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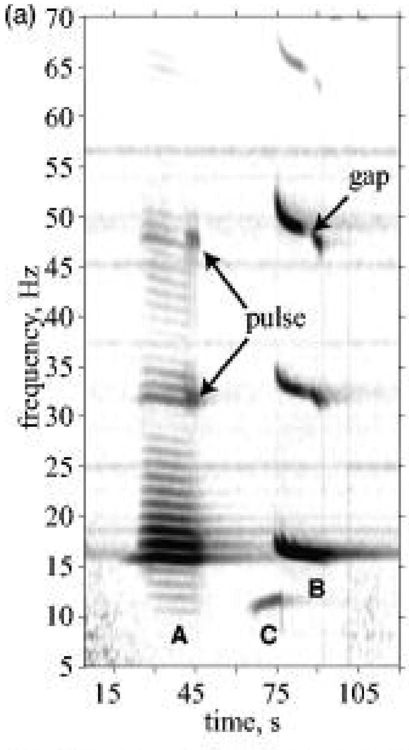
Using spectrogram cross-correlation to detect blue whale calls



North East Pacific blue whales have distinct calls which are split into several segments. The spectrogram shows the A, B, and C call harmonics of the NEP blue whale (Dunn and Hernandez, 2009). The B call is the most powerful of the three, and is often the only one visible when a call is recorded of a whale some distance away from the recording instrument. For that reason, the B call is used to detect the whales acoustically. The relative consistency of blue whale call frequency modulation allows us to automatically detect calls through spectrogram cross correlation.

For this exercise, we are using data from a ocean-bottom seismometer with a sample rate of 50 Hz.

1) Draw a line at the Nyquist frequency of a 50 Hz instrument on the spectrogram. Circle the B call harmonic that would appear on a spectrogram at that sample rate.

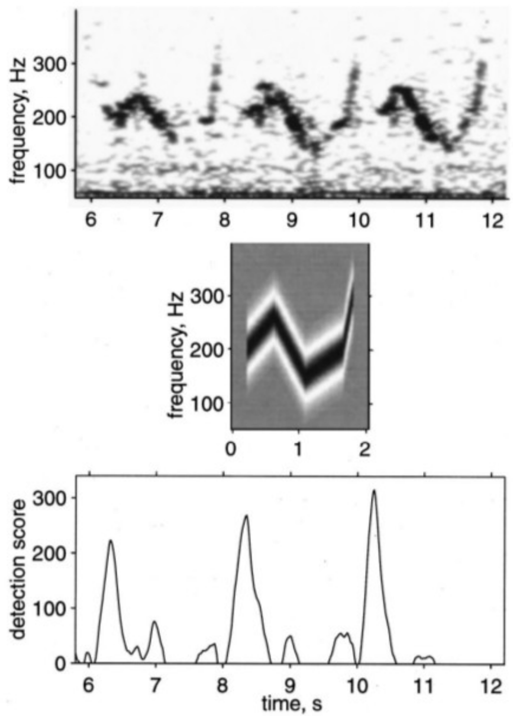
2) Predict: Why do you think we use spectrogram cross-correlation to detect blue whale calls rather than 1-D waveform cross-correlation?

Add the folder 'Wade_Project522' to your MATLAB path. Open 'showWaveformsSpects.m' in MATLAB editor. Click run, and select 'strongCalls.wav' from the user interface that appears. You can see the both the A and B blue whale calls in the spectrogram and corresponding waveform. Now, run the script again and select 'weakCalls.wav'. Observe that the A calls have faded away, and while the B calls are distinct on the spectrogram they are indistinct in the waveform. Does this support your answer to question 2? If not, refine your answer.

How is a spectrogram cross-correlator implemented?

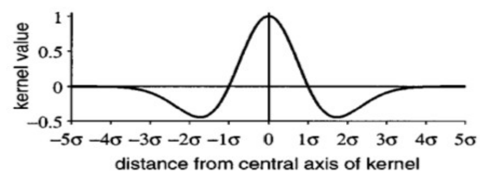
To build a spectrogram cross-correlator to detect calls automatically, a synthetic call image must be built which is representative of the average call. The term for this synthetic call is a kernel. Like in waveform cross-correlation, the spectrogram and the sample are slid past each other, multiplying each set of overlapping values together. Then, to produce a single detection score for each frame of overlap, the resulting matrix of values is summed together.

Let's look at an example kernel that was built to detect bowhead whales.



The upper left image shows three successive bowhead whale calls (Mellinger and Clark, 2000).

The middle image shows the kernel that was developed to detect bowhead whale calls through spectrogram cross-correlation. The kernel is built with repeating 'hat functions' (right figure) parallel to the y axis. The area under the positive section is equal to the area under the two negative sections. This prevents non-whale signals which cross the frequency band of the kernel from giving large spikes in the detection score.



The lower image shows the detection score of each overlapping frame as the kernel is moved across the spectrogram.

Building a blue whale B call kernel

3) Blue whale B calls have simpler frequency modulation than bowhead whales. Look at the call spectrograms you produced again. Draw a rough sketch of what you think the shape of a blue whale B call kernel should look like.

The best shape for a blue whale B call kernel is a simple downswept linear segment. Using the two spectrograms already produced in this exercise, zoom in on each B call and look at it's characteristics.

4) Using all 6 displayed calls, estimate and record these parameters:

- Average call length (in seconds)
- Average call start frequency
- Average call end frequency
- Average bandwidth (for these purposes defined as the width of the call in the frequency domain, divided by 2)
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5) Open 'makeBlueKernel.m' in the MATLAB editor. A function to create a single segment kernel is already written for your convenience. All you need to do is define the parameters. Use your average measurements of the B calls to fill in the blank parameters.

- fo=average start frequency
- f1=average end frequency
- bndwith=average bandwidth
- dur=average call length

Save your changes to the function.

<u>Implementing a spectrogram cross-correlator</u>

The file 'J28A BHZ.20120221T000001.0132.wav' contains one day of data from an ocean-bottom seismometer when a blue whale was present and calling. We will test the accuracy of your kernel parameters by running a spectrogram cross-correlator on a two-hour section this file, and checking to see if the kernel detects the blue whale B calls.

6) Open 'BlueBcallDetector.m' in the MATLAB editor. This script will use the parameters you defined in 'makeBlueKernel.m' to build the blue whale kernel and run the spectrogram cross-correlator on it's own.

- Click run.
- Look at the kernel shown in figure 1.
- A waveform, spectrogram, and cross-correlation graph will be produced for every 5 minutes of data.
- The script will pause after each figure is produced. Press any key to continue. Look at each figure to see if obvious calls produce a spike in the cross-correlation function. Peaks that cross the threshold defined by the horizontal red line are considered detected calls.
- If calls do not cause an increase in the cross-correlation function, you may need to redefine your kernel parameters. See of you can optimize the parameters to produce the best cross-correlation function.

7) Redefine the kernel parameters and run again. I found these to be the most efficient at detecting calls:

- f0=15.7;
- f1=14.4;
- bndwth=.5;
- dur=10;

8) How well did your kernel parameters perform compared with the ones provided? Did signals other than blue whale B calls cause a spike in the cross-correlation function? Can you think of any ways to reduce these false detections?

References

Mellinger, D. K., & Clark, C. W. (2000). Recognizing transient low-frequency whale sounds by spectrogram correlation. *The Journal of the Acoustical Society of America J. Acoust. Soc. Am., 107*(6), 3518. doi:10.1121/1.429434

Dunn, R. A., & Hernandez, O. (2009). Tracking blue whales in the eastern tropical Pacific with an ocean-bottom seismometer and hydrophone array. *The Journal of the Acoustical Society of America J. Acoust. Soc. Am., 126*(3), 1084. doi:10.1121/1.3158929