Estimation of Marine Mammals Using Recordings from One Microphone

Xanadu Halkias & Dan Ellis
Laboratory for Recognition and Organization of Speech and Audio
Dept. Electrical Engineering, Columbia University, NY USA
{xanadu,dpwe}@ee.columbia.edu

1. System Organization
2. Processing
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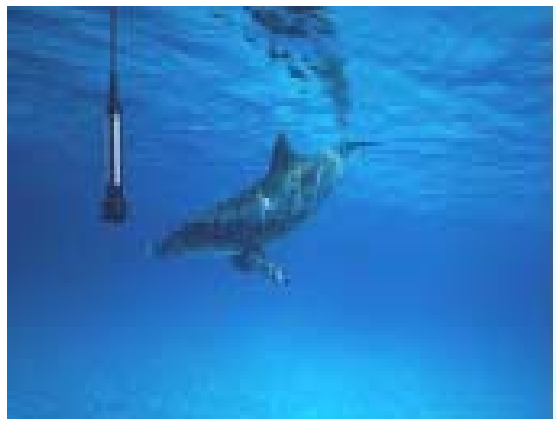
Lab ROSA
Laboratory for the Recognition and Organization of Speech and Audio

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

1. System Organization

- Localizing marine mammals
  - Track their location and population
  - Preserve and protect
- Systems used require an array of hydrophones e.g. M3R
  - Cross-correlation along all hydrophones
- Accessibility to the hobbyist who just wants to have a crude idea



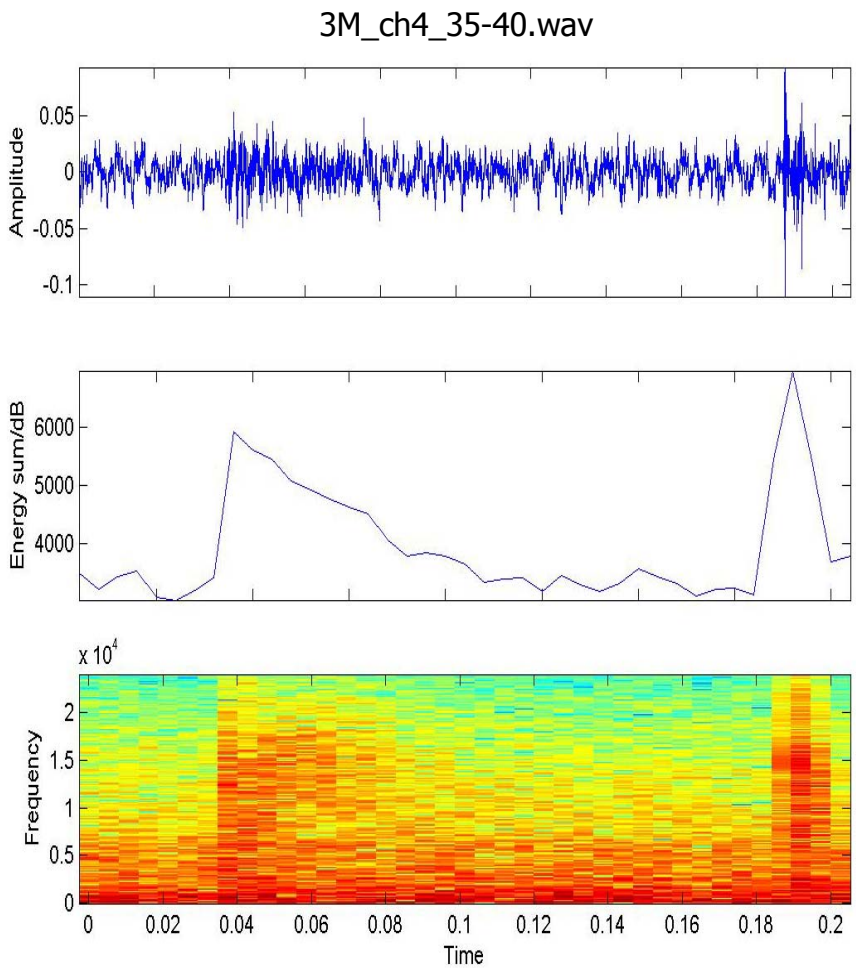
Estimation of the number of marine mammals

- Task:

  Automatically and in real time extract the number of marine mammals in a region given their audio recordings
  - Multiple hydrophones
  - Manual interference for elimination of clicks or whistles in the recordings
- Goal:
  - Provide a good approximation of the number using click recordings from one microphone

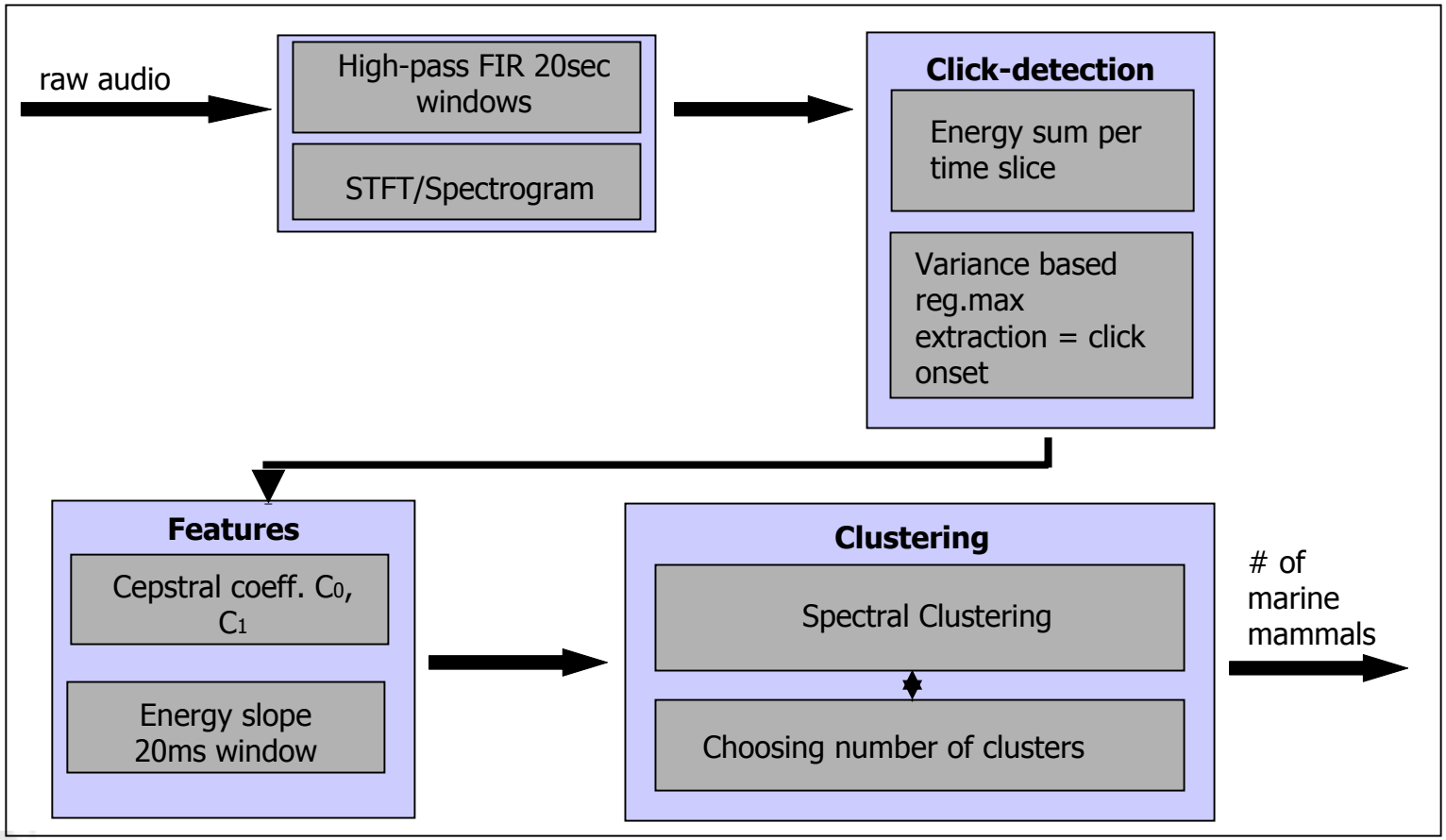
The Data - Click Examples

- Click sounds from sperm and pilot whales
- Several hydrophones
- Ground truth of possible whales available through M3R and visual inspection
- Reverberated and non-reverberated



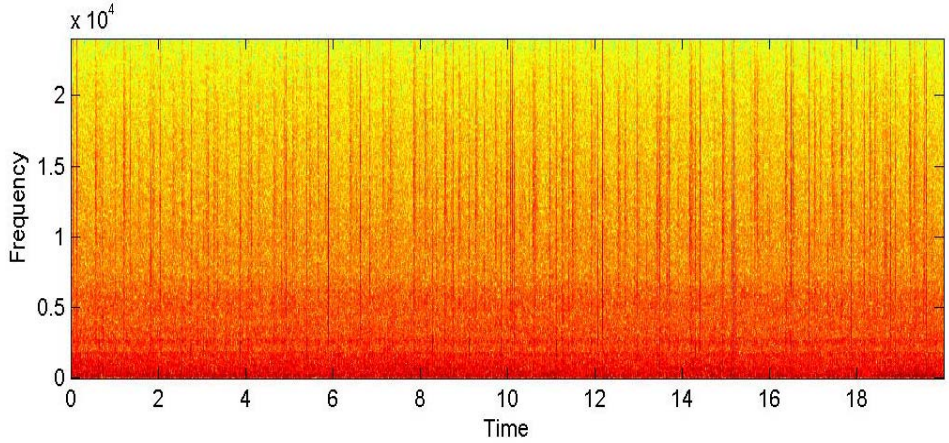
2. Processing

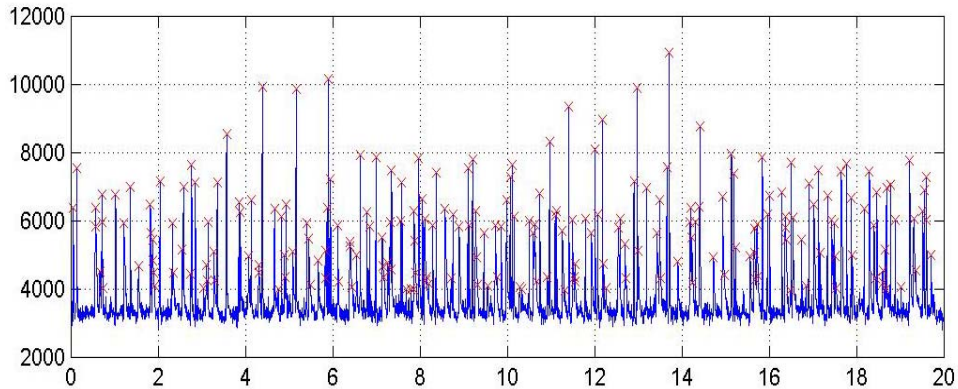
- Detection → Features → Clustering



Click Detection

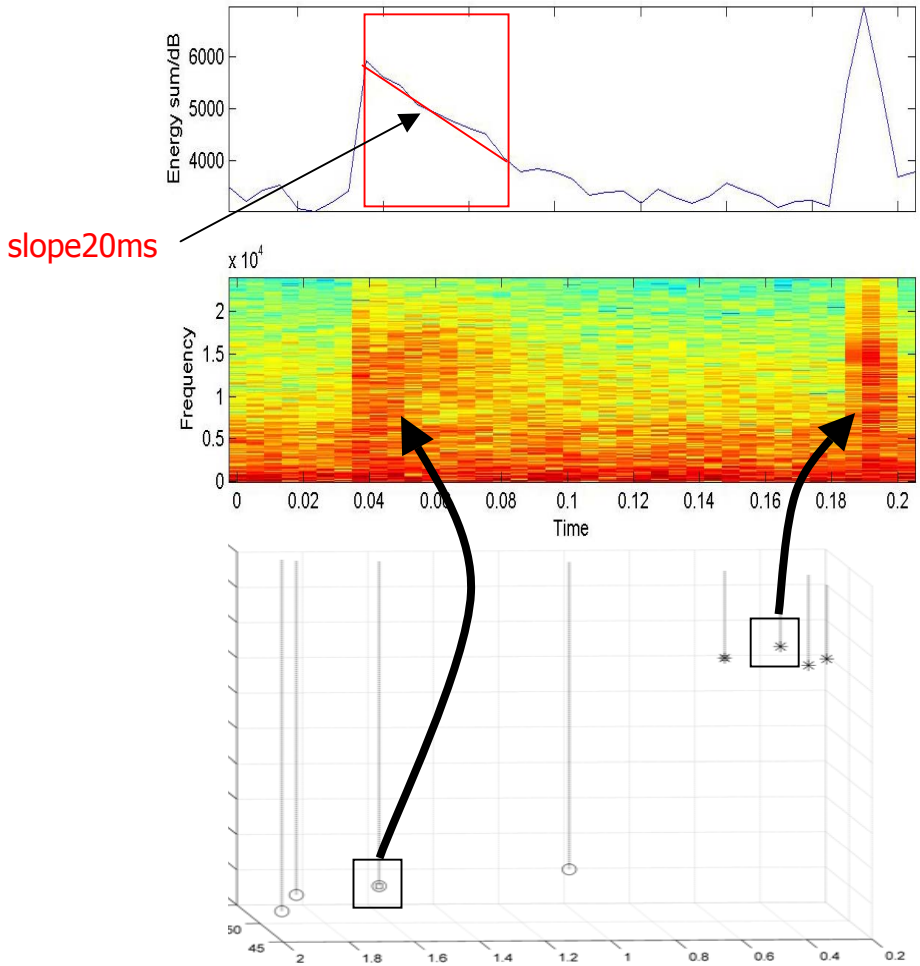
- Click detector based on variance thresholding
- Obtain onset of clicks to extract desired features
- Lack of known number of clicks per frame could lead to false positives/negatives





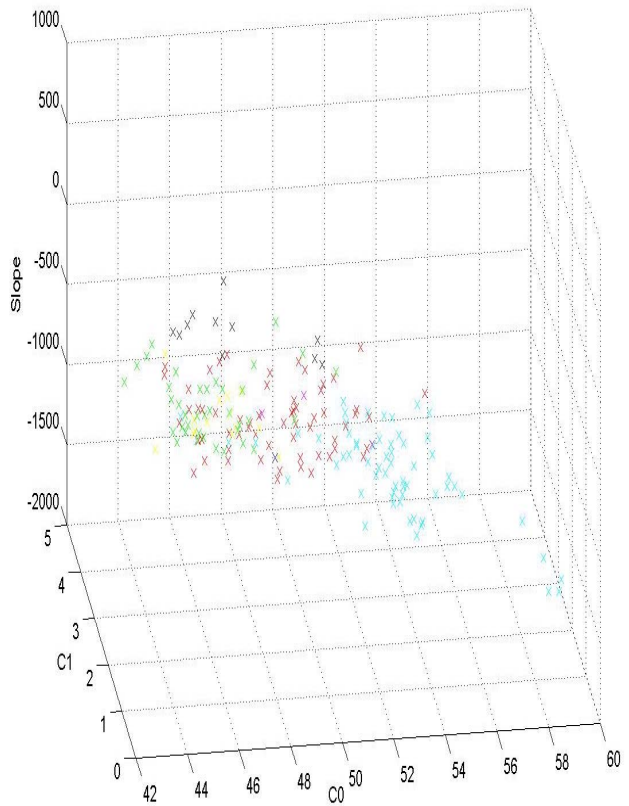
Features

- Cepstral coefficients C_0, C_1 for click time slices as obtained from click detection
  - Energy
- Energy slope at click onset in a 20msec window
  - Discriminate reverb



Spectral Clustering

- Build affinity matrix *A* using reverse euclidean distance and have Aii = 0
- Define D as the diagonal matrix whose elements are the sum of A's rows
- Form $L = D^{-1/2} A D^{-1/2}$
- Choose dominant eigenvectors of L and stack them in columns to form matrix X
  - Normalize X's rows to have unit length
- Perform Kmeans on X assuming each row as a feature vector



K for K means

- Cluster distortion

$$I_j = \sum_{t=1}^{N_j} \left[d\left(x_{jt}, w_j\right) \right]^2$$

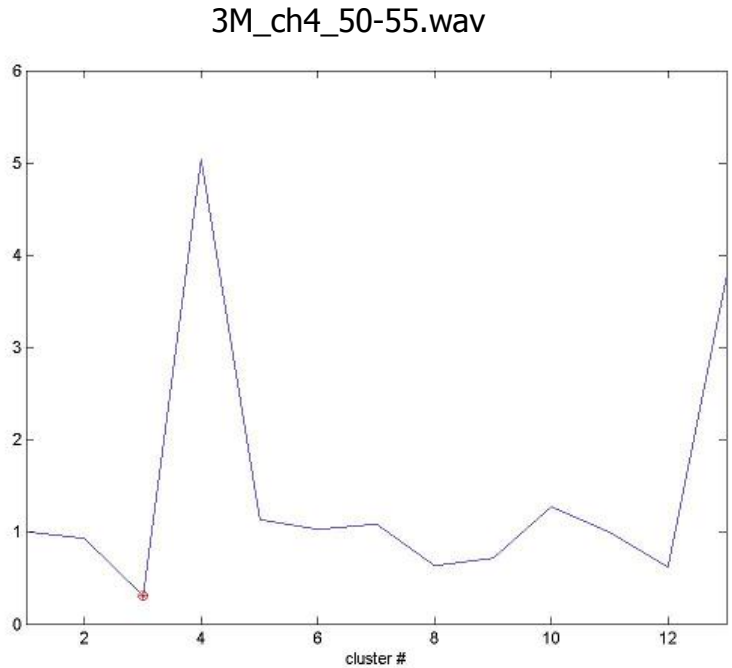
- Total distortion

$$S_K = \sum_{j=1}^{K} I_K$$

- Cluster function

$$f(K) = \begin{cases} 1 & if\ K = 1 \\ \dfrac{S_K}{\alpha_K S_{K-1}} & if\ S_{K-1} \neq 0, \forall K > 1 \\ 1 & if\ S_{K-1} = 0, \forall K > 1 \end{cases}$$

$$\alpha_K = \begin{cases} 1 - \dfrac{3}{4N_d} & if\ K = 2\ and\ N_d > 1 \\ \alpha_{K-1} + \dfrac{1 - \alpha_{K-1}}{6} & if\ K > 2\ and\ N_d > 1 \end{cases}$$



3. Experiments

- Use different hydrophones for cross-validation

Audio file (wav)	# of clusters	Size per chunk (min)	Hydrophone
3M_ch4_35-40	5	1	A
3M_ch5_35-40	7	1	B
3M_ch6_35-40	9	1	C
3M_ch4_40-45	5	1	A
3M_ch5_40-45	7	1	B
3M_ch6_40-45	7	1	C
3M_ch4_45-50	5	1	A
3M_ch5_45-50	4	1	B
3M_ch6_45-50	8	1	C
3M_ch4_50-55	5	1	A
3M_ch5_50-55	4	1	B
3M_ch6_50-55	4	1	C

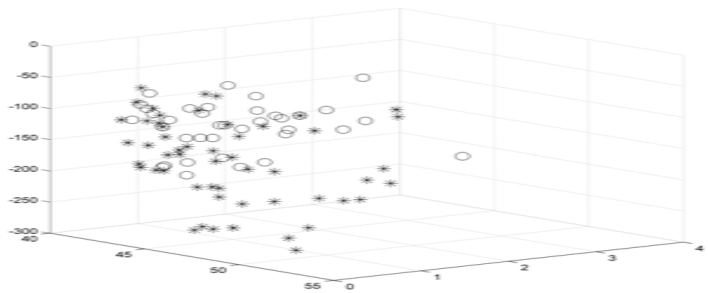
Audio file (wav)	# of clusters	Size per chunk (sec)	Hydrophone
3M_ch4_35-40	4	20	A
3M_ch5_35-40	5	20	B
3M_ch6_35-40	4	20	C
3M_ch4_40-45	5	20	A
3M_ch5_40-45	5	20	B
3M_ch6_40-45	6	20	C
3M_ch4_45-50	4	20	A
3M_ch5_45-50	4	20	B
3M_ch6_45-50	4	20	C
3M_ch4_50-55	3	20	A
3M_ch5_50-55	4	20	B
3M_ch6_50-55	4	20	C

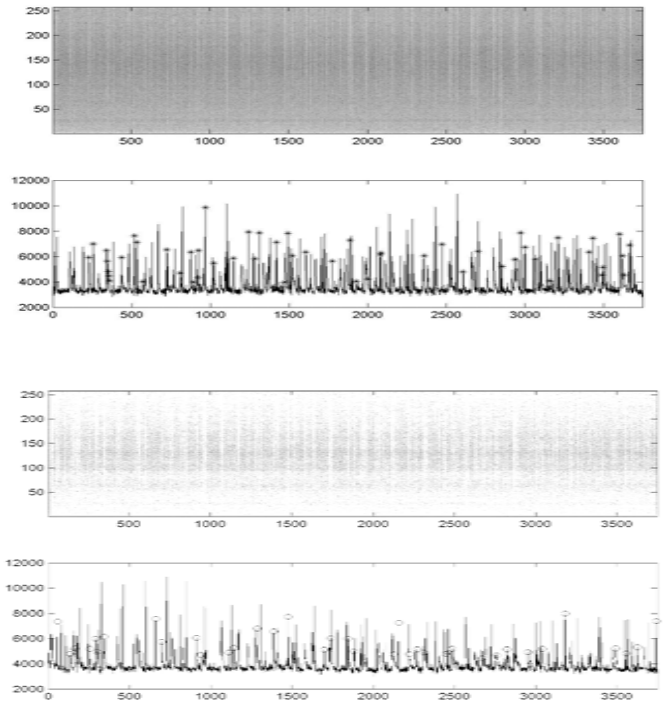
KL Divergence

- Assume single gaussian distributions for each cluster to have closed form

$$KL_N(\mu_p, \Sigma_p; \mu_q, \Sigma_q) =$$

$$\log \frac{|\Sigma_q|}{|\Sigma_p|} + Tr\left(\Sigma_q^{-1}\Sigma_p\right) + \left(\mu_p - \mu_q\right)^{-1}\Sigma_q^{-1}\left(\mu_p - \mu_q\right)$$





4. Conclusions

- Approximate number of marine mammals in area with the use of recordings from one mic
- Take advantage of click inter-timing for localization of sperm whales
- Different features could yield a better result
  - Energy ratios
- Cross-correlation with different hydrophones will identify individual whales
- In order to have a full verification of the above absolute ground truth is needed