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Improvements to Frequency Decomposition Methodologies for Use with Broad Bandwidth Seismic Datasets

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SUMMARY

Broadband technology, in its different guises has been developed to extend the spectral width of seismic data giving more sensitivity to the features imaged at high and low frequencies. This has lead to problems using existing frequency decomposition techniques with this data. We have adapted our existing code to meet these demands.

Introduction

Frequency decomposition is a widely adopted method for isolating seismic signal of a particular bandwidth, with the aim of discriminating different geological expressions in the data. There are many frequency decomposition techniques available on the market and each method utilises different filtering methods, resulting in a variety in their resolution in time and frequency (Castagna & Sun, 2006; McArdle & Ackers, 2012). Broadband technology, in its different guises has been developed to extend the spectral width of seismic data giving more sensitivity to the features imaged at high and low frequencies. Typically the technological advances in acquisition have preceded the developments in processing and we are in the process of trying to understand the best ways to process these data in order that we can best discriminate signal at the spectral extremes.

Under investigation is a multi-stage workflow based on an existing method of frequency decomposition called High-Definition Frequency Decomposition (HDFD): this is a modified matching pursuit method (Mallat & Zhang, 1996) whereby Gabor wavelets at different frequencies and phase rotations are matched to a seismic trace in an iterative process according to highest spectral energy until at least 99% of the energy has been reconstructed. Using the matching pursuit decomposition wavelet set, a band limited trace can be reconstructed within a given frequency range (a Gaussian window). This method has a particularly high vertical localisation in comparison to other methods, however the method can break down at the spectral extremes as the matching pursuit-inspired method fails to consistently match wavelets to the relatively low energies at the low and high frequencies.

Method

The methodology presented here introduces an additional stage to this decomposition process where the data is pared into band-limited frequency sections prior to the matching pursuit stage as shown in Figure 1b. Introducing low and high cuts produces low, mid and high frequency sections for wavelets to be matched to, thus forcing wavelets to be fitted to the spectral extremes that were previously overlooked. Additionally the wavelet dictionary is extended beyond hard-coded limits, to one octave above the high cut and one octave below the low cut, to ensure that appropriate matching can take place. Figure 1c shows the trace reconstructions (sum of matched wavelets) for the three band limited sections. The next stage is to combine the band limited wavelet sets and frequency reconstruction can take place as for the existing approach.

We show results of the modified technique applied to broadband seismic data supplied by Lundin Petroleum. The survey is variable depth streamer data acquired over the Johan Sverdrup discovery (Figure 1d). Conventional matching pursuit based reconstruction, used to create an RGB colour blend as shown in Figure 1e, is problematic for this dataset because there is considerable mismatch in low frequency wavelet matching between neighbouring traces, which results in spikes in the data. An equivalent result using the modified broadband frequency decomposition method is shown in Figure 1f. This shows considerable improvement with regard to mismatched noise spikes. As comparison a frequency decomposition RGB blend is created using standard bandpass frequency decomposition (generated through a convolution process) which is shown in Figure 1g; typically this decomposition method has lower vertical resolution and higher frequency resolution than the matching pursuit based decomposition. Interestingly the broadband frequency decomposition lies between the two existing methods in terms of frequency and temporal localisation. In fact it shares the best qualities of both methods and can be seen as an improvement, because it is largely still sensitive to the thin, finely separated events as shown in matching pursuit based technique, yet it also shows much more variation in colour, like the bandpass method, which is important for sub tuning thickness interpretation.

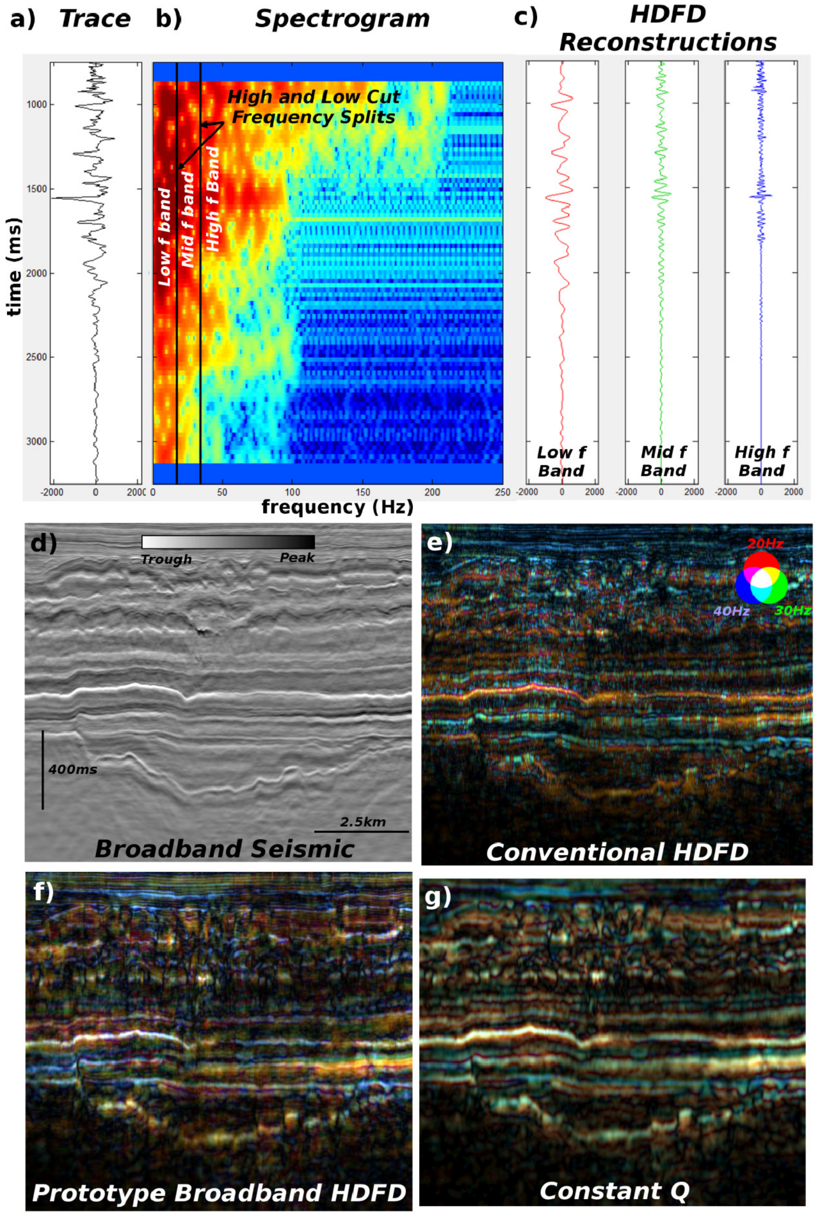

***Figure 1** a) Example broadband seismic trace and b) its spectrogram; c) Modified broadband reconstructions for the low, mid and high frequency splits; d) section of the original broadband data and equivalent frequency decomposition RGB blend generated using e) matching pursuit based FD, f) modified broadband FD and g) standard 'constant Q' bandpass decomposition.*

References

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