TOWARDS AN AUTOMATED REAL-TIME ACOUSTIC MONITORING OF BEAKED WHALES

A PRELIMINARY CLASSIFIER FOR ANTARES UNDERWATER OBSERVATORY

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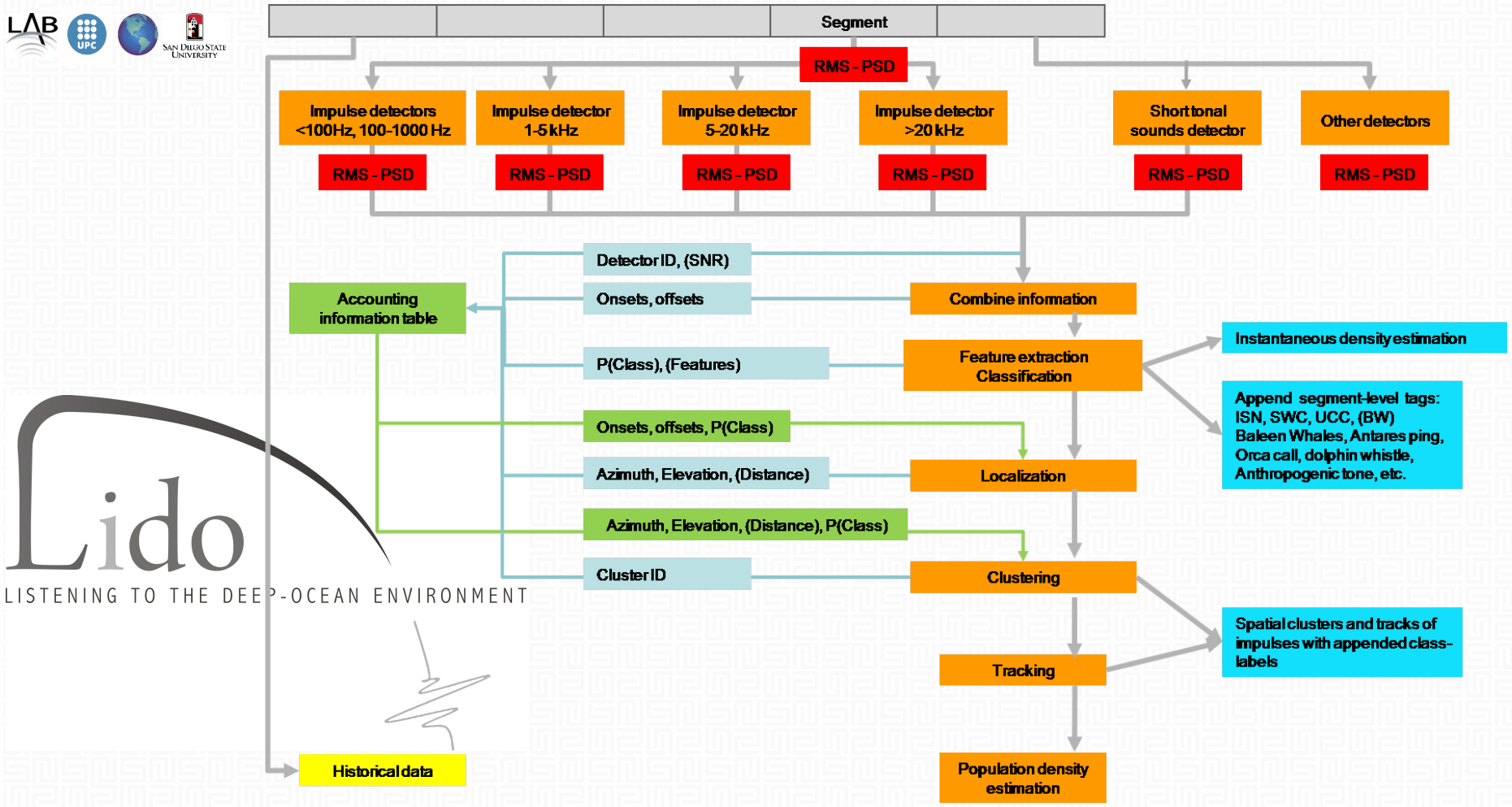

Segment
RMS - PSD
Impulse detectors <100Hz, 100-1000 Hz
Impulse detector 1-5 kHz
Impulse detector 5-20 kHz
Impulse detector >20 kHz
Short tonal sounds detector
Other detectors
RMS - PSD
RMS - PSD
RMS - PSD
RMS - PSD
RMS - PSD
RMS - PSD
Detector ID, (SNR)
Onsets, offsets
P(Class), (Features)
Onsets, offsets, P(Class)
Azimuth, Elevation, (Distance)
Azimuth, Elevation, (Distance), P(Class)
Cluster ID
Accounting information table
Combine information
Feature extraction Classification
Localization
Clustering
Tracking
Population density estimation
Instantaneous density estimation
Append segment-level tags: ISN, SWC, UCC, (BW) Baleen Whales, Antares ping, Orca call, dolphin whistle, Anthropogenic tone, etc.
Spatial clusters and tracks of impulses with appended class-labels
Historical data
Lido
LISTENING TO THE DEEP-OCEAN ENVIRONMENT


LAB
UPC
San Diego State University
DCNS
Tsi
european multidisciplinary seafloor observatory
emso
JAMSTEC
ESONET NOE
KM3NeT
CESA
COMMUNITY OF EUROPEAN SHIPYARDS' ASSOCIATIONS
SSPA
European Commission
Agence des aires marines protégées
FOI
Quiet oceans
Ocean Noise Forecasting Monitoring & Mitigation
PERSEUS
BUREAU VERITAS
LISTENING TO THE DEEP-OCEAN
ANTARES
CSA
VENUS
The Ocean Online, Real Time, Any Time™
OCEAN NETWORKS CANADA
FixO3
FIXED-POINT OPEN OCEAN OBSERVATORIES
Achieve QUieter Oceans
bp
ACCESS
Arctic Climate Change Economy and Society
NURC
PARTNERING FOR MARITIME INNOVATION
CTBTO
COCONET
NEMO
NEUTRINO MEDITERRANEAN OBSERVATORY

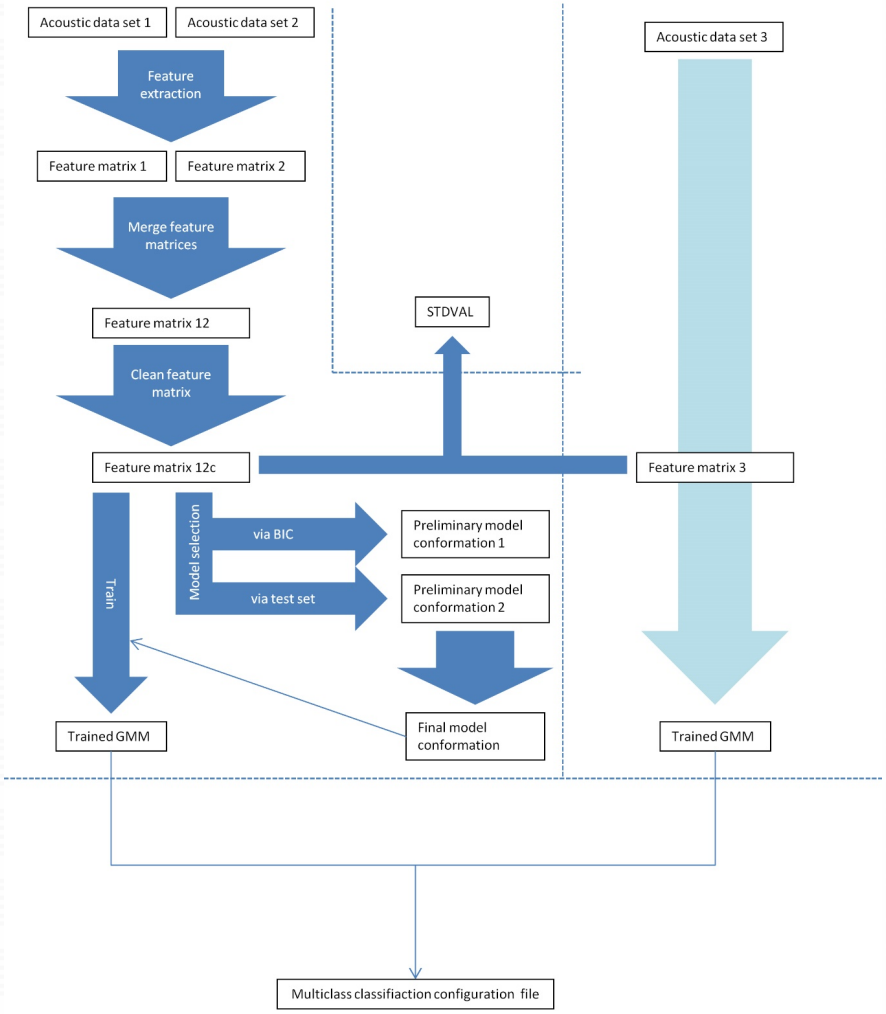
TRAINING PROCESS

1. Extract features from training data
2. Standardize feature values
3. Train model for each class with Gaussian Mixture Models

   and select a good model conformation via

   1. BIC (Bayesian Information Criterion): select model type and number of components
   2. Test data: select regularization parameter

4. Validate the models



DATA

BW: Cuvier's beaked whales
Not BW: Dolphins and Unidentified Odontocetes

Training Data

BW: N = ~30,000 clicks	20 files
Not BW: N = ~1,070,000 clicks	22 files

Season: late spring and beginning autumn

Validation Data

BW: N = ~9,000 clicks	15 files
Not BW: N = ~1,130,000 clicks	12 files

Season: late spring and summer

FEATURE EXTRACTION

8 SPECTRAL FEATURES

1. Center of Spectrum
2. Standard deviation
3. Skewness
4. Kurtosis
5. Degree of Peakiness
6. Peak Frequency
7. Sweep Rate
8. R^2 – Goodness of fit

8 TEMPORAL FEATURES

9. Standard deviation
10. Skewness
11. Kurtosis
12. Degree of peakiness
13. Duration
14. Duration envelope above 50%
15. Inter-pulse-interval (IPI)
16. Reliability Measure (RM)

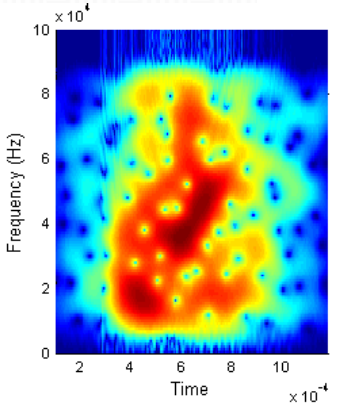
SWEEP RATE ESTIMATION

1. Problematic with non zero mean pulses.

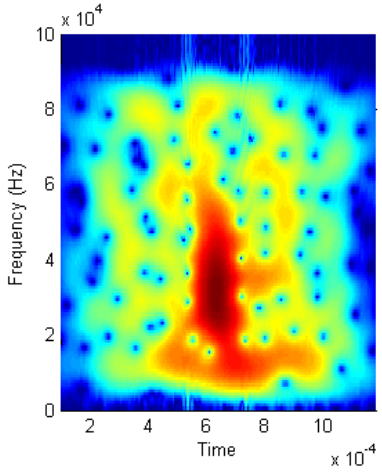
   Solution: **Osculating Circle Method**

2. Problematic with distorted envelopes.

   Solution: **Smoothing the phase**



BW



Not BW

SWEEP RATE ESTIMATION

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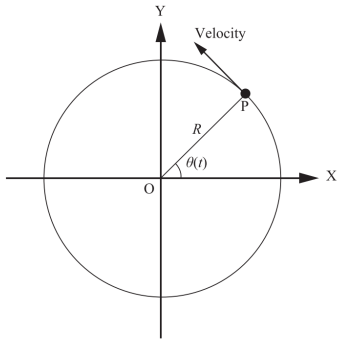
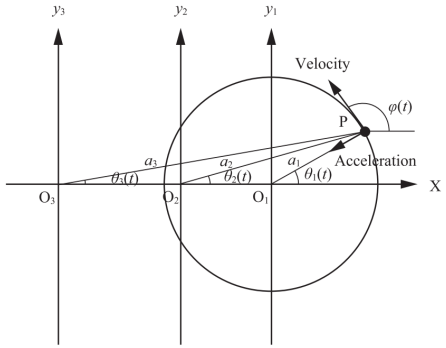
Traditional Gabor's method using Hilbert Transform



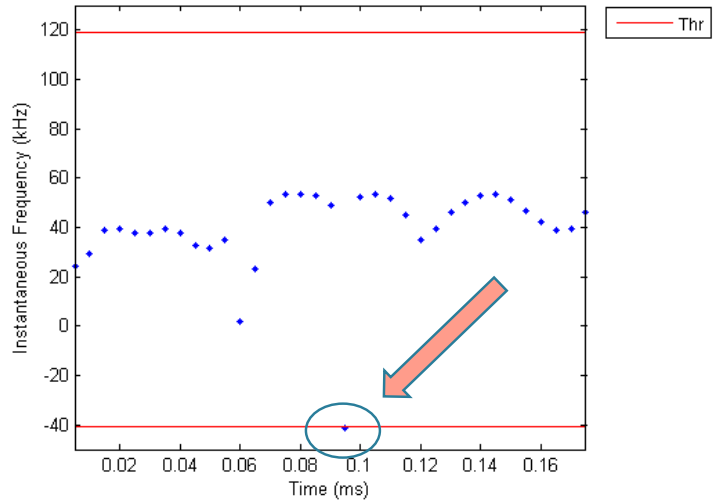
Osculating Circle Method

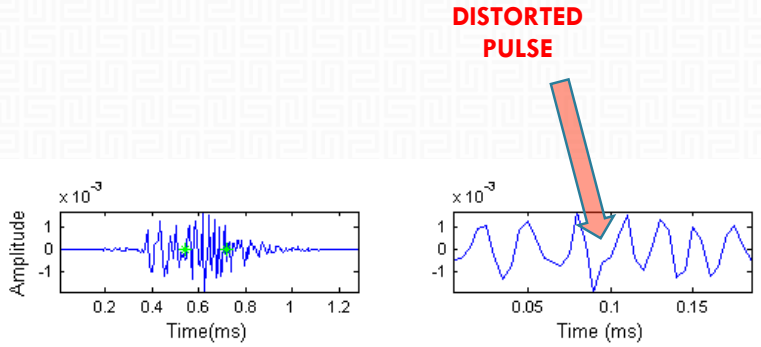


Hsu et al. 2011

OVERCOMING THE NEGATIVE INSTANTANEOUS FREQUENCIES

Find negative instantaneous frequencies





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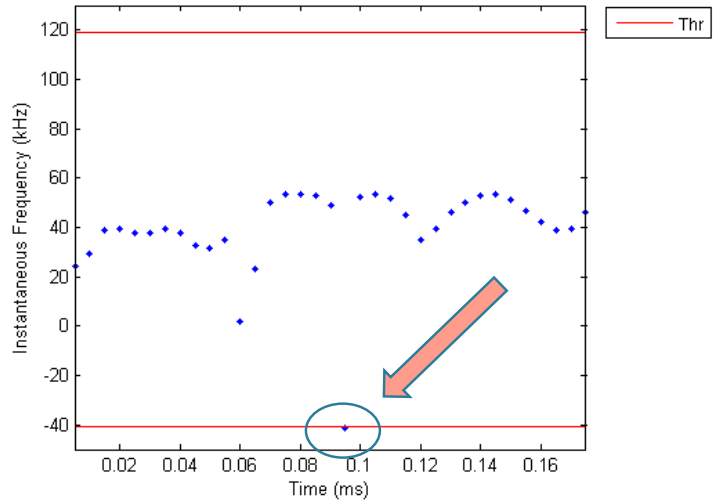
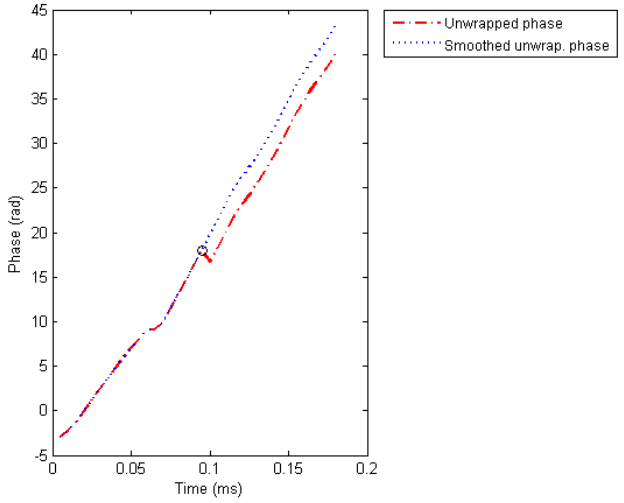
Find negative instantaneous frequencies

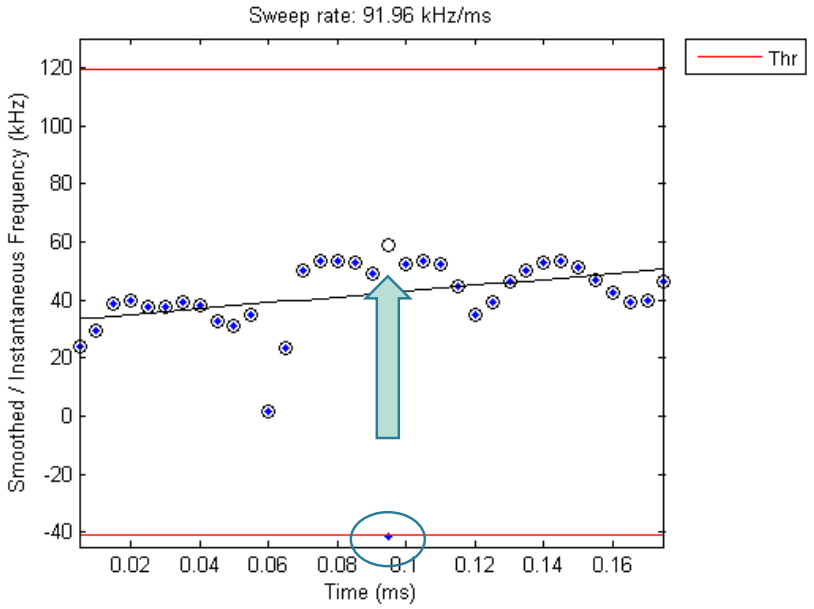


Smoothing the unwrapped phase

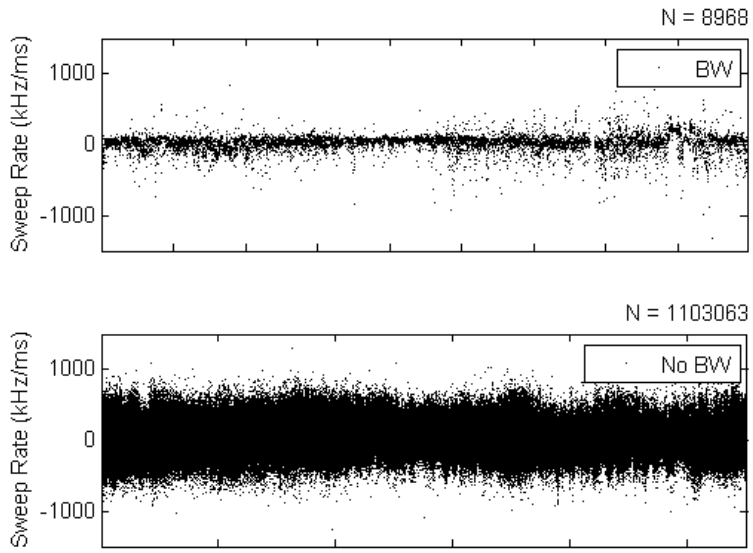


OVERCOMING THE NEGATIVE INSTANTANEOUS FREQUENCIES

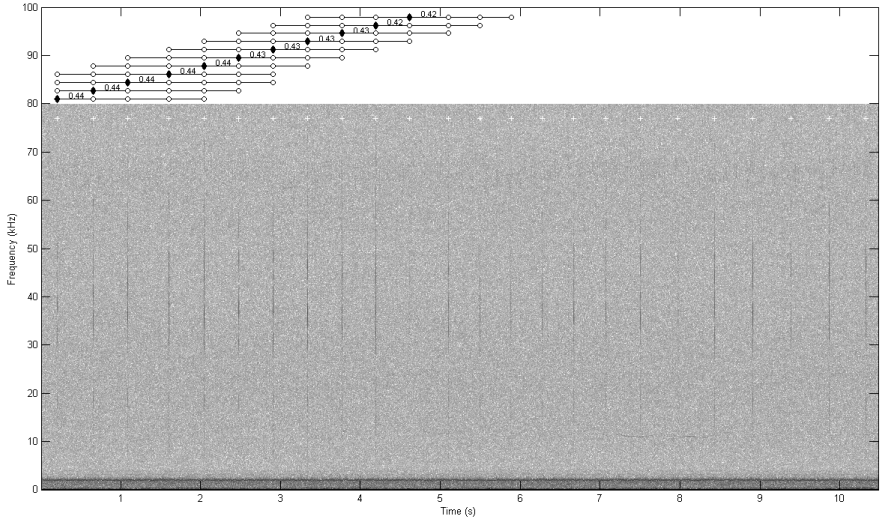
Smoothed Instantaneous Frequencies



SWEEP RATE ESTIMATION RESULTS



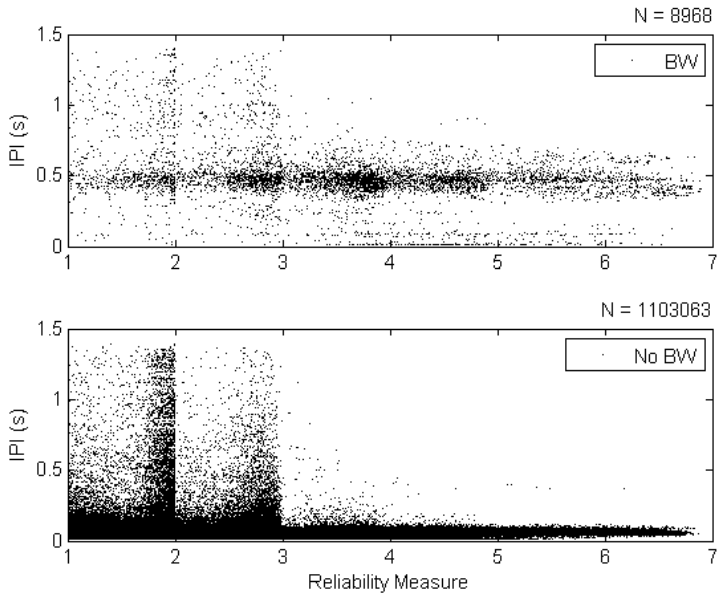
INTER-PULSE-INTERVAL (IPI) ESTIMATION



IPI estimation modules:

1. Select neighbors of focal pulse
2. Select neighbors by spectral dissimilarity
3. **Estimate IPI** with respect to neighboring pulses.
4. **Obtain the Reliability Measure (RM):** estimates the number of pulses that could be joined to a consistent sequence that contains the analyzed pulse.

INTER-PULSE-INTERVAL (IPI) ESTIMATION



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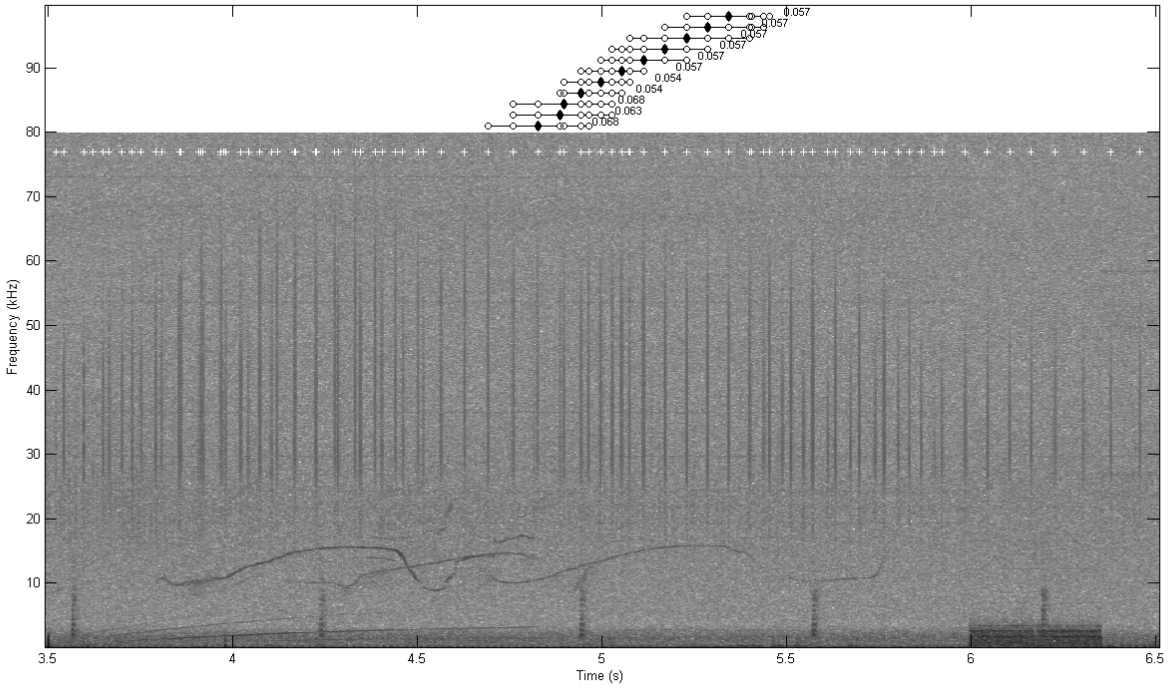
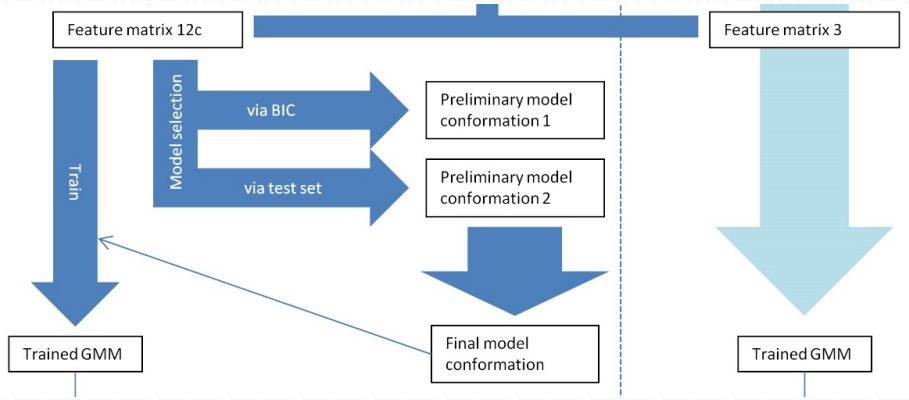
IPI ESTIMATION: NOT BEAKED WHALE



TRAINING CLASS MODELS

Classification technique:

Gaussian Mixture Models (GMMs)

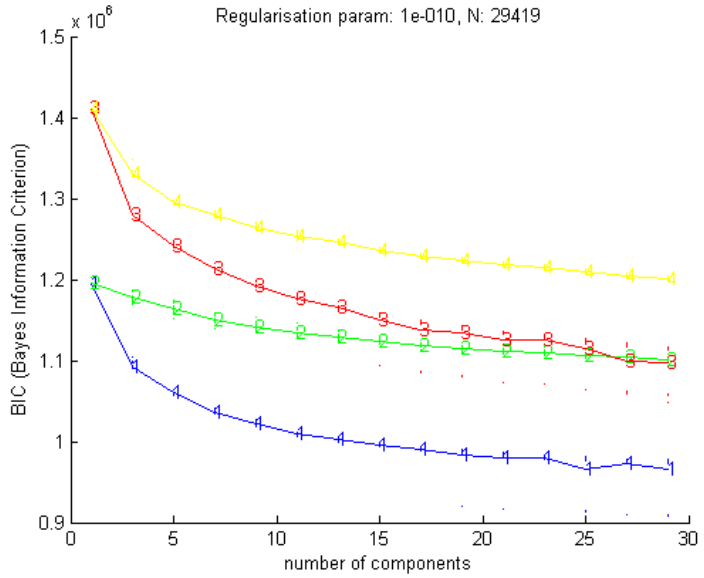


GMMs input – extracted features

GMMs output – a class prediction

MODEL SELECTION FOR EACH CLASS

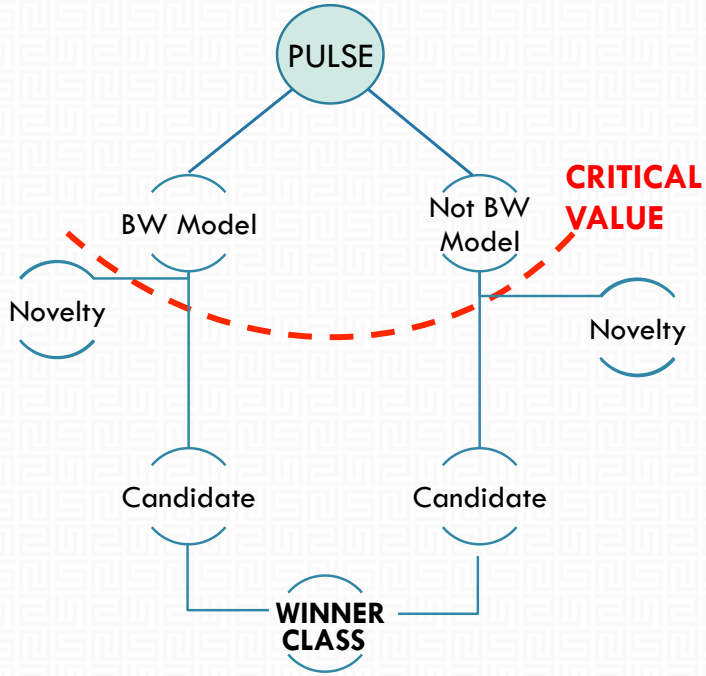
1. Full and not Shared Cov.
2. Full and Shared Cov.
3. Diagonal and not Shared Cov.
4. Diagonal and Shared Cov.

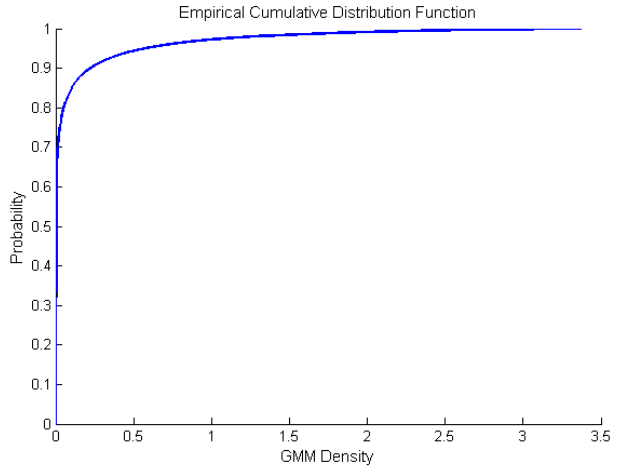


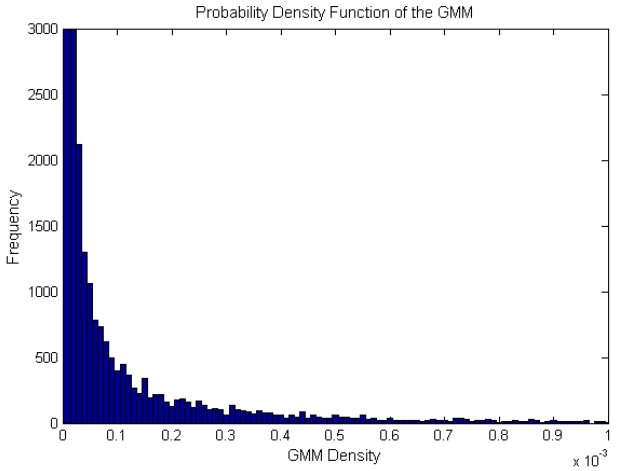
The best model is selected using the **BAYESIAN INFORMATION CRITERION (BIC)**

BIC is based on the likelihood function that introduces a penalty term on the number of parameters.

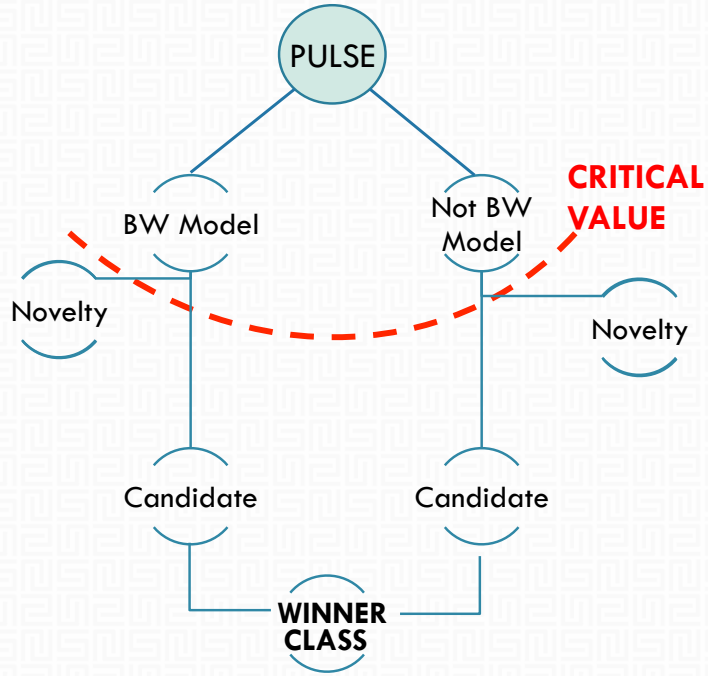
PULSE-LEVEL DECISION

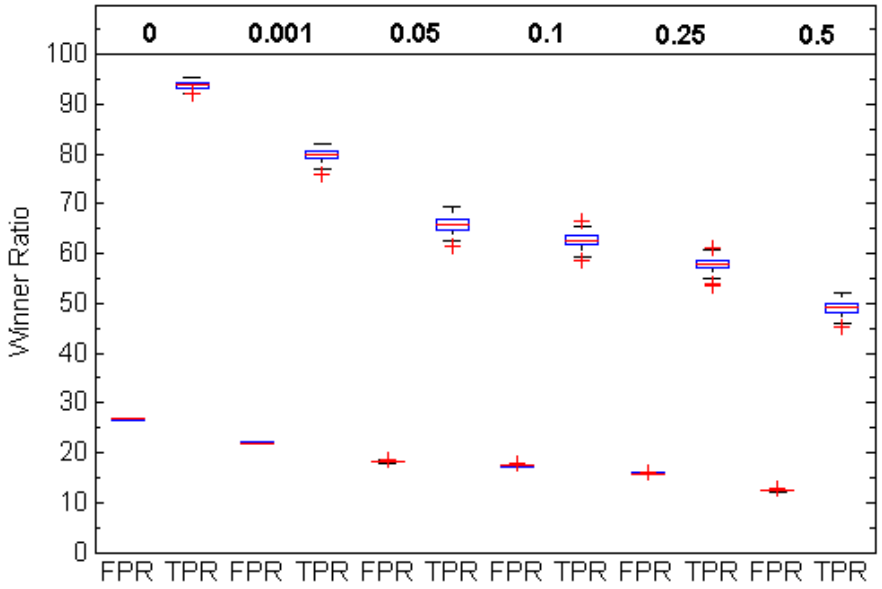






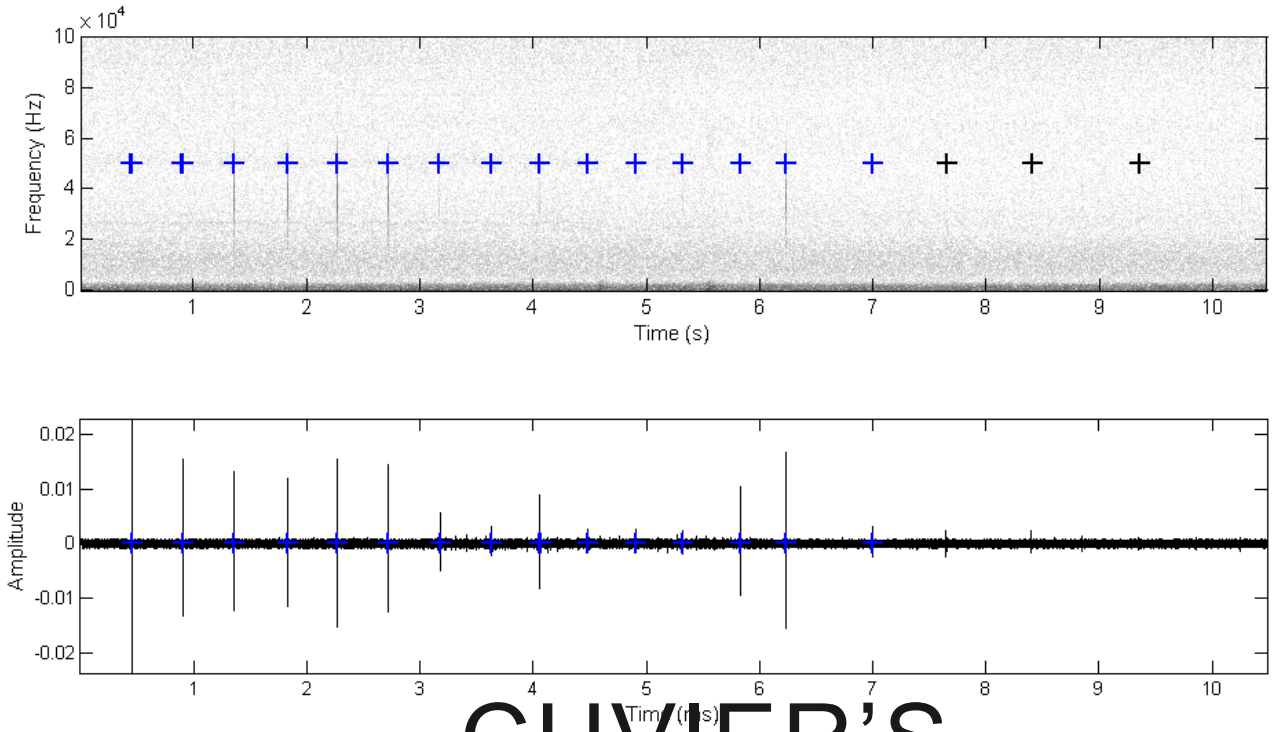
PULSE-LEVEL DECISION





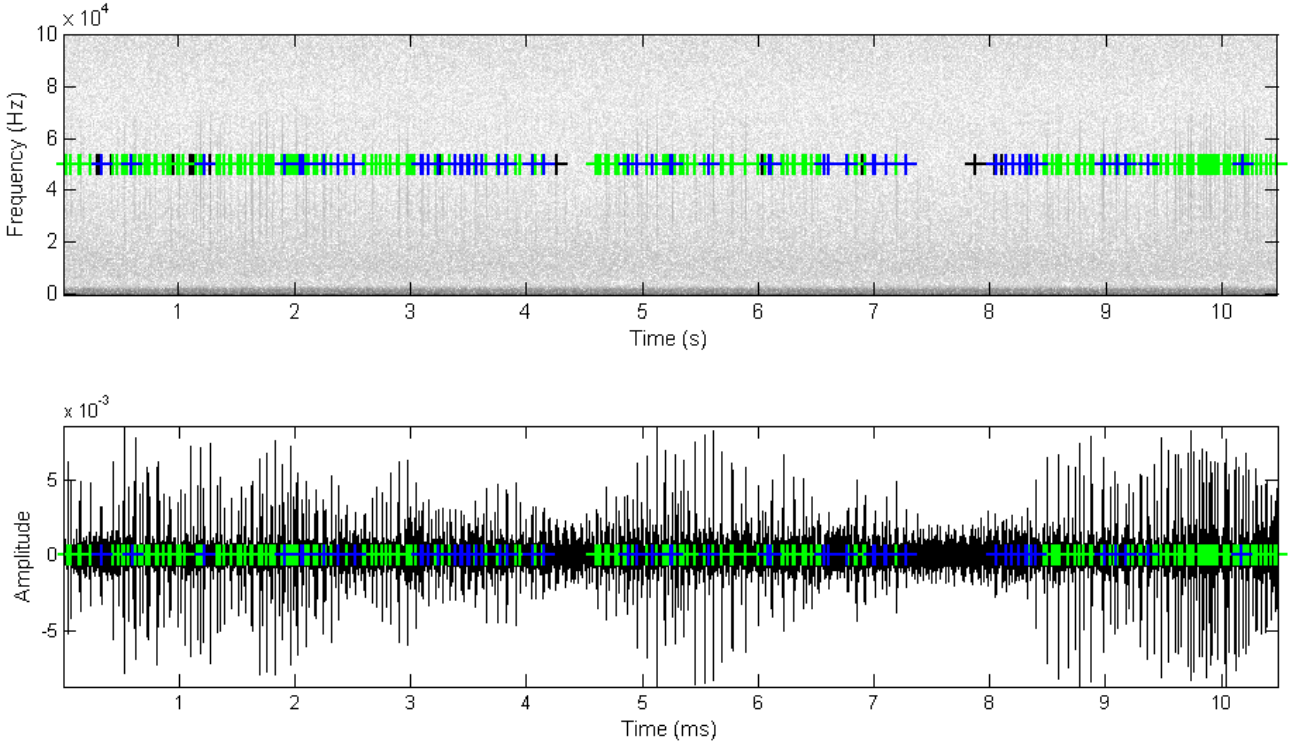
FPR: False Positive Rate, **TPR**: True Positive Rate

Blue: BW
Green: Not BW
Black: Novelty



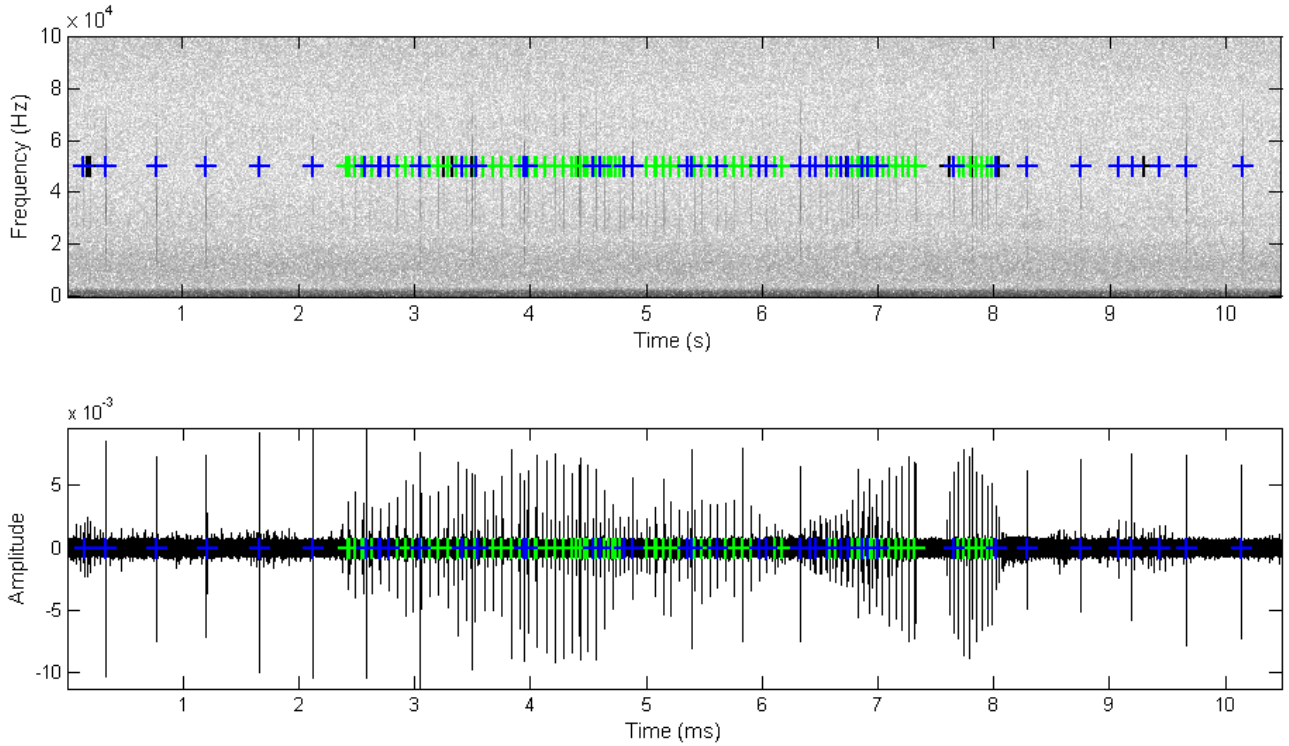
CUVIER'S BEAKED WHALES | OUTPUT CLASSIFIER

Blue: BW
Green: Not BW
Black: Novelty



UNIDENTIFIED ODONTOCETES | OUTPUT CLASSIFIER

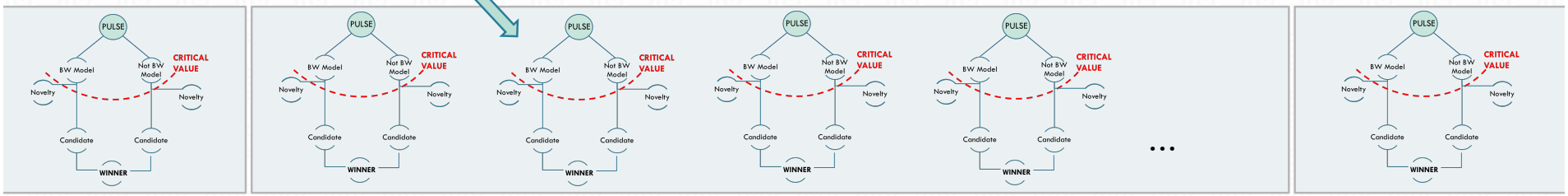
Blue: BW
Green: Not BW
Black: Novelty



MIXED SPECIES | OUTPUT CLASSIFIER

SEGMENT-LEVEL DECISION

PULSE-LEVEL DECISION



SEGMENT-LEVEL DECISION:

$$\text{Winner Ratio}_{BW} = \frac{\sum \text{Winners}_{BW}}{\sum \text{Candidates}_{BW}}$$

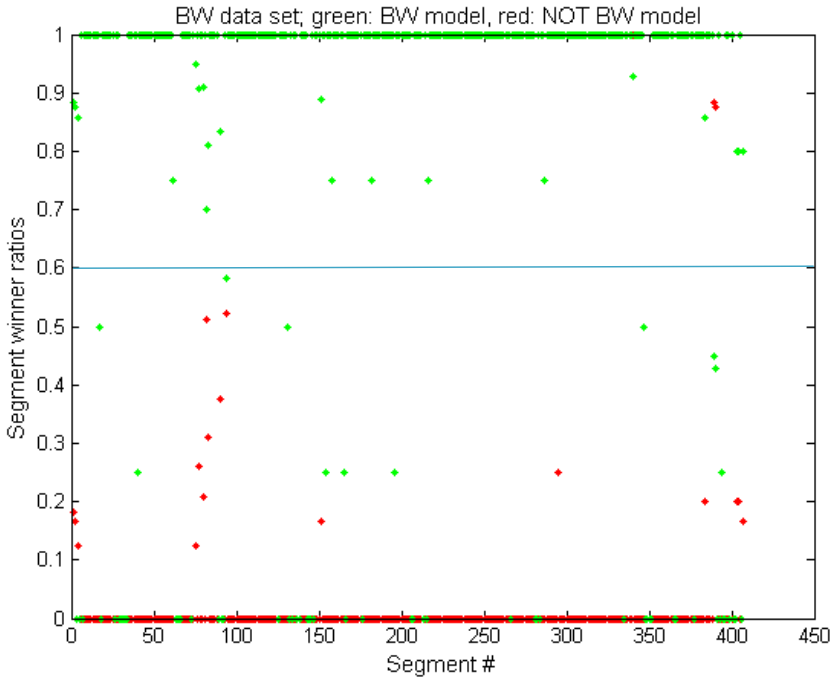
$$\text{Winner Ratio}_{NotBW} = \frac{\sum \text{Winners}_{NotBW}}{\sum \text{Candidates}_{NotBW}}$$

SEGMENT-LEVEL DECISION: VALIDATION DATASET

If winner ratio is < 60%: model classification unreliable

Segment class decision:

- ✓ BW: $WinnerRatio_{BW} > 60\%$ and $WinnerRatio_{NotBW} < 60\%$
- ✓ Not BW: $WinnerRatio_{BW} < 60\%$ and $WinnerRatio_{NotBW} > 60\%$
- ✓ Mixed: $WinnerRatio_{BW} > 60\%$ and $WinnerRatio_{NotBW} > 60\%$
- ✓ UnRelib.: $WinnerRatio_{BW} < 60\%$ and $WinnerRatio_{NotBW} < 60\%$



SEGMENT-LEVEL CLASSIFICATION

Validation Dataset ID	BW (%)	Not BW (%)	Mixed (%)	Unreliable (%)	Number of segments
BW	83.78	0.49	0.25	15.48	407
Not BW	8.46	86.66	1.82	3.06	2091
Mixed	83.67	16.84	14.29	23.47	271

QUESTIONS?

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