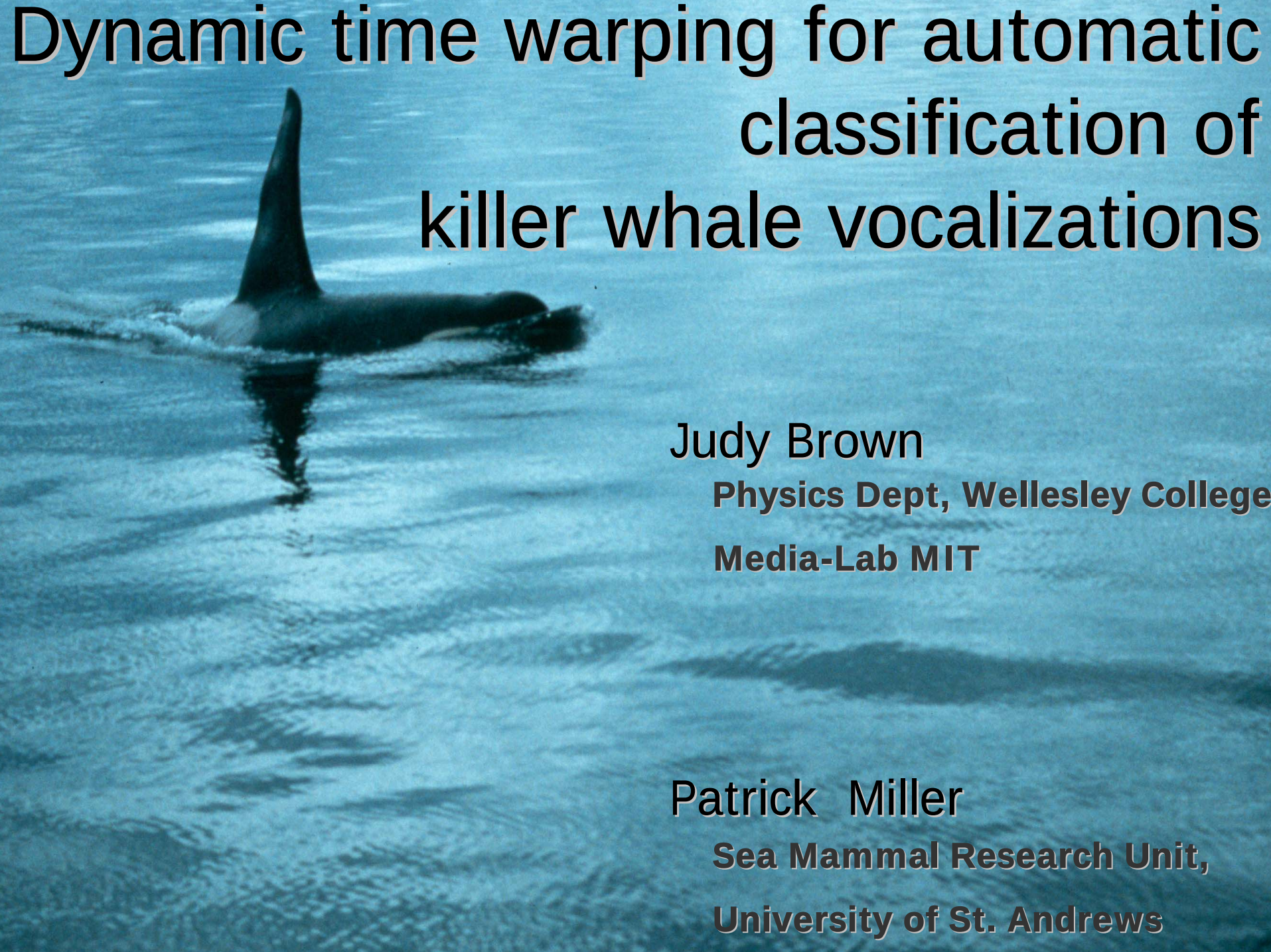
Dynamic time warping for automatic classification of killer whale vocalizations



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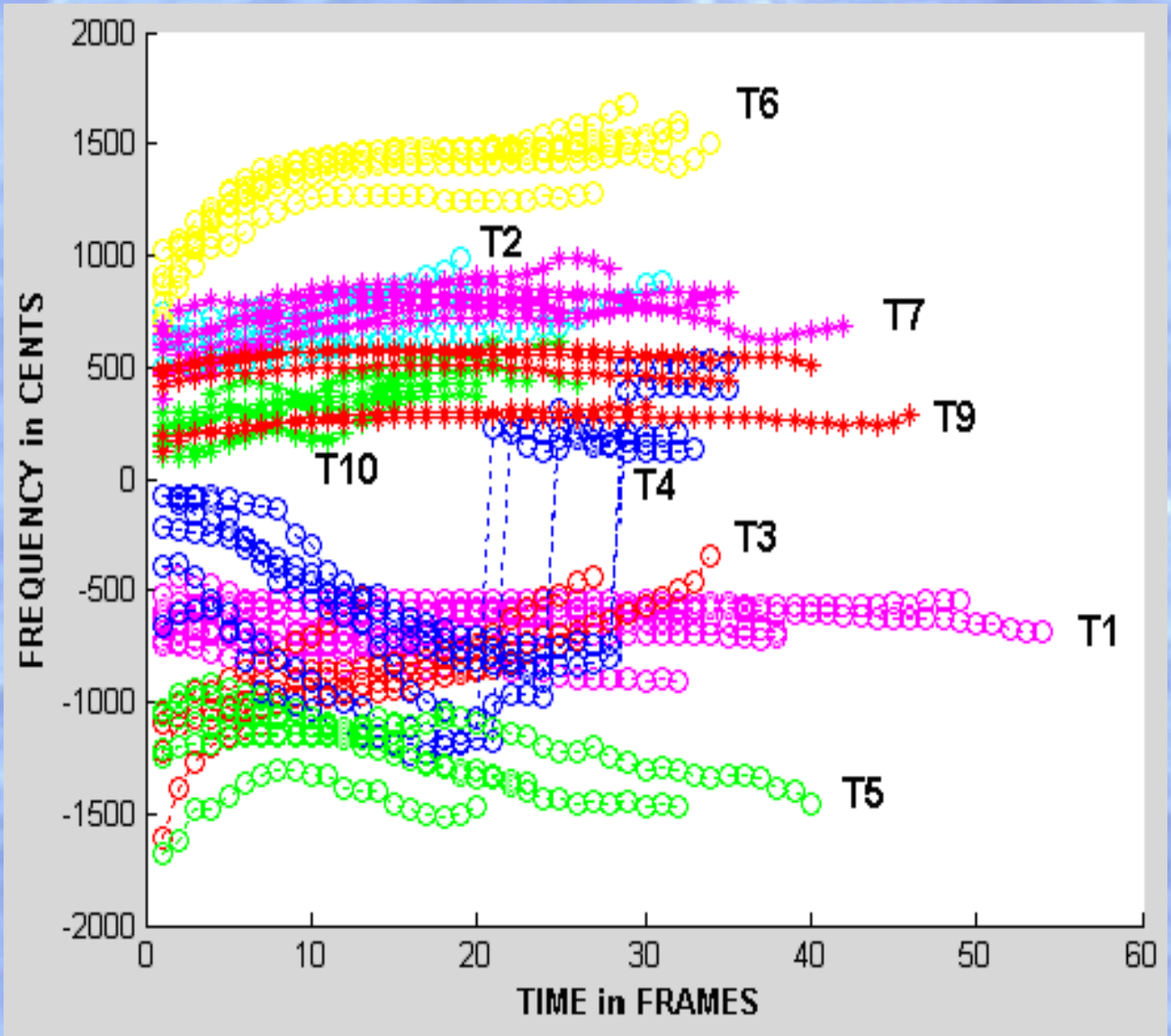
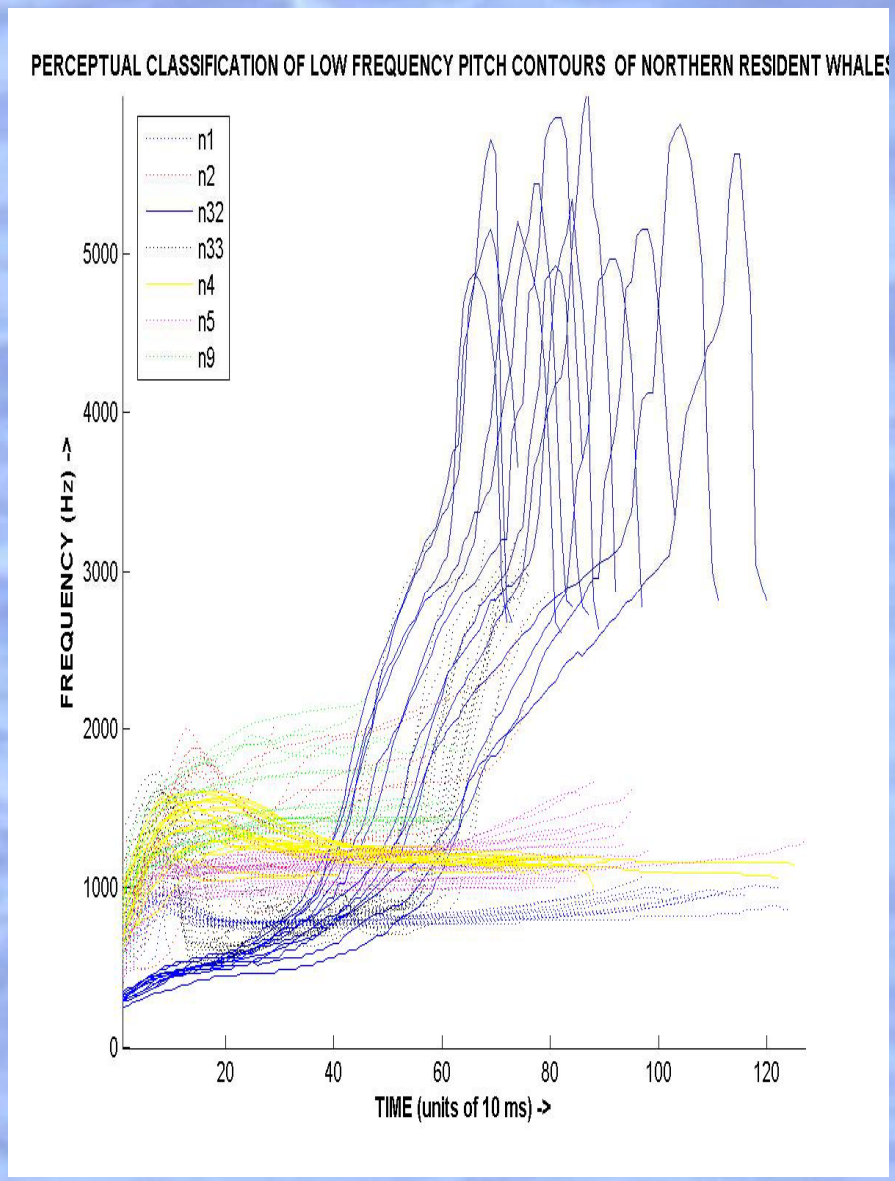
the Plan :

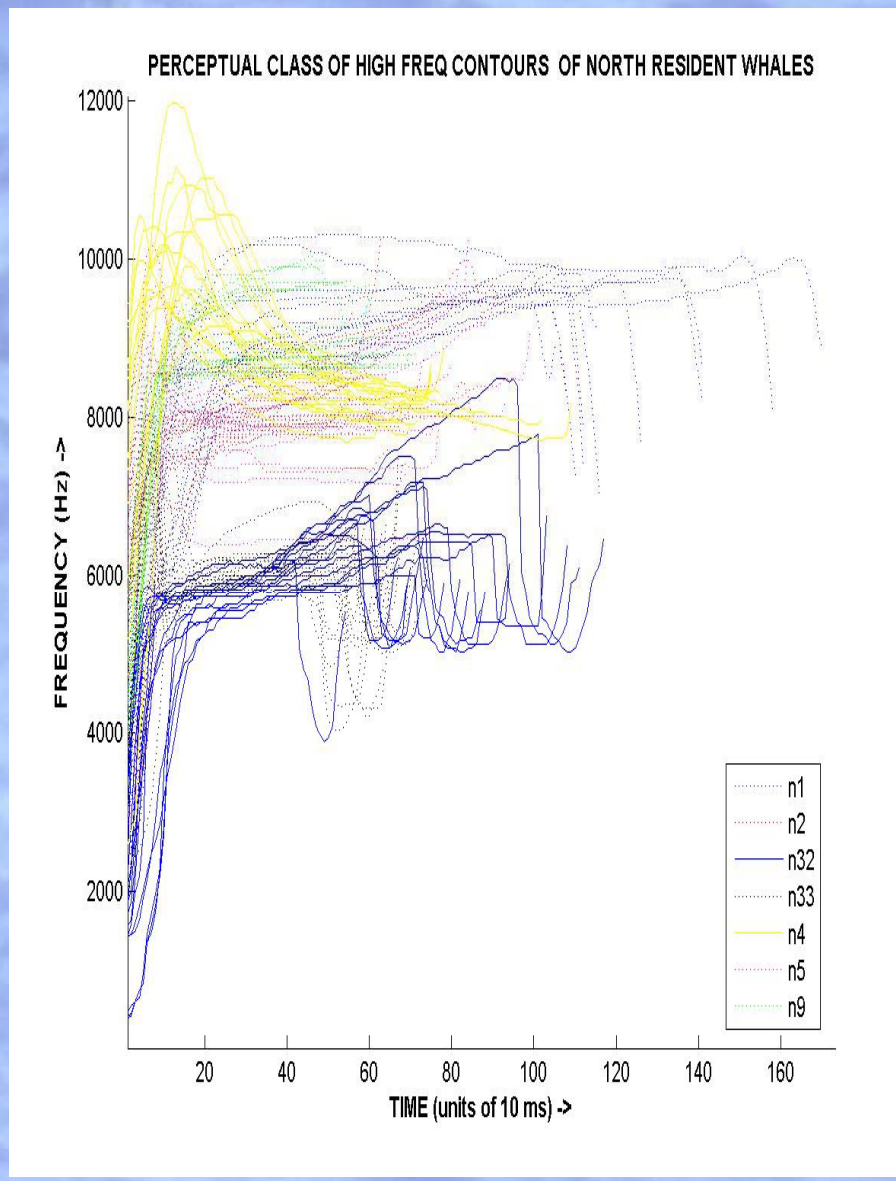
- **Data: Pitch contours from two sets of vocalizations previously classified perceptually**
  - **Marineland group – 9 call types**
  - **Northern resident whales - 7 call types**
- **Digression: two-source calls**
- **Dynamic time warping for automatic classification of pitch contours**
- **Results**

Pitch contours of Marineland set



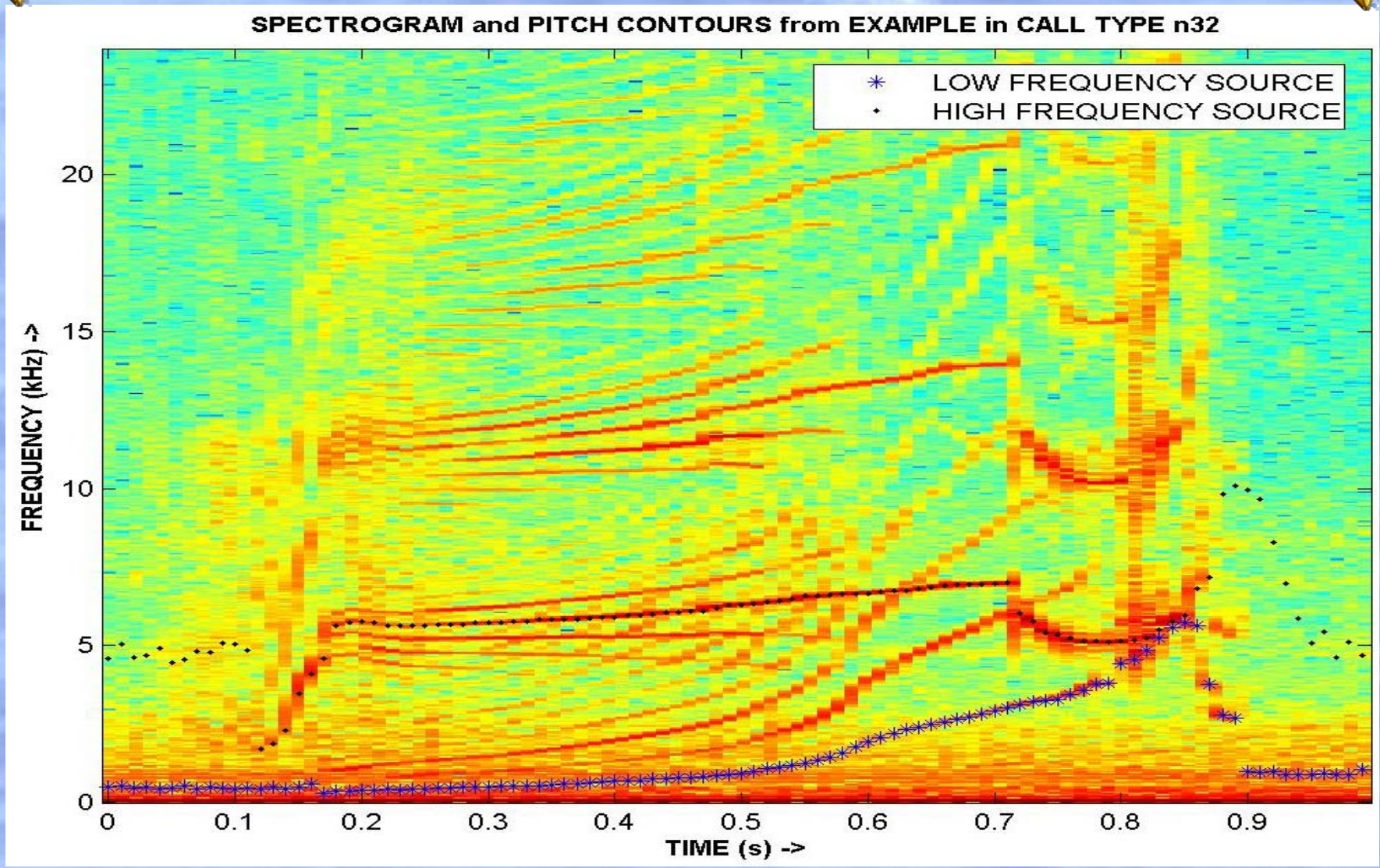
Pitch contours of Northern resident set





Example with low freq and high freq sources

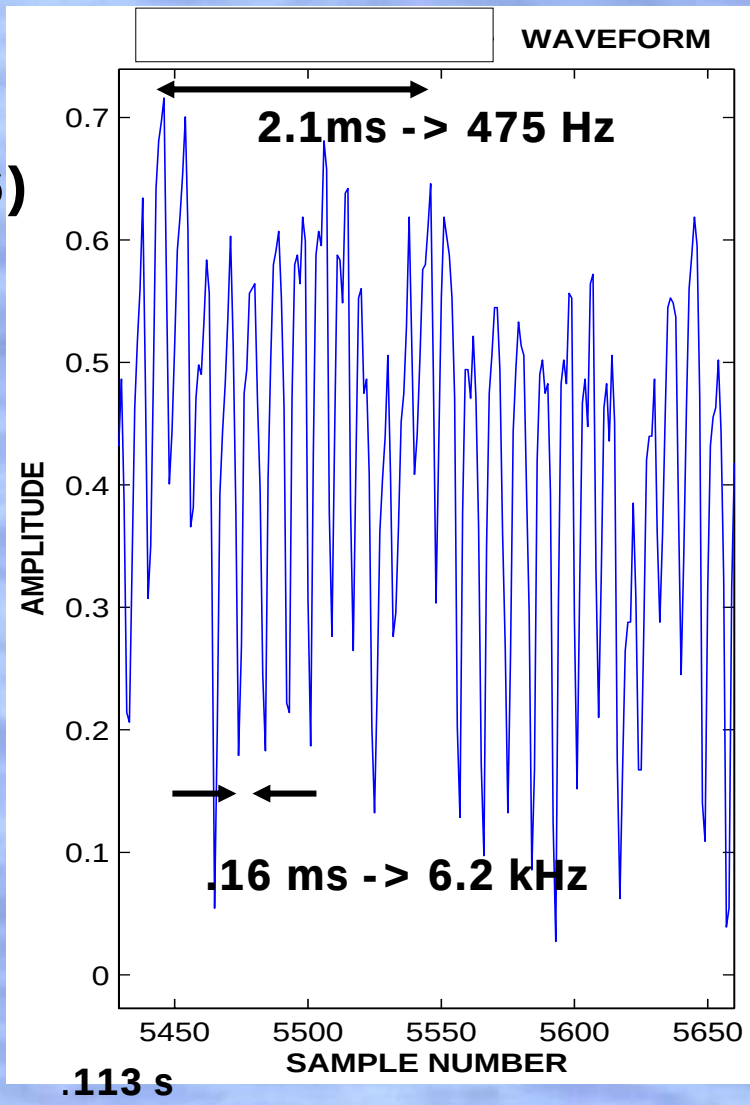
(slowed by 6)



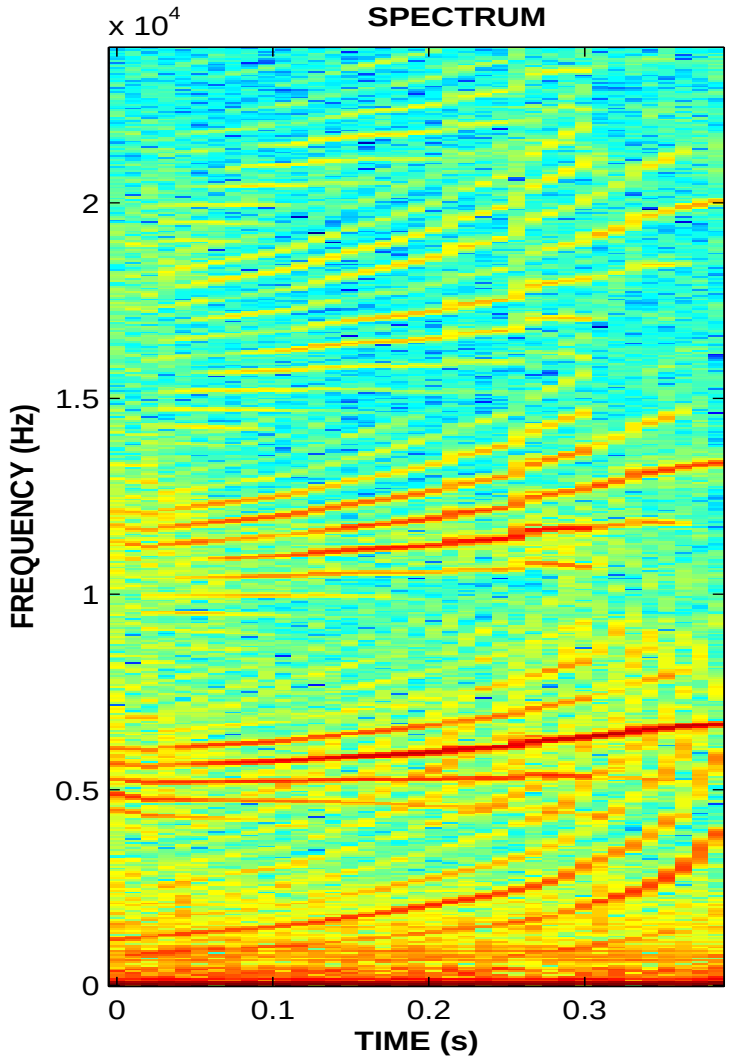
Digression: Mechanism for Two Sources

Central portion of Call

(slowed by 6)



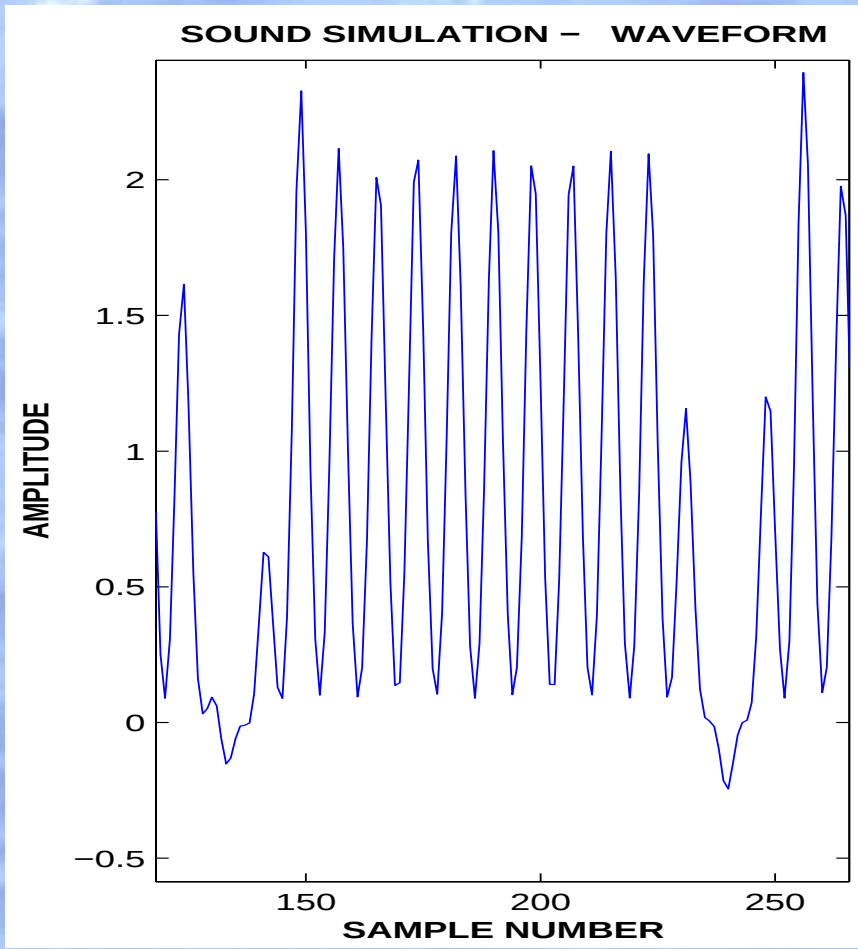
.113 s

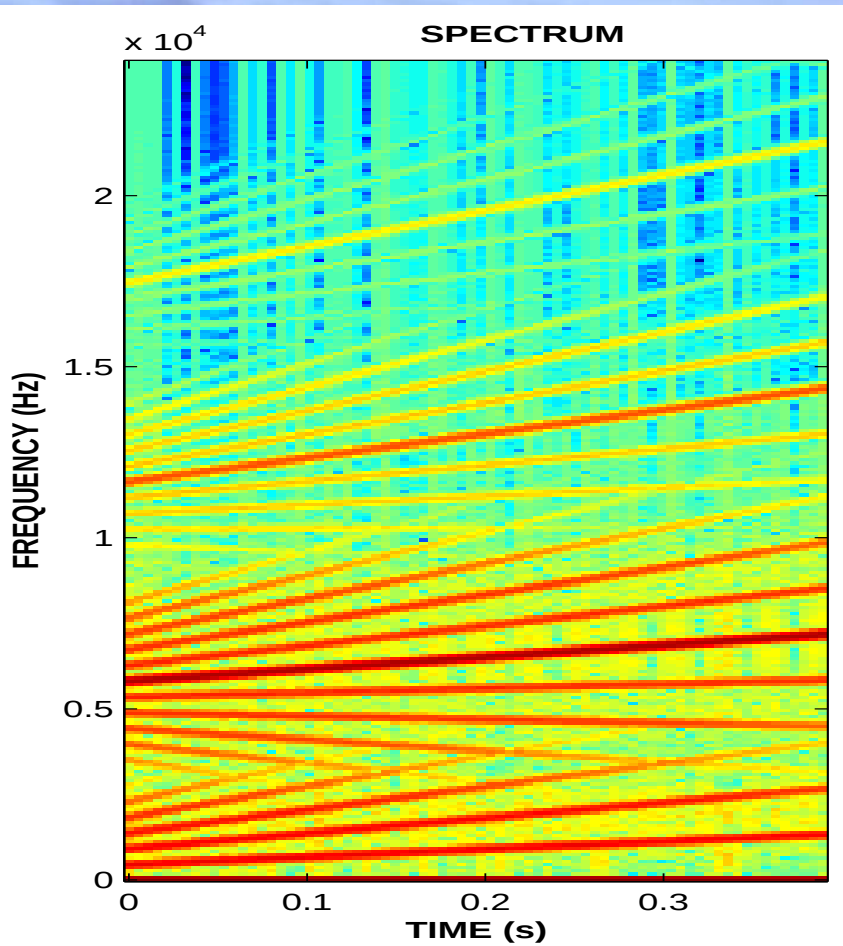


SIMULATION

(slowed by 6)

LOW FREQUENCY COMPONENT 450 - 900 Hz
HIGH FREQUENCY COMPONENT 5800 - 6500 Hz

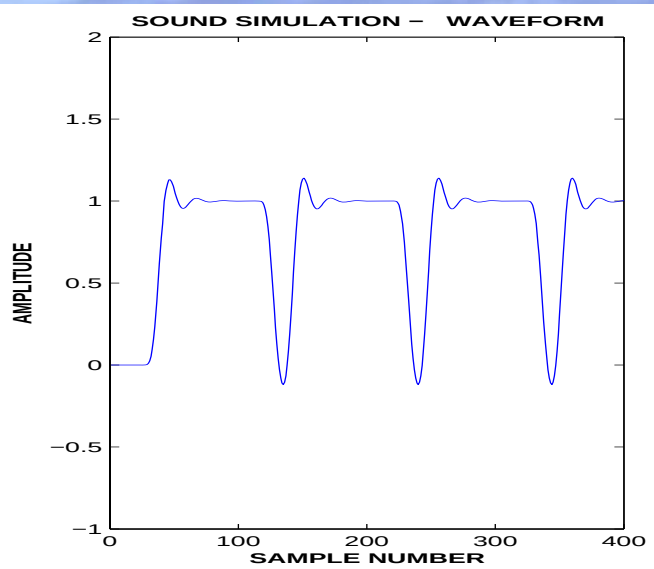


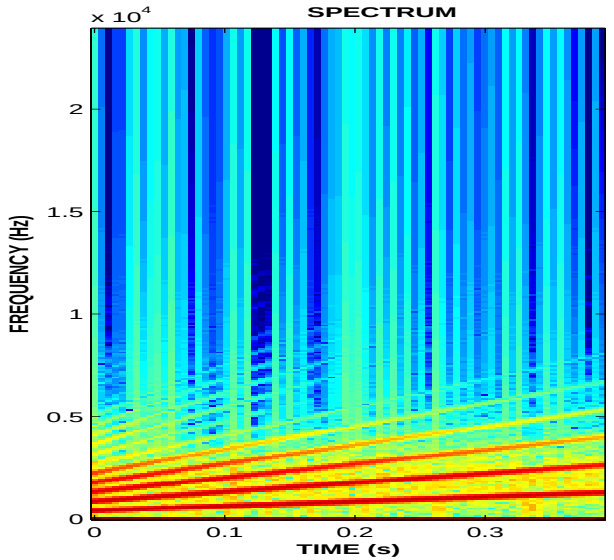


SIMULATION

LOW FREQUENCY COMPONENT
450 - 900 Hz

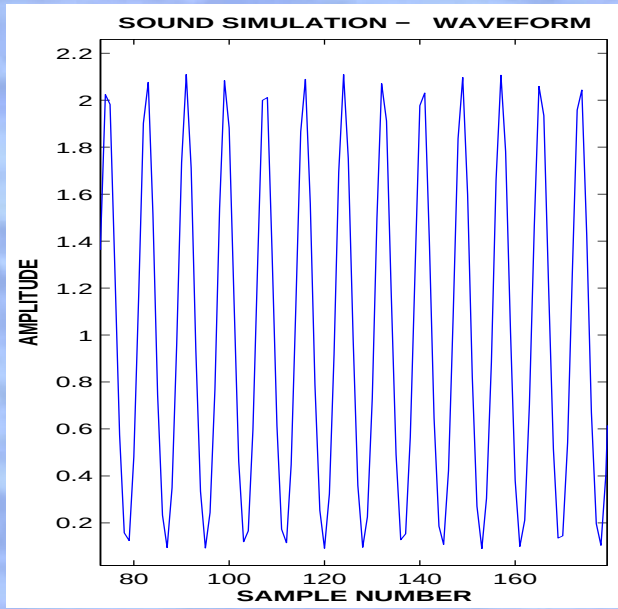
(slowed by 6)

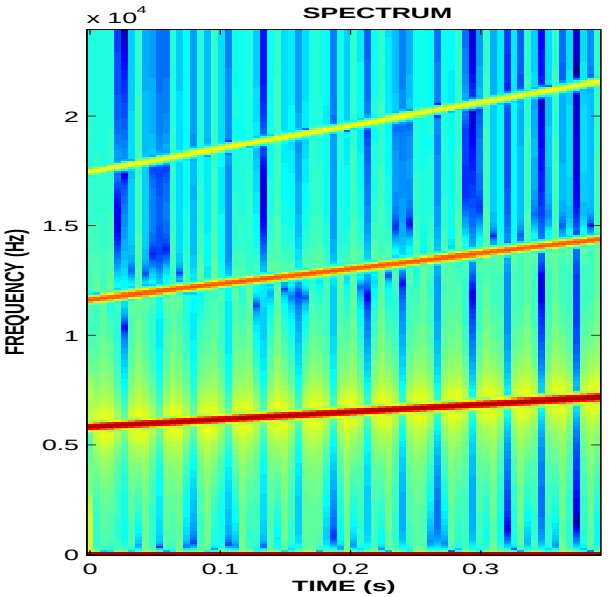




HIGH FREQUENCY COMPONENT
5800 - 6500 Hz

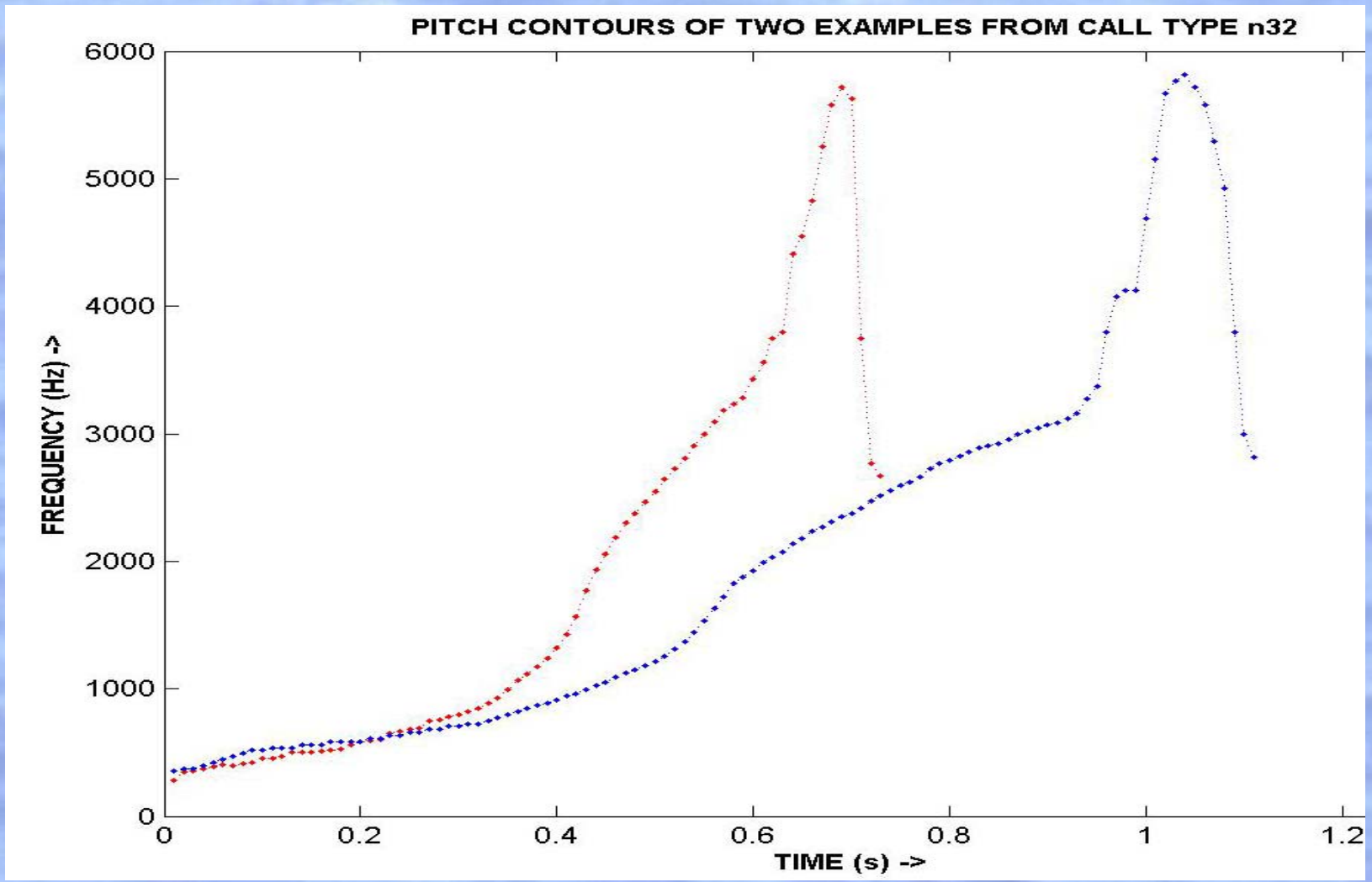
(slowed by 6)





Dynamic Time Warping : the Goal

Compare contours and quantify the difference.



Difference Matrix

$$D[i,j] = |T(j) - Q(i)|$$

Q\T	1	2	3	4	5
3	2	1	0	1	2
4	3	2	1	0	1
5	4	3	2	1	0
4	3	2	1	0	1

Difference Matrix and Cost Matrix

D[i,j] = |**T**(j) - **Q**(i)|

q\t	1	2	3	4	5
3	2	1	0	1	2
4	3	2	1	0	1
5	4	3	2	1	0
4	3	2	1	0	1

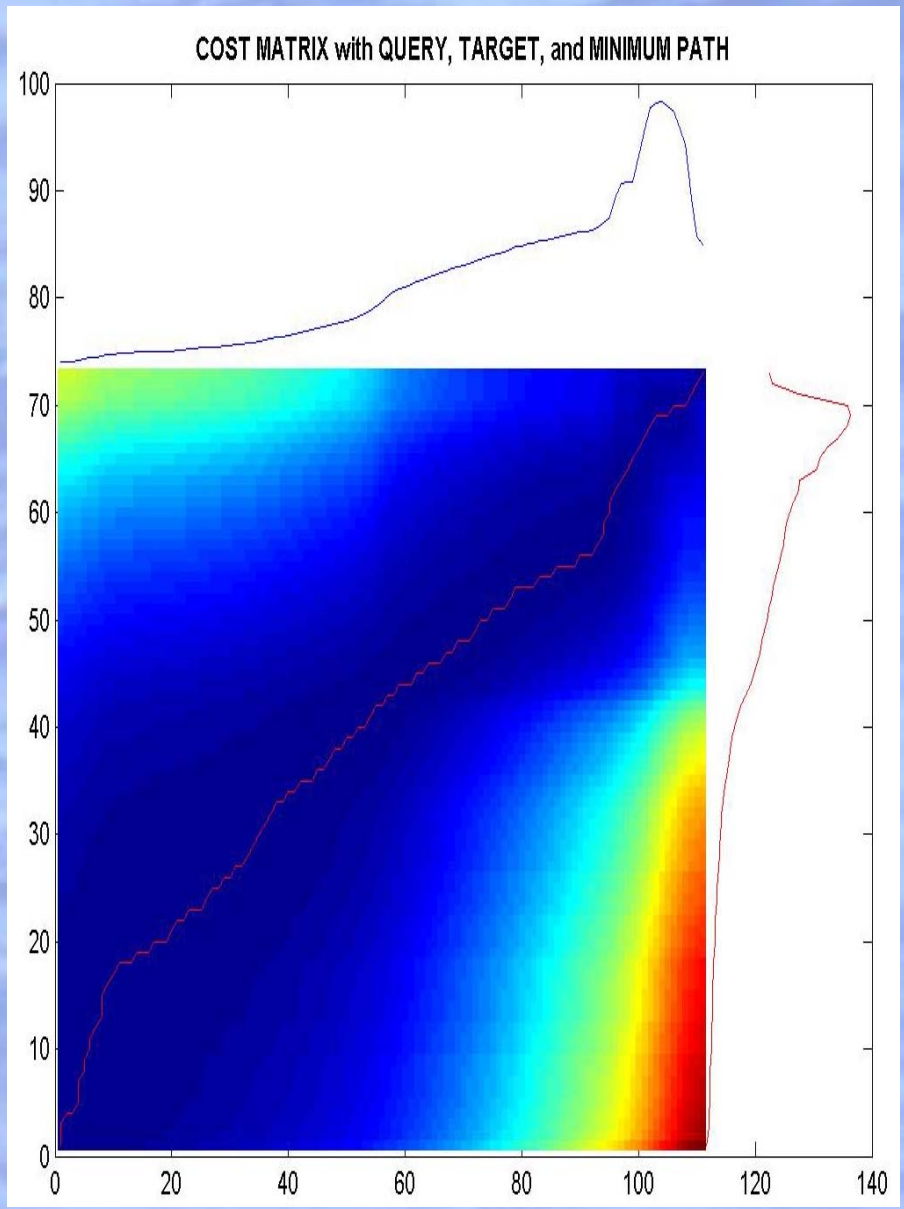
M(i – 1, j-1) + **D**(i,j)	**M**(i – 1, j) + insertion cost
M(i , j-1) + deletion cost	**M**(i,j) = minimum of the three

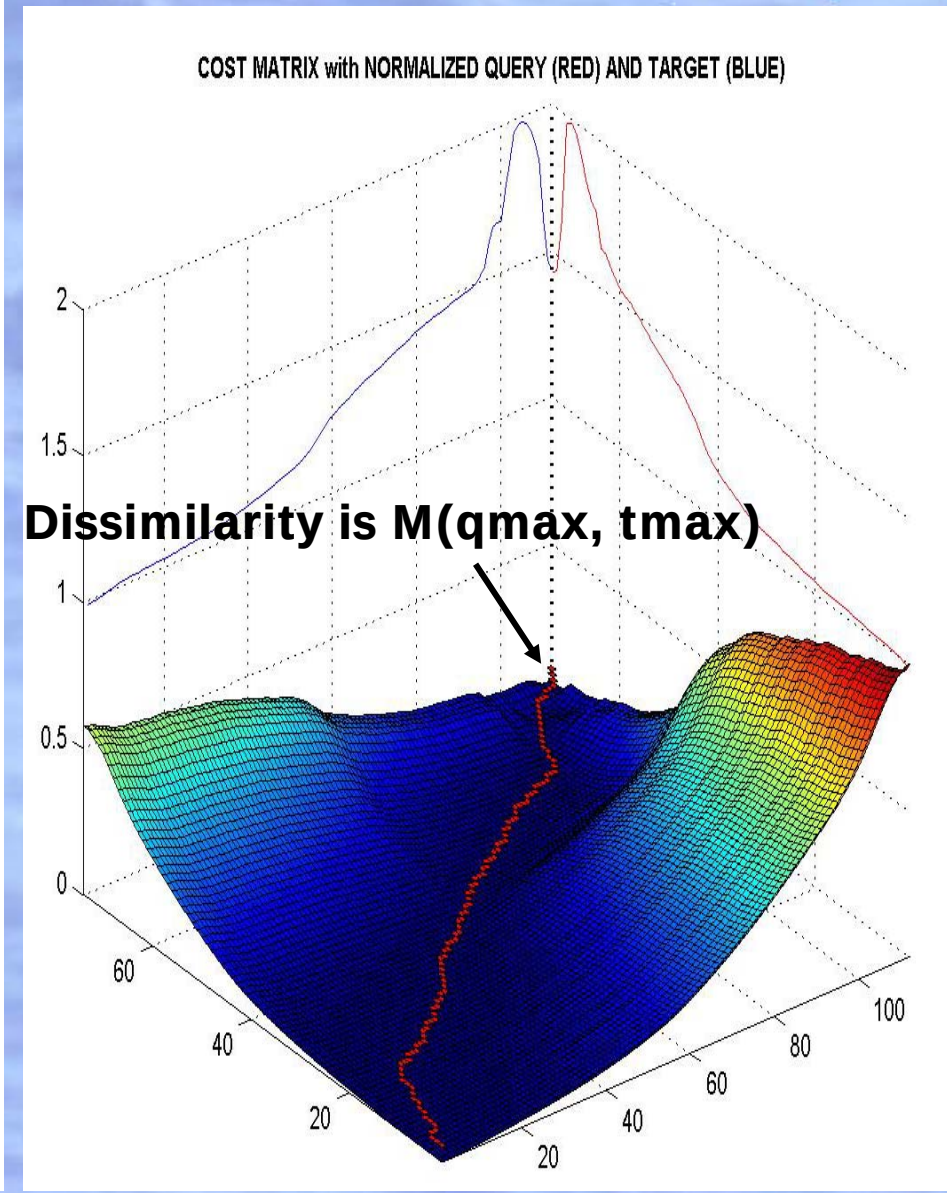
M =

Example: insertion = 1 deletion = 0

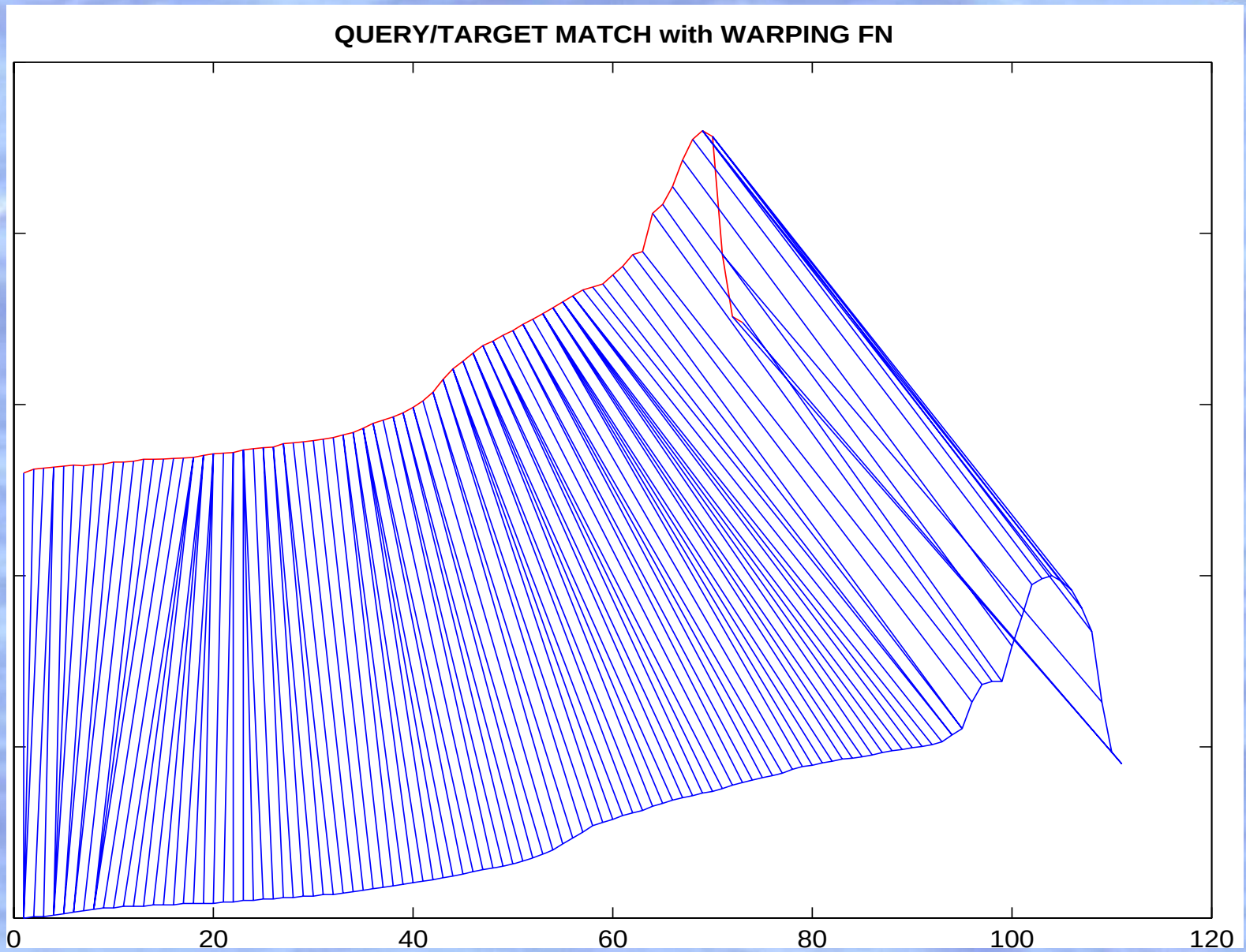
Q\T		1	2	3	4	5
	0	0	0	0	0	0
3	1	1	1	1		
4	2	2	2			
5	3	3				
4	4	4				

Cost Matrix with Query and Target

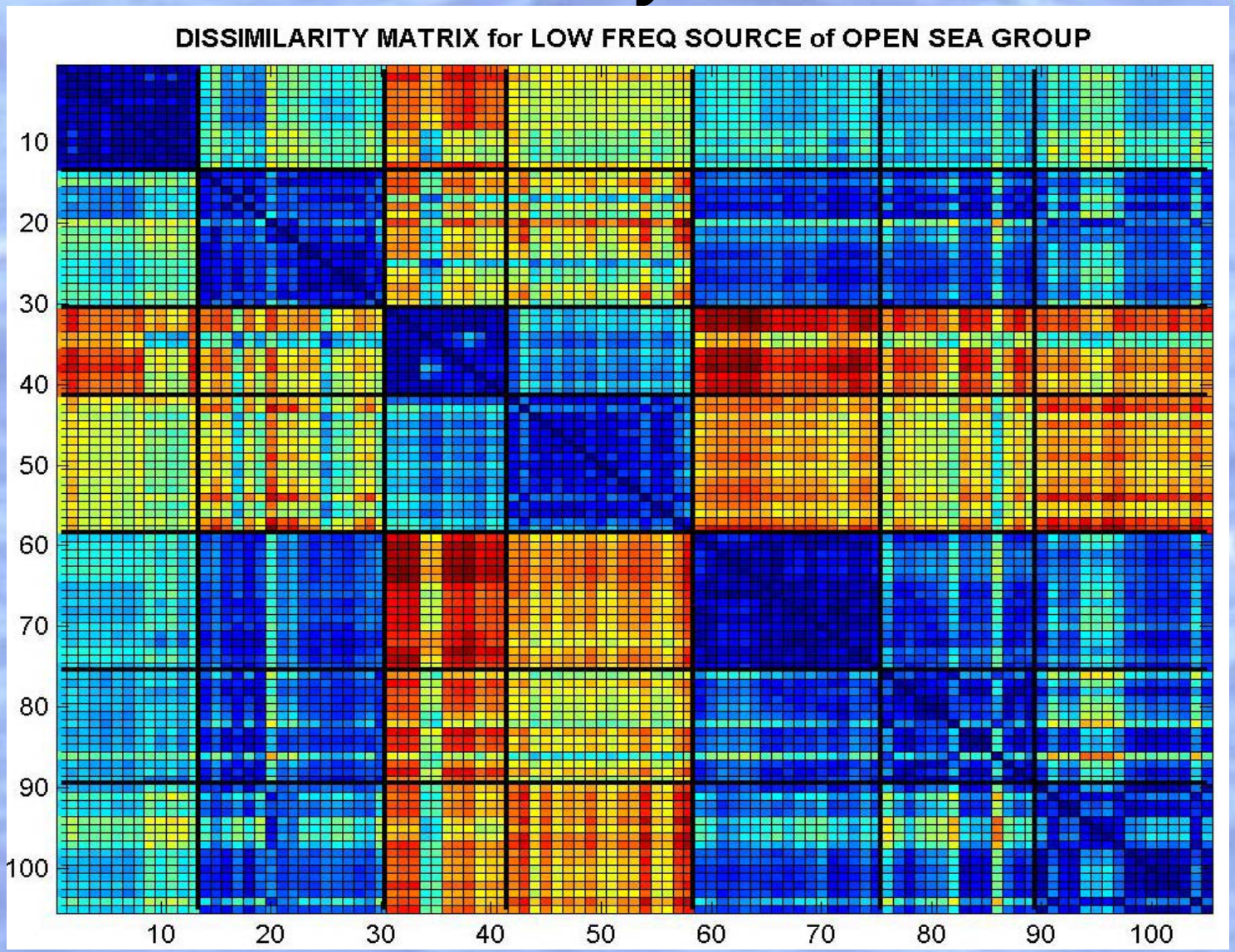




Warping Function=Minimum Path

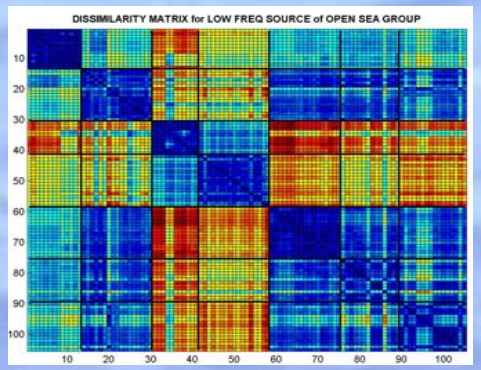


Dissimilarity Matrix



n1 n2 n32 n33 n4 n5 n9

Clustering



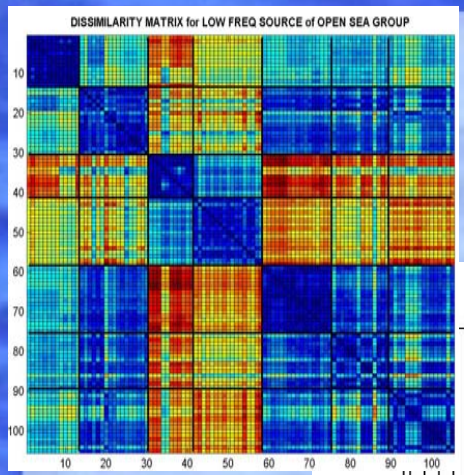
⟶ **DISTANCES**

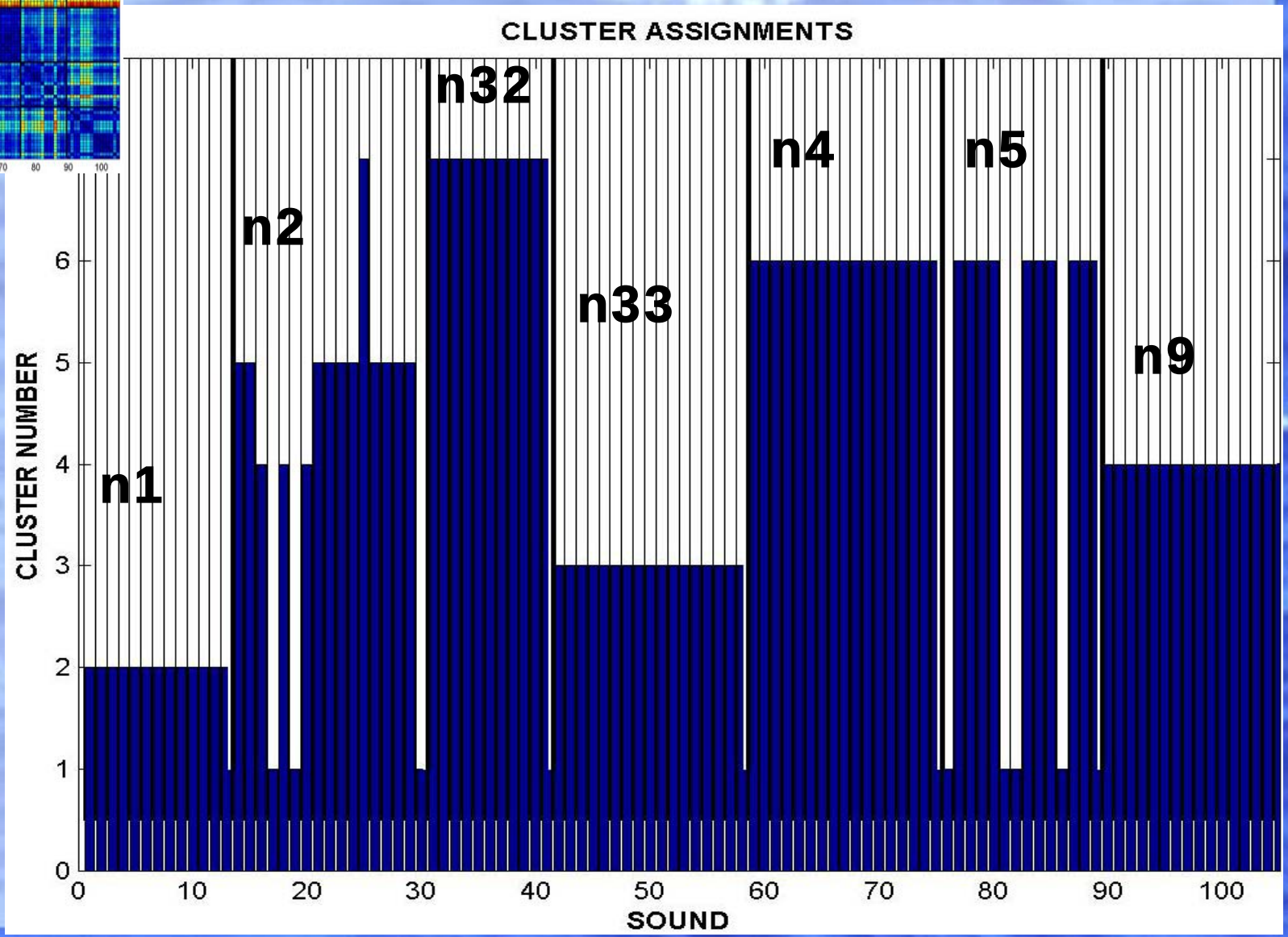
MULTIDIMENSIONAL SCALING (mds)

Distances → Positions in coordinate-like Space

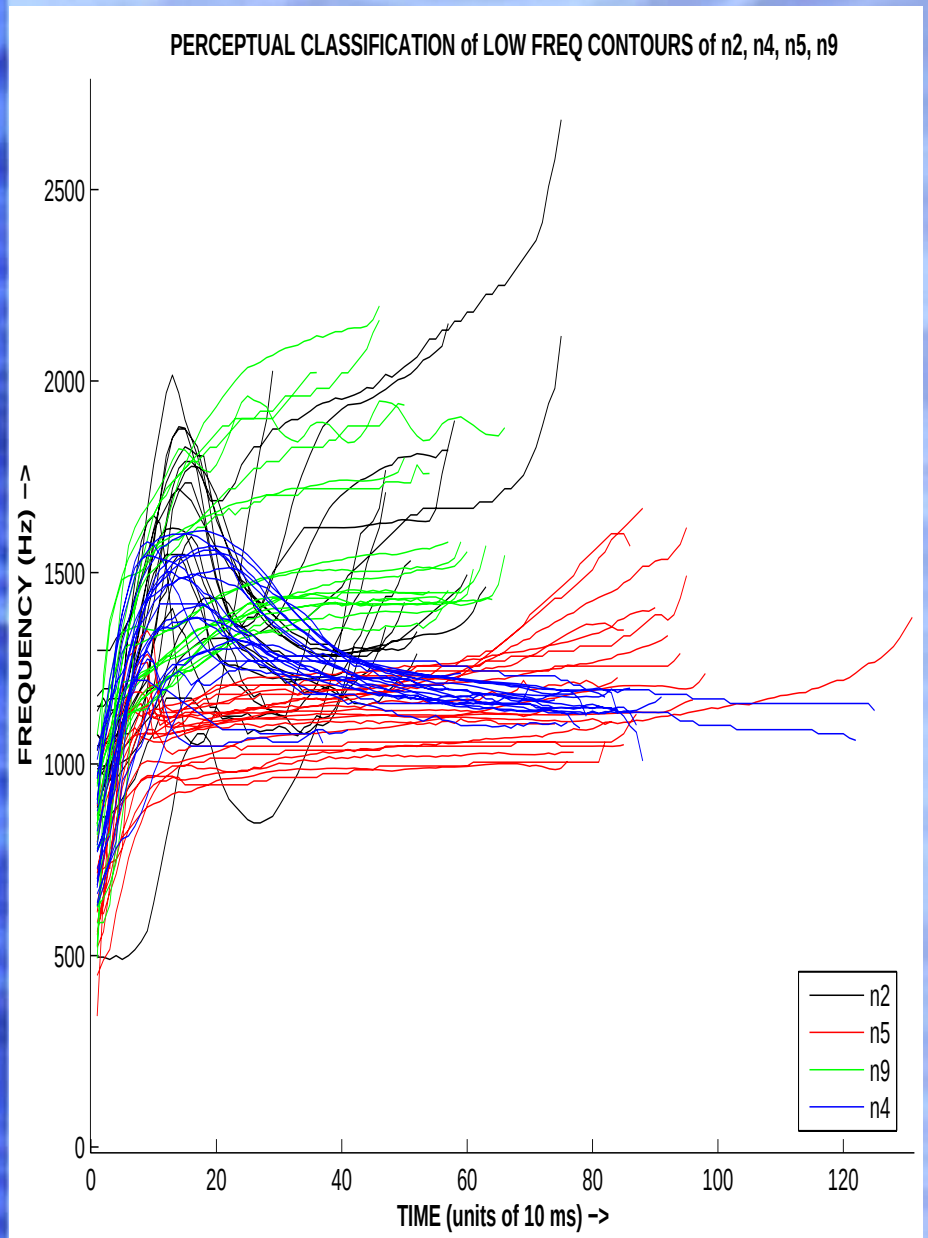
CLUSTERING – Form groups with minimum distances within a group

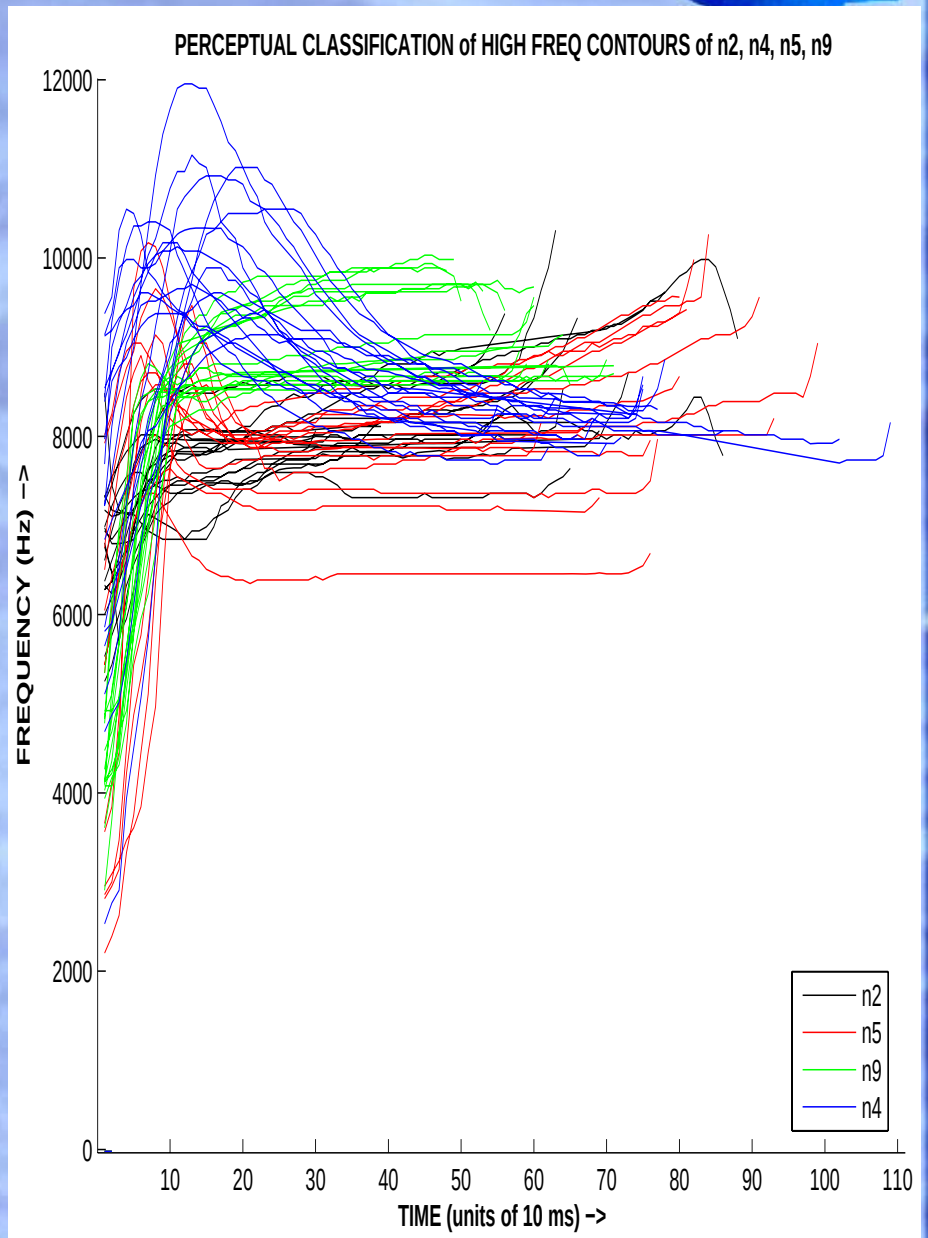
Clustering Results



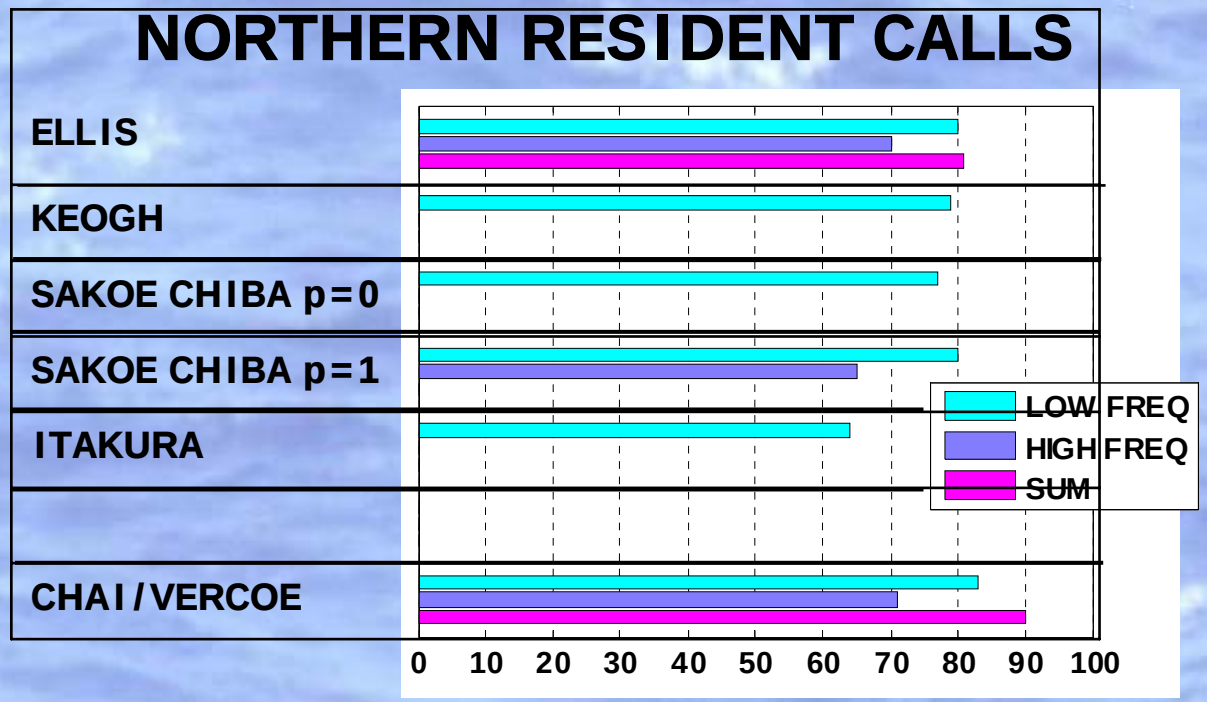


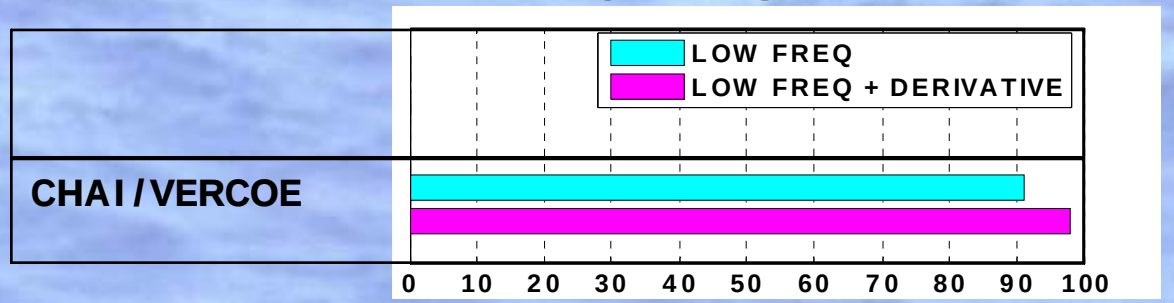
Another Look at n2, n4, n5, n9





Results


NORTHERN RESIDENT CALLS
ELLIS
KEOGH
SAKOE CHIBA p=0
SAKOE CHIBA p=1
ITAKURA
CHAI/VERCOE
LOW FREQ
HIGH FREQ
SUM
0 10 20 30 40 50 60 70 80 90 100


MARINELAND CALLS
CHAI/VERCOE
LOW FREQ
LOW FREQ + DERIVATIVE
0 10 20 30 40 50 60 70 80 90 100

CONCLUSIONS

- **UPSIDE**
  - **HIGH ACCURACY for SEPARATED CONTOURS**
  - **VALIDITY of COMPARISON to HUMAN CLASSIFICATION ?**

- **DOWNSIDE**
  - **TIME-CONSUMING MEASUREMENT of the PITCH CONTOURS**

Brown, J. C., A. Hodgins-Davis, and P. J. O. Miller (2006).
"Classification of vocalizations of killer whales using dynamic time warping"
J. Acoust. Soc. Am. 119, EL34-EL40.

Acknowledgements:

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