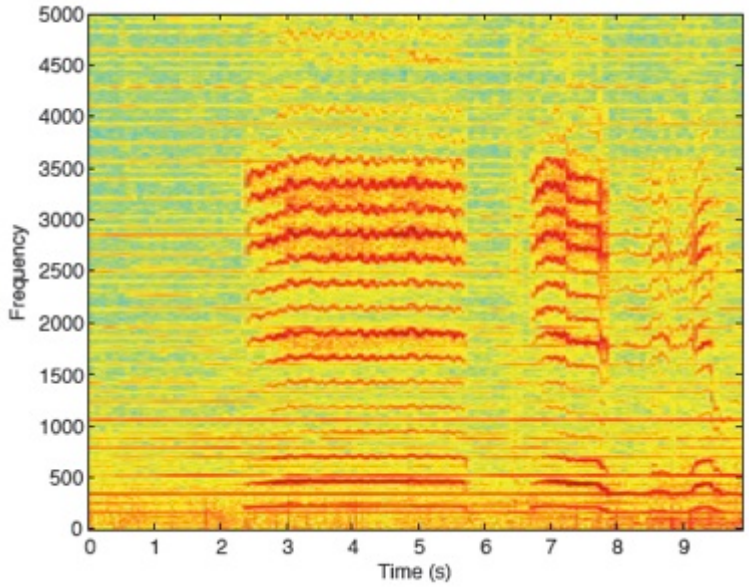


Methodology: System Overview

- Culture specific characteristics for tonic identification
  - Presence of drone*
  - Culture specific melodic characteristics
  - Raga knowledge
  - Melodic Motifs
- Use variable amount of data that is sufficient enough to identify tonic with maximum confidence.
  - Audio data
  - Metadata (Male/Female, Hindustani/Carnatic, Raga etc.)

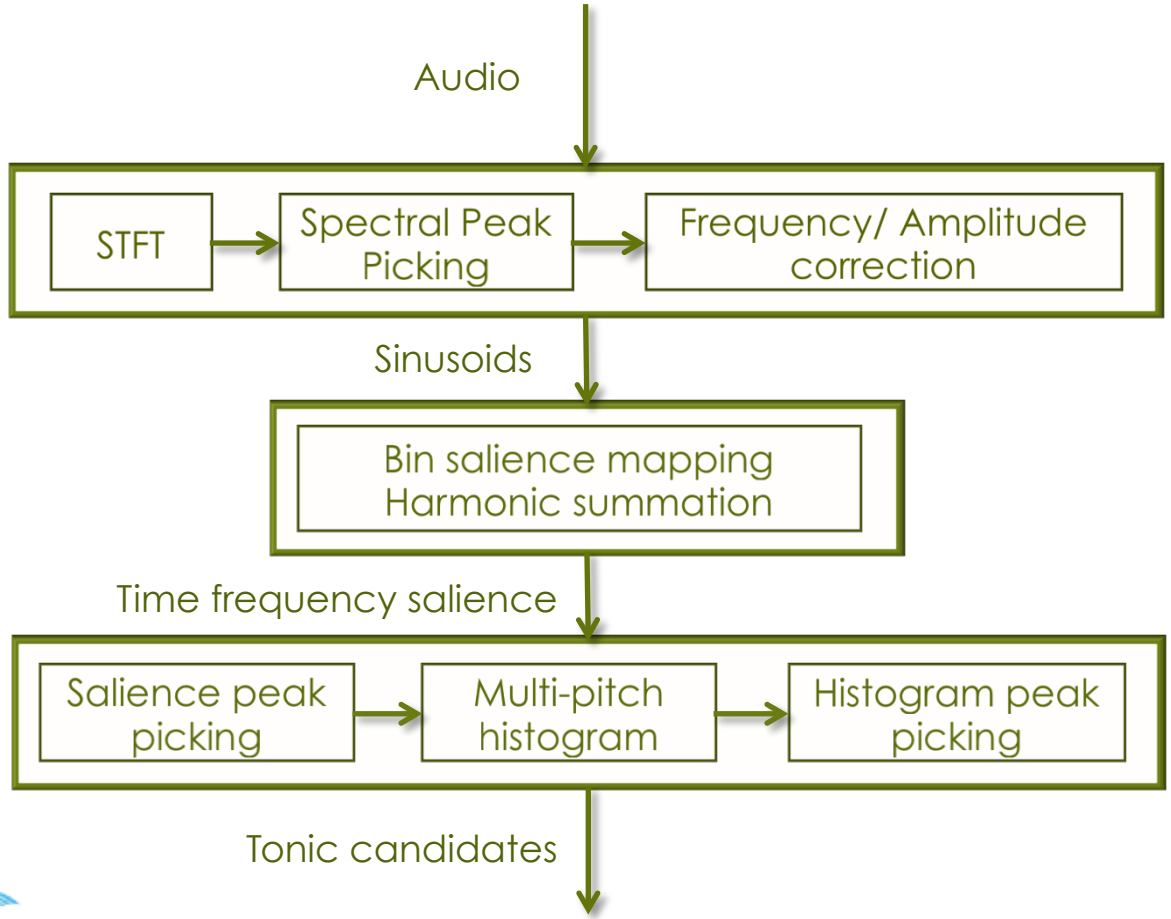
Methodology: Tonic Identification

- Audio example:
- Utilizing drone sound
- Chroma or multi-pitch analysis



Multi-pitch Analysis [7]

Tonic Identification: Signal Processing



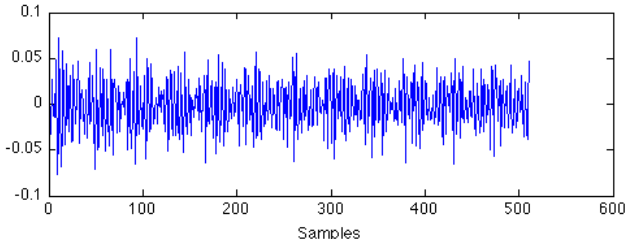
Sinusoid Extraction

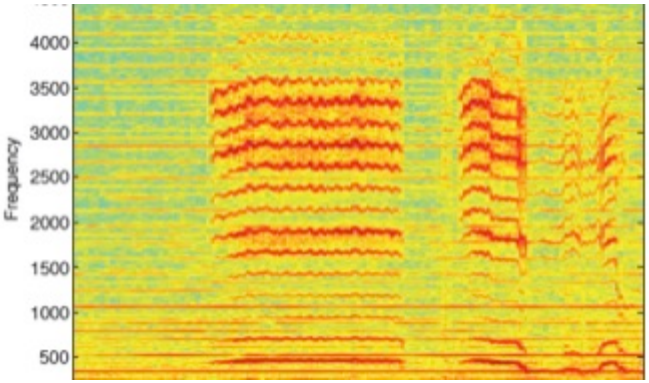
Pitch Salience computation

Tonic candidate generation

Tonic Identification: Signal Processing

STFT

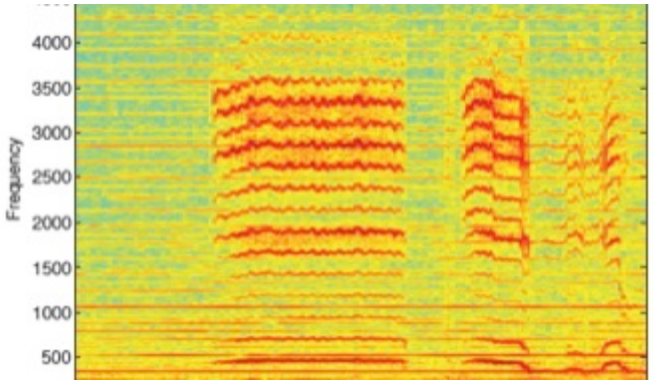


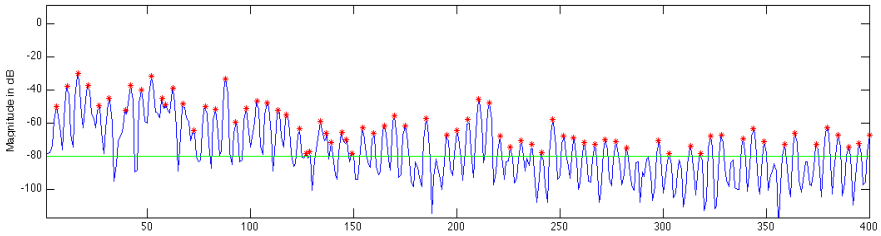


- STFT
  - Hop size: 11 ms
  - Window length: 46 ms
  - Window type: hamming
  - FFT = 8192 points

Tonic Identification: Signal Processing

Spectral Peak Picking

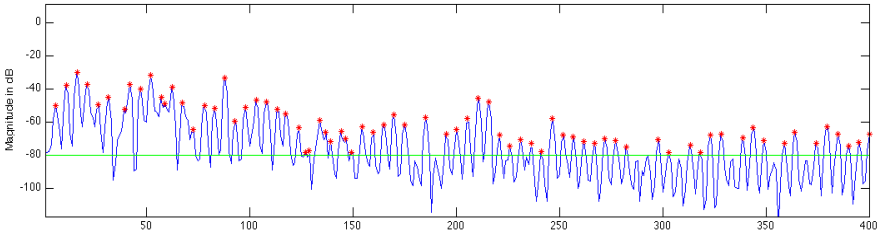




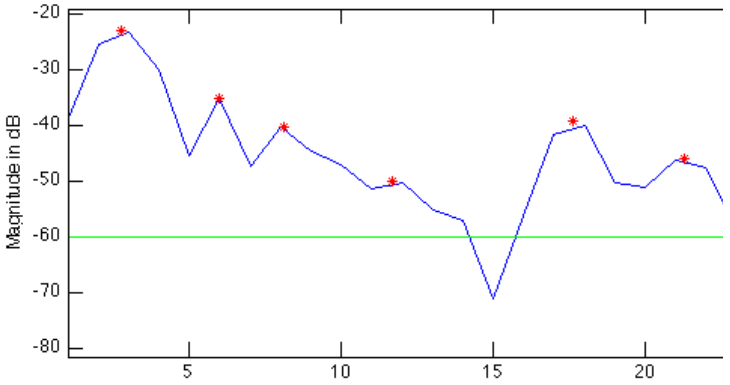
- Spectral peak picking
  - Absolute threshold: -60 dB
  - Relative threshold: -40 dB

Tonic Identification: Signal Processing

Frequency/ Amplitude correction

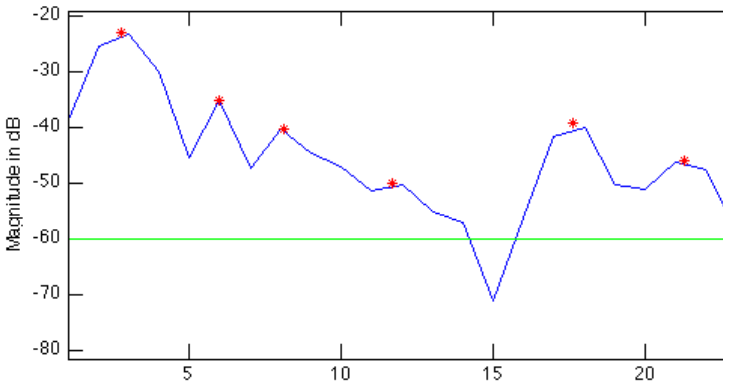


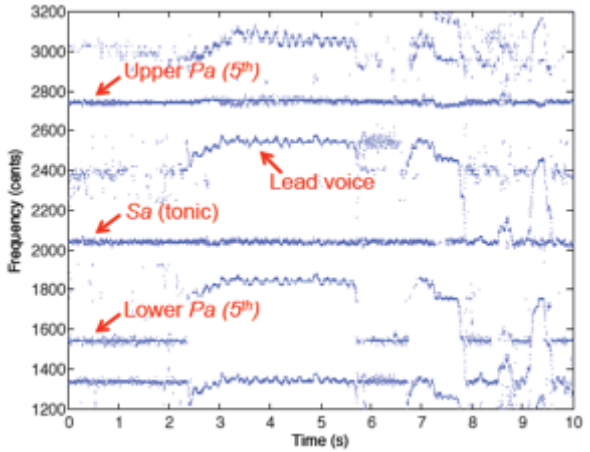
- Frequency/Amplitude correction
  - Parabolic interpolation



Tonic Identification: Signal Processing

Bin salience mapping
Harmonic summation

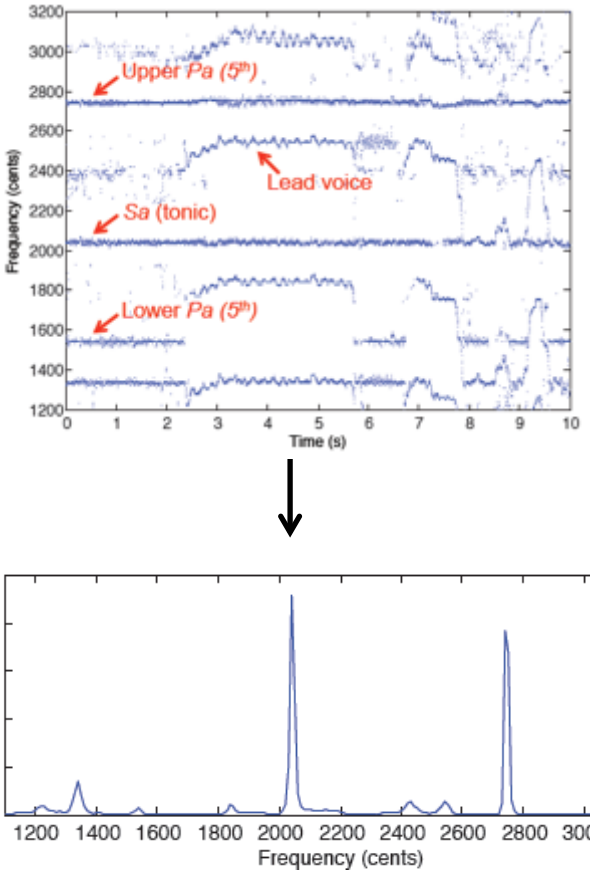




- Harmonic summation [7]
  - Spectrum considered: 55-7200 Hz
  - Frequency range: 55-1760 Hz
  - Base frequency: 55 Hz
  - Bin resolution: 10 cents per bin (120 per octave)
  - N octaves: 5
  - Maximum harmonics: 20
  - Alpha: 1
  - Beta: 0.8
  - Square cosine window across 50 cents

Tonic Identification: Signal Processing

Multi-pitch histogram



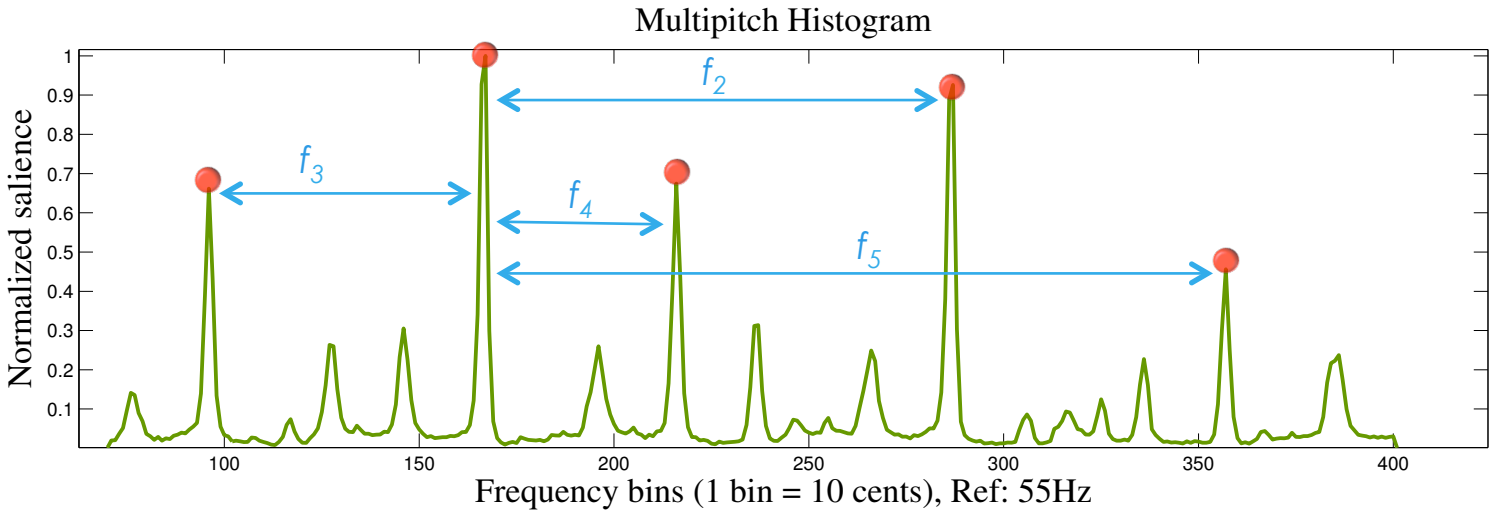
- Tonic candidate generation
  - Number of salience peaks per frame: 5
  - Frequency range: 110-550 Hz
  - After candidate selection salience is no longer considered!!!!

Tonic Identification : Two sub-tasks

- Caters to both vocal and instrumental excerpts
  - Identify tonic pitch class (PC) using multi-pitch histogram
  - Estimate the correct octave using predominant melody
- Use predominant melody extraction approach proposed by Justin Salamon et al. [6]
- Tonic PCP
  - Peak Picking + Machine learning
- Tonic octave estimation
  - Rule based method + Classification based approach

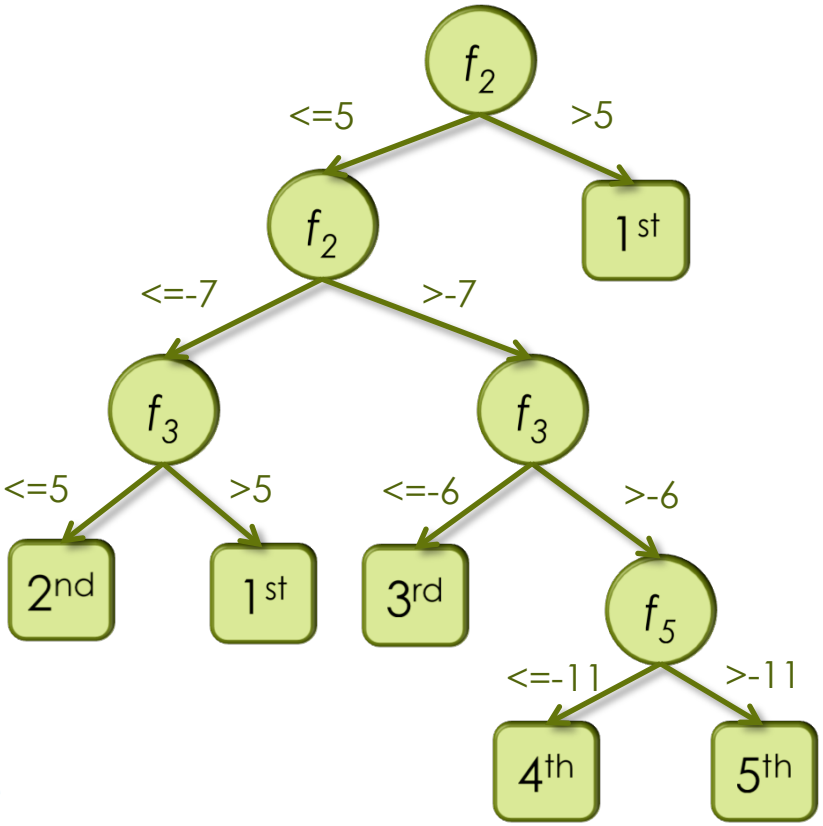
Tonic Identification : PC identification

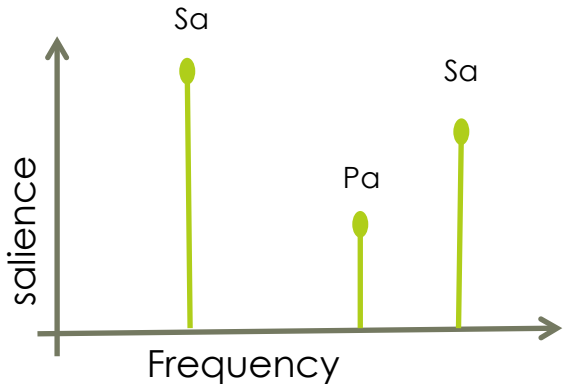
- Classification based template learning
- Two kind of class mappings
  - Rank of the highest tonic PC
  - Highest peak as Tonic or Non tonic
- Feature extracted # 20 (f_1-f_{10}, a_1-a_{10})

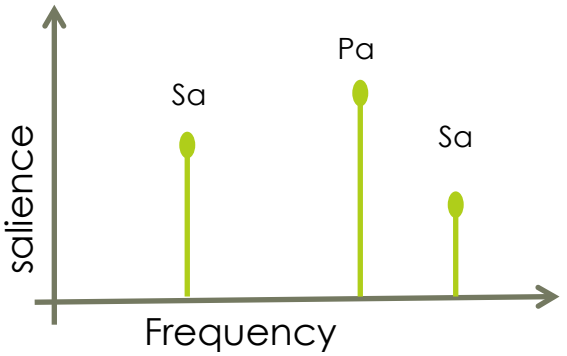


Tonic Identification : PC identification

- Decision Tree:

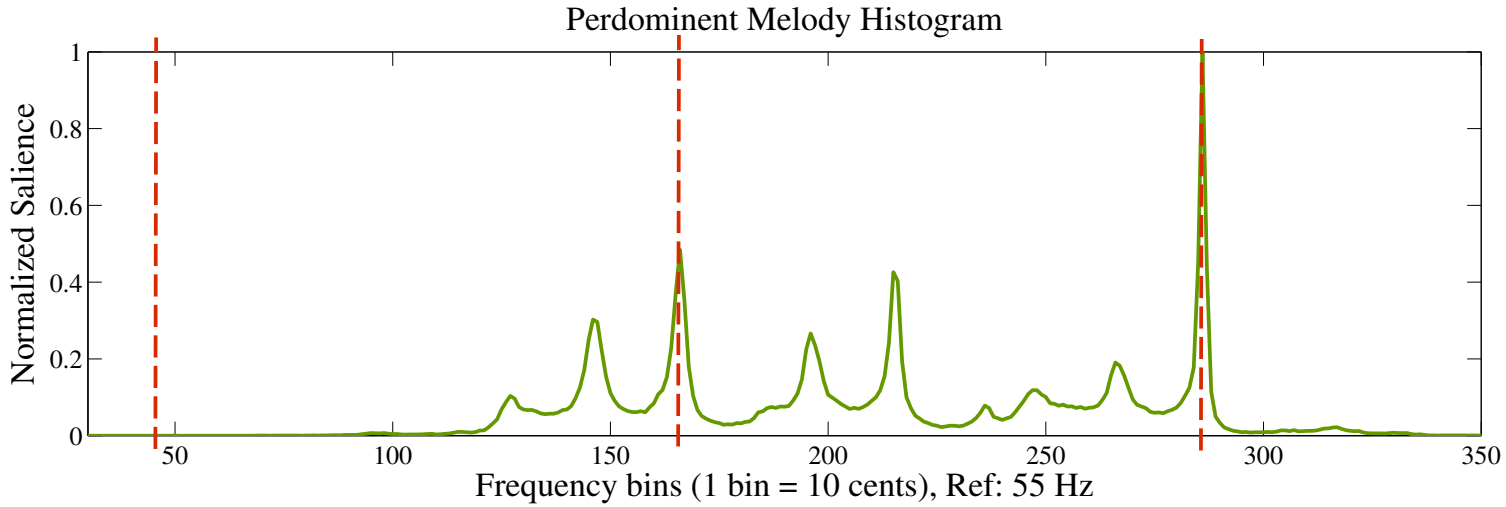






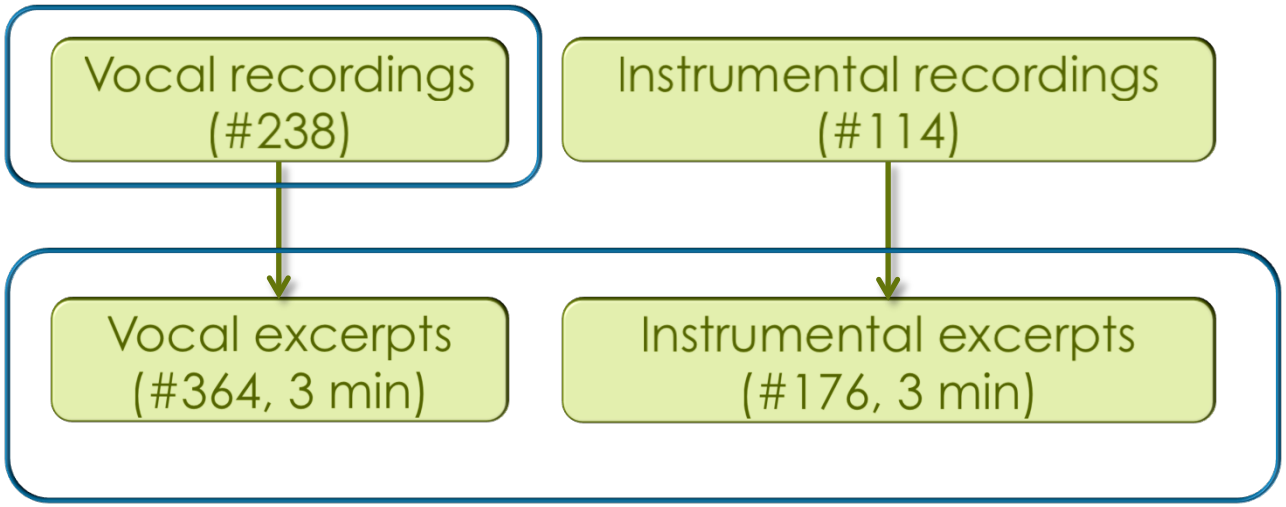
Tonic Identification : Octave Identification

- Tonic octave
  - Rule based method
  - Classification based approach
- 25 Features: a_1-a_{25}



Evaluation: Database

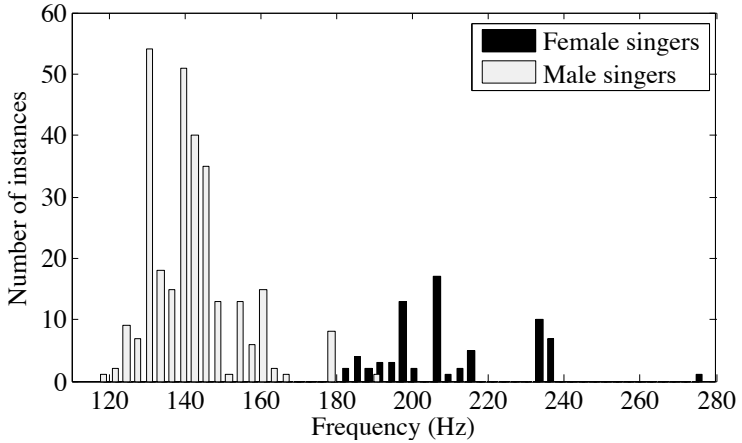
- Subset of CompMusic database (>300 Cds) [3]



Approach 2: #540, 3min (PCP) + 238, full recordings (Octave)

Evaluation: Database

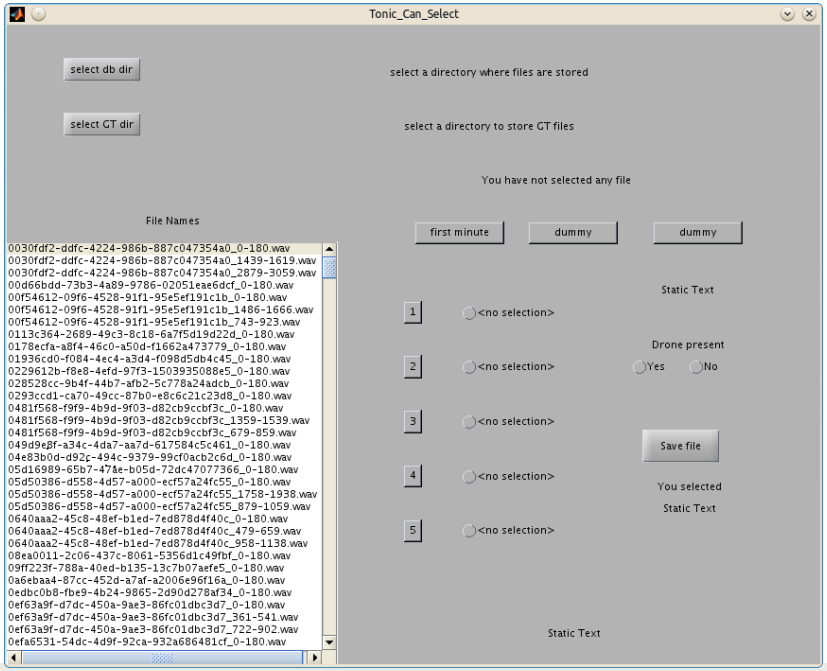
- Tonic distribution



- Statistics (for 364 vocal excerpts)
  - Male (80 %), Female (20%), Hindustani (38%), Carnatic (62%), Unique artist (#36)
- Statistics (for 540 vocal and instrumental excerpts)
  - Hindustani (36%), Carnatic (64%), Unique artist (#55)

Evaluation: Annotations

- Annotations done by the author
- Extracted 5 tonic candidates from multi-pitch histograms between 110-370 Hz
- Matlab GUI to speed up the annotation procedure



Evaluation: Accuracy measures

- Output correct within 50 cents of the ground truth
- 10 fold cross validation + rule based classification
- Weka: data mining tool
- Feature selection: CfsSubsetEval (features > 80% folds)
- Classifier: J48 decision tree
- Performs better than
  - SVM-polynomial kernel (6% difference in accuracy)
  - K* classifier (5% difference in accuracy)

Results

Approach\(%)	Map	#folds	Class EQ	# Features	Tonic pitch	Tonic PCP	5th	4th	Other
AP1_EXP1	-	-	-	-	-	85	10.7	0.93	3.3
AP1_EXP2	M1	1	no	1, S2	-	**93.7**	1.48	8.9	0.9
AP1_EXP3	M1	10	no	4, S3	-	92.9	1.9	3.5	1.7
AP1_EXP4	M1	10	yes	4, S4	-	74.2	11	7.6	6.7
AP1_EXP5	M2	1	no	1, S2	-	91	3.3	3	2.7
AP1_EXP6	M2	10	no	2, S5	-	91.8	2.2	3	3
AP1_EXP7	M2	10	yes	2, S5	-	87.8	4.2	4	3.9

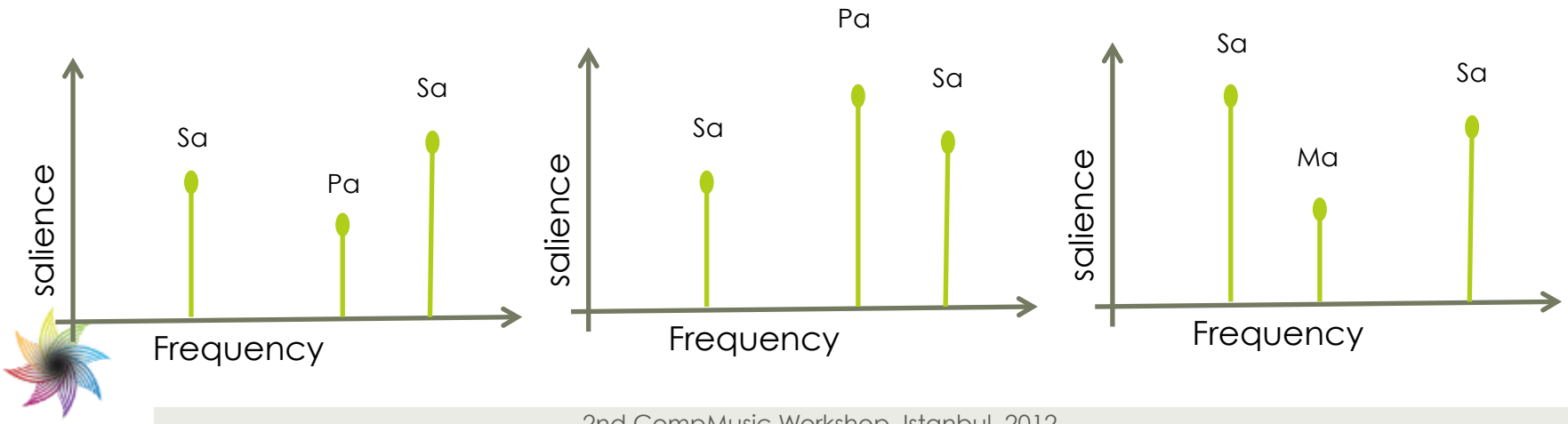
- M1 : tonic PCP rank, M2 : highest peak tonic or non-tonic
- S1: $[f_2, f_3, f_5]$, S2: $[f_2]$, S3: $[f_2, f_4, f_6, a_5]$, S4: $[f_2, f_3, a_3, a_5]$, S5: $[f_2, f_3]$

Results

- Approach 2, Octave identification
  - Rule based approach – 99 %
  - Classification based approach – 100%

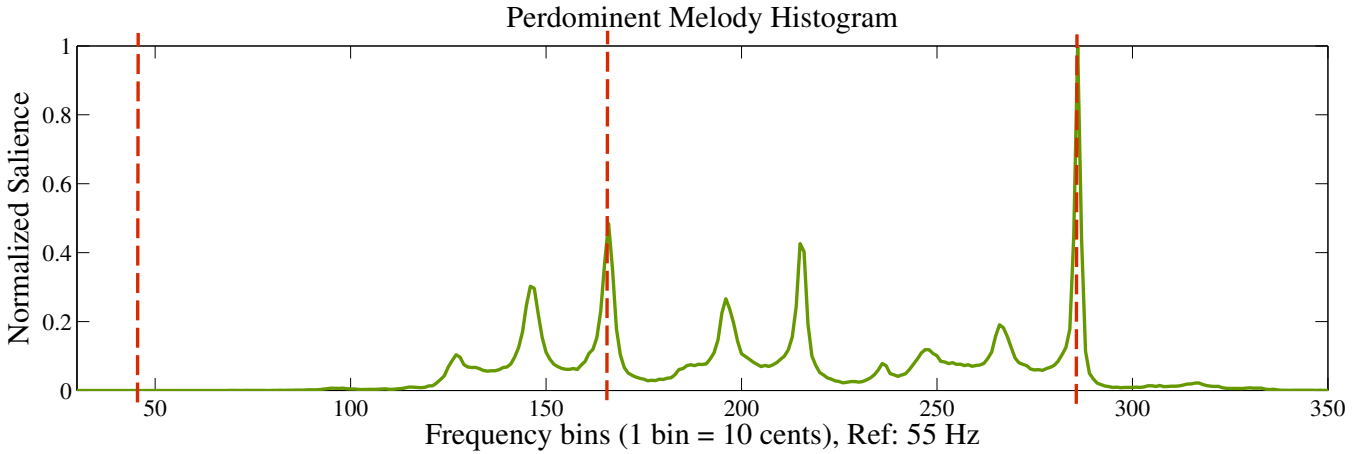
Discussion: PCP Identification

- AP-1: Performance for male singers (95%), female singers (88%)
- Error cases
  - Mostly Ma tuning songs
  - More female singers
- Sensitive to selected frequency range for tonic candidates, a range of 110-370 Hz works optimal



Discussion : Octave Identification

- Challenges faced by rule based approach
  - Hindustani musicians go roughly -500 cents below tonic
  - Carnatic musicians generally don't go that below tonic
  - Melody estimation errors at low frequency
  - Concept of Madhyam shruti



Conclusions and Future Work

- Drone sound in the background provides an important cue for the identification of tonic and can be utilized to automatically perform this task
- System should be fed with more information to differentiate between '*Pa*' and '*Ma*' tuning
- Future Work:
  - Exploring melodic characteristics for tonic identification
  - Deeper analysis of confidence measure concept
  - Study influence of cultural background on human performance for this task

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Thank you

Questions?