

## Simultaneous source deblending with the radially and source-similarity attributes

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### Summary

Seemingly unrelated developments in seismic methods are broadband, multi-component sensors, and simultaneous sources. In this paper we explain how these are related.

Different sources have different voices that can be recognized. Multi-component sensors provide information on the direction of the source of incoming waves.

We have developed a method that assigns a probability to the existence of simultaneous source interference indicating the likelihood that at any certain time on any certain trace, interference originated from one source or another. To estimate this probability, we compute two attributes, which we call radially and source-signature similarity. Radiality is calculated from data with horizontal components such as multi-component land or ocean bottom nodes seismometers or multi-sensor streamers. Similarity can be calculated when different sources have different source signatures or voices. The goal of this work is to use this probability as additional information in processing simultaneous source data.

### Introduction

As humans we have a remarkable ability to focus our attention on one voice and one direction in a crowd. As an industry we are developing methods to give data processing similar capabilities so that seismic data can be acquired more efficiently using simultaneous sources. Such data are commonly called blended data and the process of focusing attention on the sources one by one or imaging them together and avoiding cross talk artifacts is commonly called deblending. In the context of auditory perception, this is known as the cocktail-party problem (Ikelle, 2007).

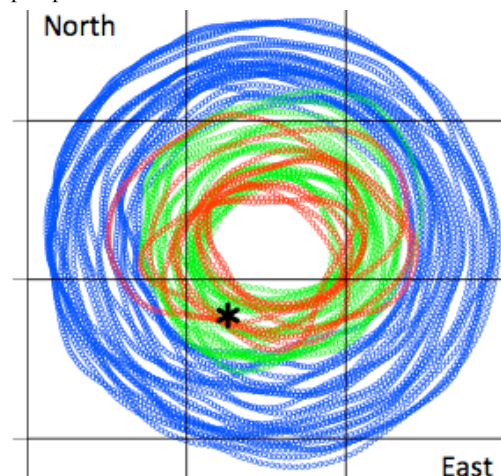
The human brain is using auxiliary data in addition to the main audio channel. We use the directivity; without two ears or the ability to turn, we would not have the ability to identify the direction from which acoustic waves are coming. We also use voice discrimination; we can focus on one voice.

We can design seismic surveys so our data processing can use similar auxiliary to deblend. In particular, we can record multi-component data on land and on the seabed and multi-sensor data in seismic streamers. We are already recording such data for other purposes and reasons. Deblending is becoming an additional motivation. We can also use variations in seismic source signature. This paper puts deblending in the context of multi-component and broadband methods. As we will argue below, low frequency seismic sources are leading to simultaneous

sources with different signatures or voices, and to the ability to calculate the similarity attribute. Thanks to Apache Corporation, we can use the Forties data (Ronen et al, 2012) to test ideas. The data were acquired with a single source, but coming from continuously recording nodes, it is possible to blend the data to simulate simultaneous shooting. The node data are multi-component, providing directivity to the source. The data are also multi-voice. Due to acquisition problems, a few different seismic source configurations were used in the survey. The different sources were used consequentially and not simultaneously but we blended them to generate multi-voice blended data

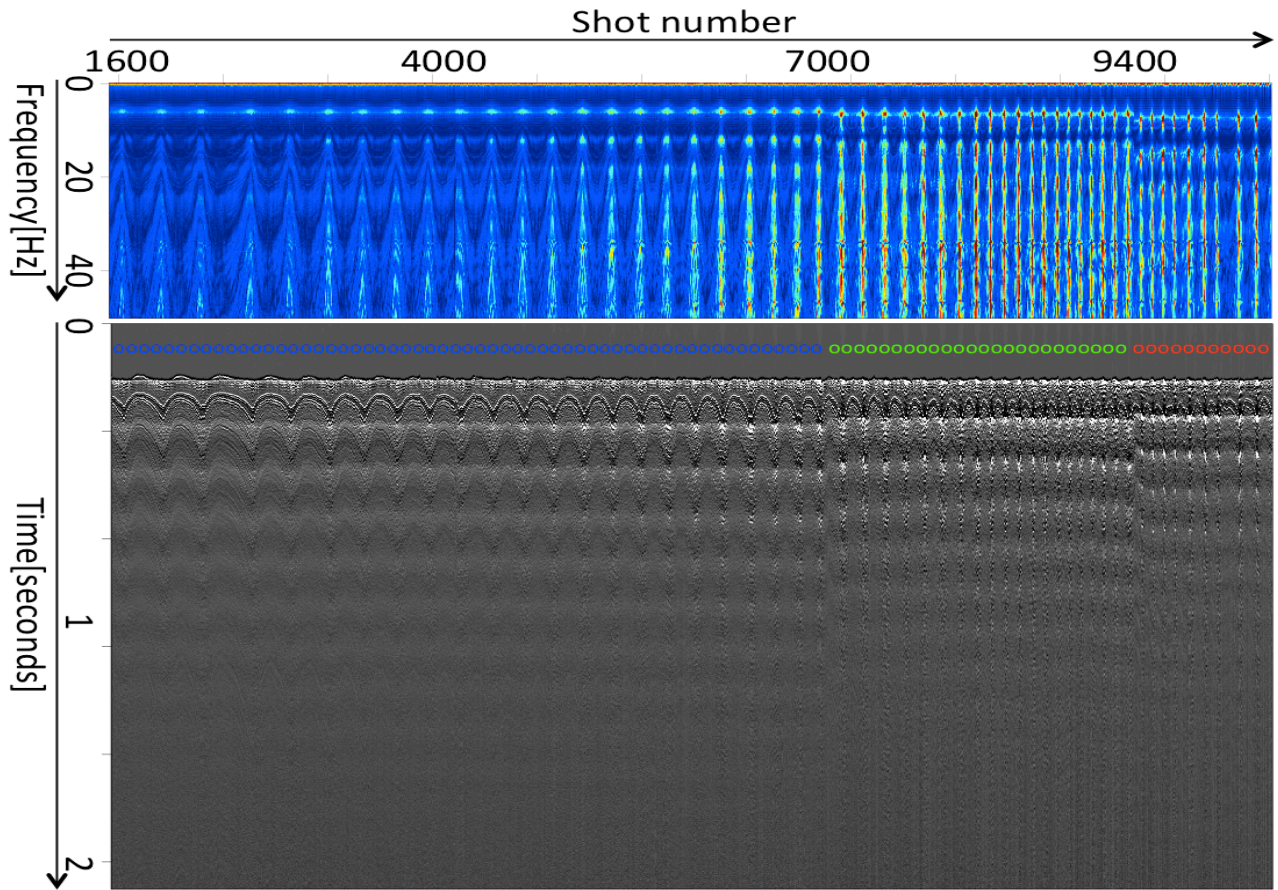
### Separating seismic sources by voice

The high frequency content of the seismic band is limited by attenuation and scattering in the overburden and in practice there is not much we can do to broaden the band on the high frequency side, as long as we have either receivers or sources on the surface. On the other hand, the low frequency content is limited by our seismic sources. Our receivers record much lower frequencies than our sources produce. We record low frequency waves that are generated by ambient sources such as wind and swell, but the waves from such ambient sources are mainly surface waves that may help us build velocity models of the upper overburden, but are not very useful for exploration prospects and reservoirs.

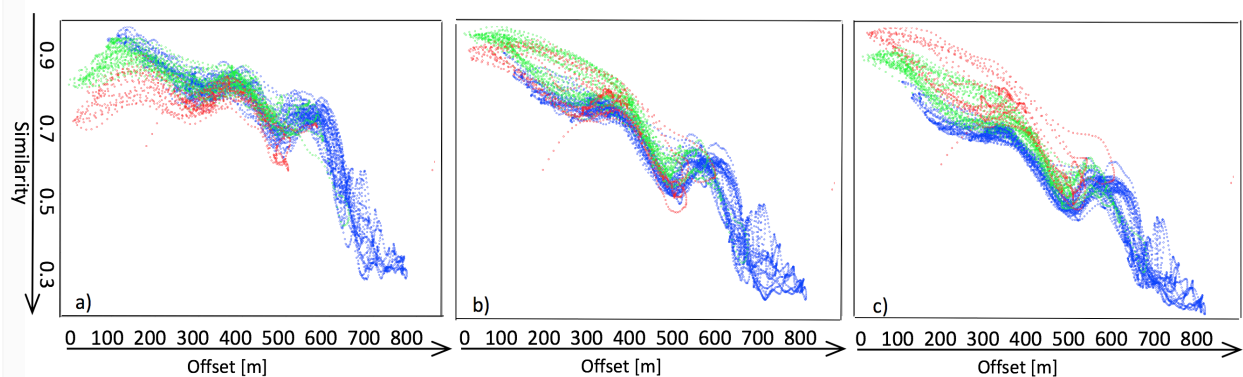


**Figure 1:** The acquisition geometry of the Apache Forties dataset. One vessel spiraled around a platform located at the center. The colored points indicate the shot point locations. The black star indicates the location of the node from which all the data are shown in this abstract. The colors indicate different source voices

### Deblending with radially and similarity



**Figure 2:** The amplitude spectrum of each trace in the common-receiver gather (top). Color (center) indicates source voice. The data in the time domain after applying HMO (bottom).



**Figure 3:** Color coded maxima of correlations of source signatures with each shot in the CRG sorted with offset. (a) Maxima of the signature of the blue source cross-correlated with all traces. (b) and (c) Cross-correlation maxima of the green and red sources. In general, the correlation is higher for near offsets. Blue is on top in (a), green is on top in (b), and red is on top in (c) showing that we can recognize sources by their voices.

## Deblending with radially and similarity

We must have active broadband sources to build high-resolution blocky reservoir models and to explore under complex overburden such as sub-salt and sub-basalt. Low frequency seismic sources must be big. Low frequency vibes require long sweeps. Low frequency air guns require a high volume of air, and unless we increase compressor capacity on seismic vessels, we have to increase the shot interval. Either way, the number of shots per day is lower and offshore the source interval is larger. Fortunately, imaging low frequency data requires sparser sampling. An offshore example may be an array of small airguns providing high frequency source at short time and space intervals, blended with an array of large airguns shooting at larger intervals. Larger time intervals enable shooting the large guns without upgrading compressor capacity. Larger spatial intervals are sustainable thanks to the long wavelength of low frequency waves. Whether such low- and high-frequency sources are deployed from a single source vessel, or from two or more, in practice, the data that we will record will be blended. While this technique has already been implemented with Vibroseis (Bell et al, 2015), we suspect that this is going to happen with airguns.

The last platform of the 2010 Forties node survey started with a source consisting of a single cluster of 3X250 in<sup>3</sup> airguns at 2000psi. During the shoot, an air leak started so at least one gun was operating at a reduced pressure lower than 2000psi. Later on during the survey, the leak became a disconnect and the source consisted of a cluster of 2X3X250 in<sup>3</sup> airguns at an unknown pressure. Data processing was able to “fix” the problem and produce a good quality image from the data, and the source problem was forgotten until we decided to use the opportunity to develop deblending methods using different source signatures or voices.

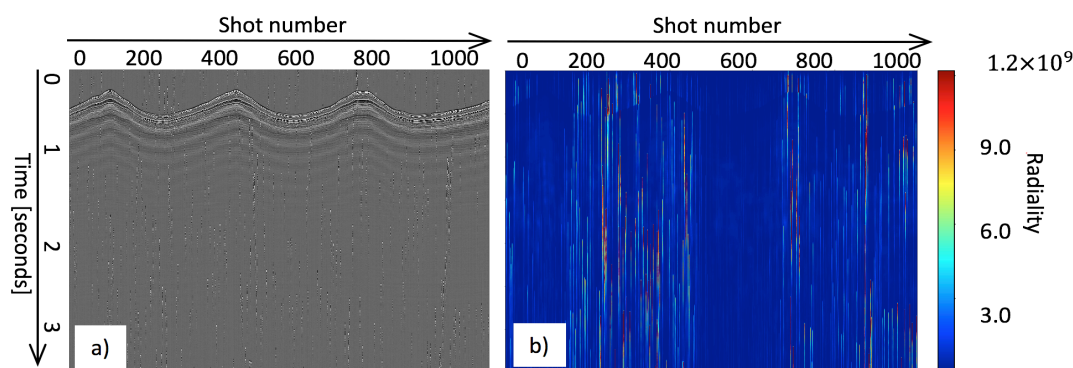
Figures 1 and 2 describe the geometry and the different

voices of the seismic source. Figure 3 is a result of a demonstration of the ability to identify each source by its voice, using cross correlation of each trace with each source signature.

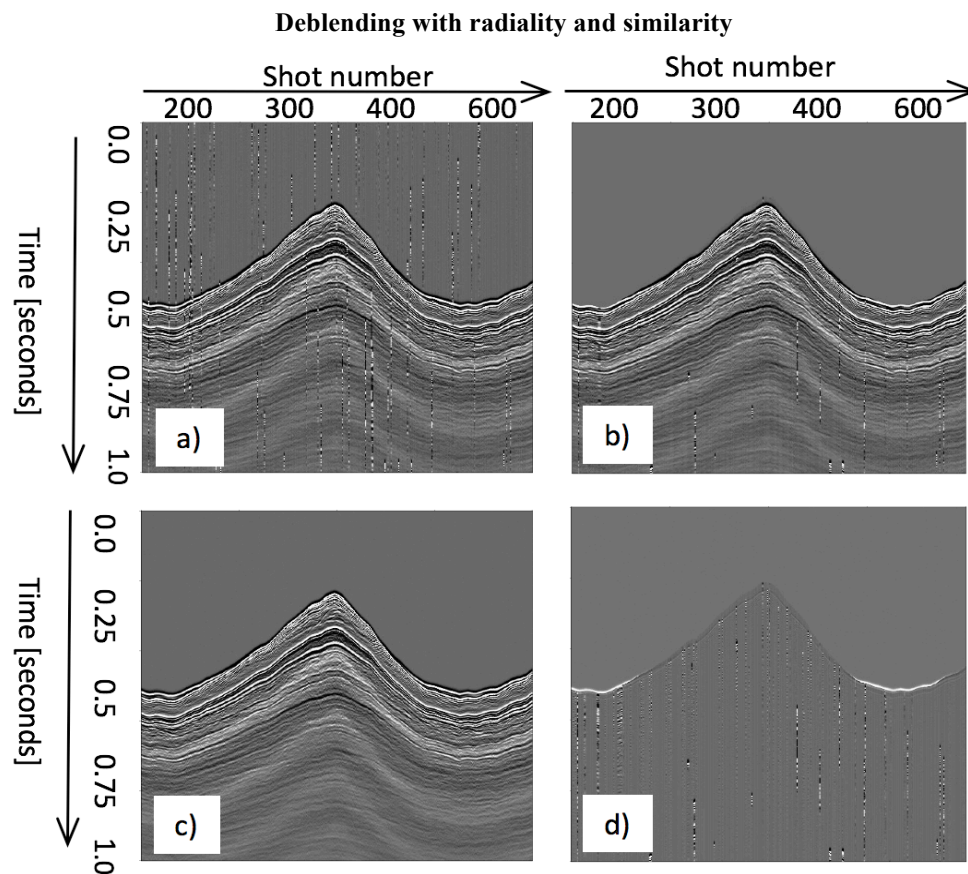
### Separating seismic sources by direction

In order to detect the different sources by direction, we use the data recorded on the horizontal components of the ocean-bottom nodes that were used. By rotating the data axes into the azimuth of each shot (radial and transverse), and using the fact that in the water the direct arrival will be predominantly radial, we developed an attribute that we call radially to detect the dominant and interfering sources. We obtain radially by computing the ratio of envelopes of the transverse component squared and the radial component (we admit that mathematically this appears to measure non-radiality, but we denote it as radially). Assuming predominantly radial polarity of P waves, seismic interference from a simultaneous source with a different direction of the primary source is likely. Figure 4 shows that radially detects the interfering sources when the azimuths of the two sources are different.

Using the radially attribute, we implemented a proof-of-concept deblending scheme where we mute the interfering sources based on high values of radially, and then interpolate from trace to trace to fill in the gaps. Panel (a) of Figure 5 shows the first one second of 400 shots of a blended common receiver gather and panel (b) shows the deblended result. Much of the interference has been removed except for shots in which the two source-receiver azimuths are nearly the same. Panel (c) shows the unblended data and panel (d) shows the difference between panels (c) and (d).



**Figure 4:** (a) Blended common-receiver gather; 1000 shots of synthetically blended pressure component data. The random look of the interference is due to the randomizing of the interfering shot times on a common receiver gather. (b) Radially attribute over the shots shown in panel (a). The oscillating light and dark regions occur due to changing source azimuths. Radially is low where the azimuth difference between the shots is large, here in shots 200-400. It is high when there is no interference or when the interference is coming from the same direction, here around shots 100 and 600.



**Figure 5:** Deblending results using radially attribute. (a) Raw blended common receiver gather. (b) Deblended result using radially attribute. (c) Unblended data. (d) Difference between panels (b) and (c). Note in panel (b) that a significant amount of the interference has been removed. The differences shown in panel (d) are largely due to small azimuthal differences between the sources. We speculate that shipping noise and waves scattered from platforms are also attenuated.

## Conclusions

Using the source similarity and radially attributes, we can assign a probability to each time sample of a blended dataset indicating at any time on any receiver whether there is seismic interference and if so, which source is more likely to dominate at that time. We showed that using the radially attribute we were able to remove a significant amount of the interference of a blended common receiver gather from the Apache Forties dataset. We implemented this proof-of-concept method with the end goal of incorporating these attributes into state of the art deblending inversions for separating and imaging.

To explore under complex overburden such as salt and basalt, to build high resolution blocky reservoir models, to monitor production under obstructing facilities, all lead to broad band receivers and sources, ocean bottom nodes and cables which are multi-component, and multi-sensor streamers. To do all at high value/cost ratio leads to simultaneous sources. These seemingly unrelated

solutions; broadband, multi-sensor, and simultaneous shooting, are linked. Broadband sources with sparse low-frequency sources and dense high-frequency sources have different signatures that can be used for voice recognition. Multi-sensor data provide direction recognition because most of the seismic interference has a polarity that is radial with respect to the interfering noise source and usually not with respect to the primary signal source. Voice and direction recognitions are useful in separation and imaging blended data from simultaneous sources

## Acknowledgements

We thank the Apache Corporation for releasing the data to Stanford University, the affiliates of the Stanford Exploration Project for their support, and the other students and professors at Stanford for their help and advice.

## EDITED REFERENCES

Note: This reference list is a copyedited version of the reference list submitted by the author. Reference lists for the 2017 SEG Technical Program Expanded Abstracts have been copyedited so that references provided with the online metadata for each paper will achieve a high degree of linking to cited sources that appear on the Web.

## REFERENCES

- Bell, L., J. Archer, and R. Verm, Multi-gridded broadband land acquisition and processing: 11th Biennial International Conference and Exposition on Petroleum Geophysics, Society of Petroleum Geophysicists (SPG).
- Ikelle, L., 2007, Coding and decoding: Seismic data modeling, acquisition and processing: 77th Annual International Meeting, SEG, Expanded Abstracts, 66-70, <https://dx.doi.org/10.1190/1.2792383>.
- Ronen S., A. Rokkan, R. Bouraly, G. Valsvik, L. Larson, E. Ostensvig, J. Paillet, A. Dynia, A. Matlozsz, S. Brown, S. Drummie, J. Holden, K. Koster, D. Monk, and M. Swanson, 2012, Imaging shallow gas drilling hazards under three Forties oil field platforms using Ocean Bottom Nodes: The Leading Edge, **31**, 466-469, <https://dx.doi.org/10.1190/tle31040465.1>.