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Frequency Decomposition of Broadband Seismic Data: Challenges and Solutions

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SUMMARY

An improved, matching pursuit based high definition frequency decomposition method has been introduced to meet the challanges of broad bandwidth seismic data. It is largely sensitive to the finely separated thin events, yet it also has an enhanced frequency resolution and lateral consistency.

Introduction

Frequency decomposition is a widely used method for identifying and discriminating different geological expressions in the seismic data by isolating seismic signals of particular frequency ranges. Several frequency decomposition techniques are available for the interpreter: each utilises different filtering methods, resulting in a variety in their resolution in time and frequency (e.g. Castagna and Sun 2006; McArdle and Ackers 2012).

The highest vertical resolution is achieved by a method based on a matching pursuit approach (Mallat and Zhang, 1996), whereby Gabor wavelets at different frequencies and phase rotations are matched to a seismic trace in an iterative process according to the highest spectral energy. Using the matched wavelet set, a band-limited trace can be reconstructed within a given frequency interval. This method offers a particularly high resolution vertical localisation in comparison to other methods; however, it is partial to the dominant frequency of the seismic data and occasionally fails to consistently match wavelets to the relatively low energies at the low and high frequencies.

Method

The improved methodology introduces an additional stage to this decomposition process: the data is divided into band-limited sections prior to the matching pursuit stage (see Figure 1). Introduction of these limiting frequencies produces low, mid and high frequency bands. With this modification the matching pursuit based frequency decomposition is forced to fit wavelets to the previously overlooked spectral extremes. A further improvement is the introduction of a dynamic wavelet library ensuring that appropriate matching is achieved for both broadband and conventional seismic data. Figure 1 illustrates how the three band-limited sections are reconstructed using the matched wavelets. In the final stage the band-limited wavelet sets are combined and frequency reconstruction can take place as for the existing technique.

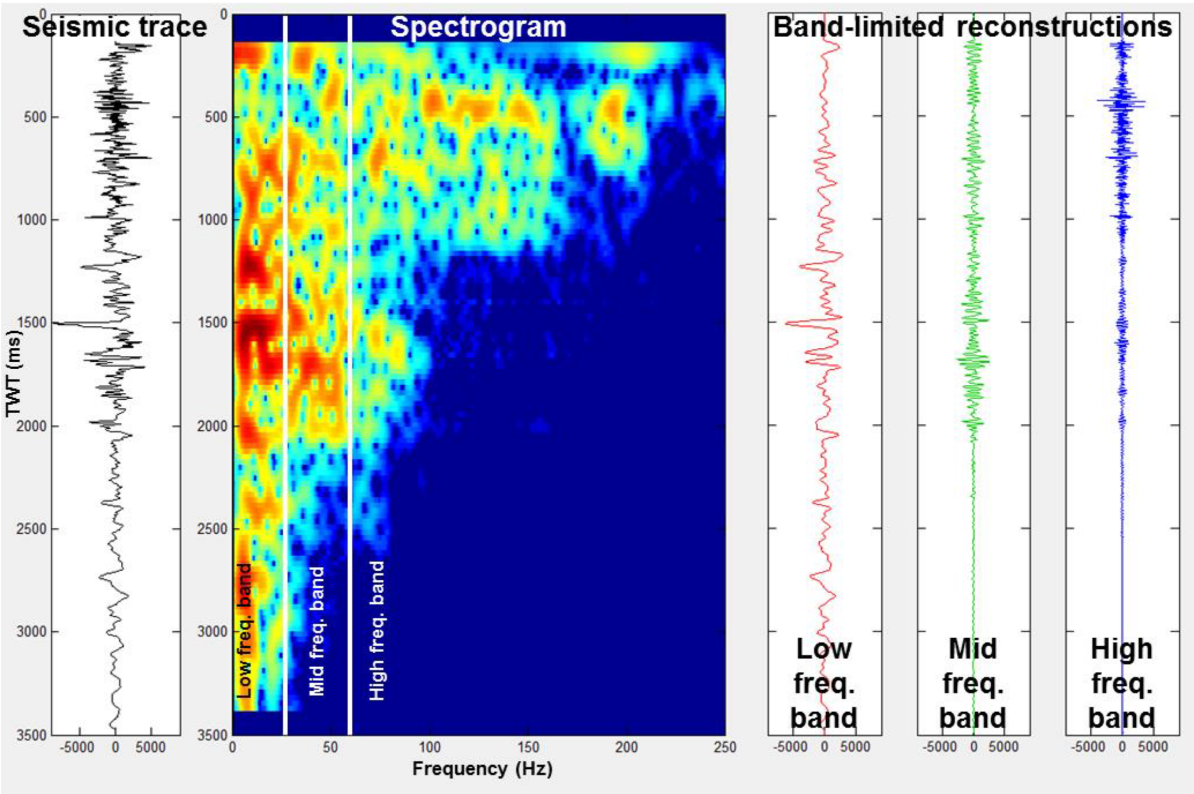

Figure 1 *An example broadband trace (left), its spectrogram (middle) with the limiting frequencies indicated in white and the band-limited reconstructions (right) for the three frequency bands.*

Examples

The different frequency decomposition methods are illustrated with a variable depth streamer seismic data set supplied by Lundin Norway (Figure 2). The ultimate goal would be to create an RGB blend with very high frequency and temporal (vertical) resolutions. Comparison between the results of the standard and the matching pursuit based frequency decomposition methods shows that the former is characterised by a significantly better frequency resolution (the higher number of colours means an increased sensitivity to the different frequencies and their interplay), while the latter provides a vertical resolution that is comparable to that of the seismic data. Unfortunately, as these two RGB blends clearly show, maximising one type of resolution has a deteriorating effect on the other one (cf. uncertainty principle in signal processing).

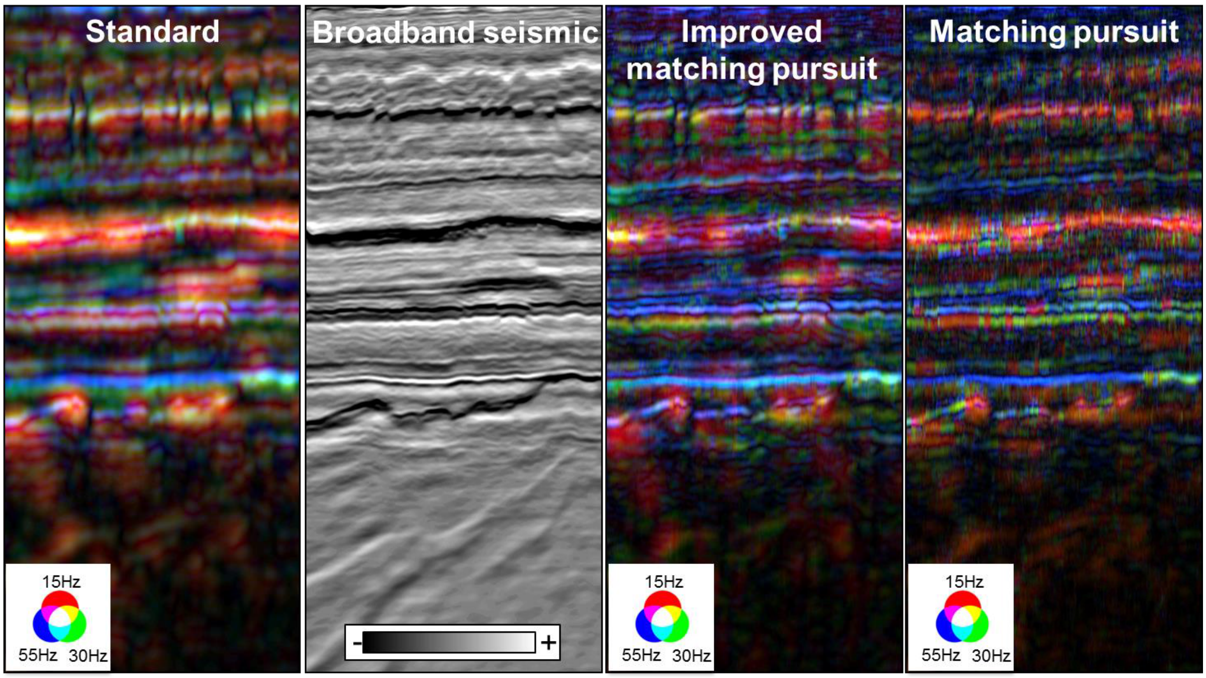

Figure 2 *Broadband seismic data and equivalent frequency decomposition RGB blends generated using standard, matching pursuit based and improved matching pursuit based frequency decomposition methods.*

A closer look at the conventional matching pursuit based RGB blend (Figure 3, left) reveals why broadband seismic data require an improved frequency decomposition methodology. Although low frequencies provide a substantial contribution to the energy of the signal (cf. Figure 1), they are inadequately reconstructed by the matching pursuit based method. The lateral inconsistencies in the reconstruction are revealed by vertical spikes, especially at low frequencies (red spikes), which hide geologically relevant information and prevent a detailed interpretation.

The new methodology (Figure 3, right) shows a considerable improvement with regard to the mismatched noise spikes and lateral consistency. Areas dominated by low frequency responses (shades of red) are much better resolved, providing more reliable information about the complex geometry of the subsurface.

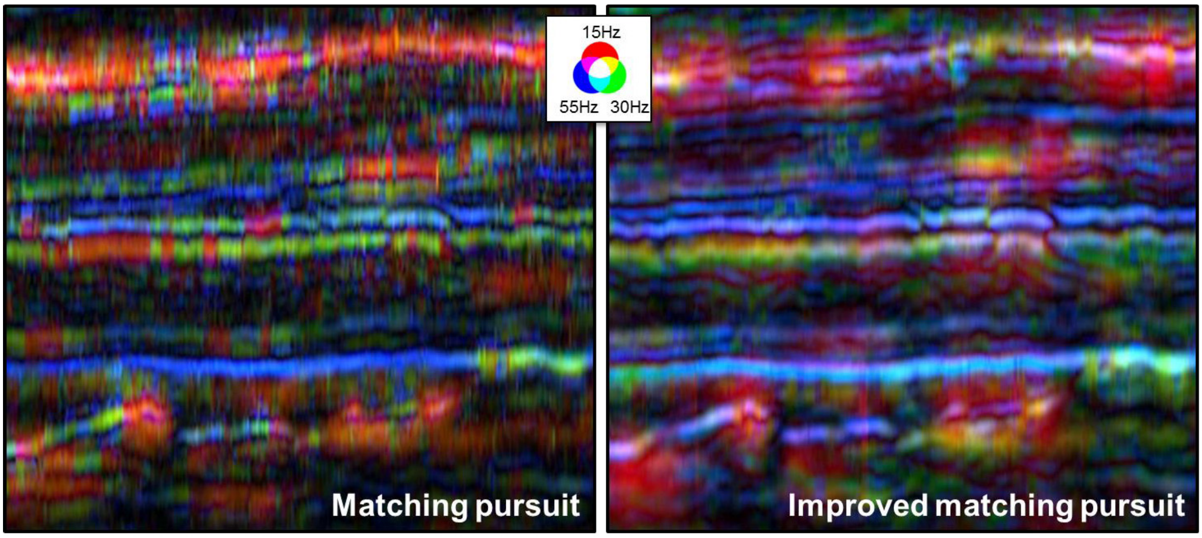

__Figure 3__ A comparison of the results of frequency decomposition and RGB blending using the conventional (left) and the improved (right) matching pursuit based methods. The temporal resolutions of the two blends are equally high, but a significantly better lateral consistency is achieved with the new method.

The improved matching pursuit based frequency decomposition method also helps interpretation with an enhanced frequency resolution (Figure 4), which is comparable to that of the standard frequency decomposition. This, combined with the high temporal resolution, enables more detailed mapping and extraction of geological features and variations identified in the colour blends.

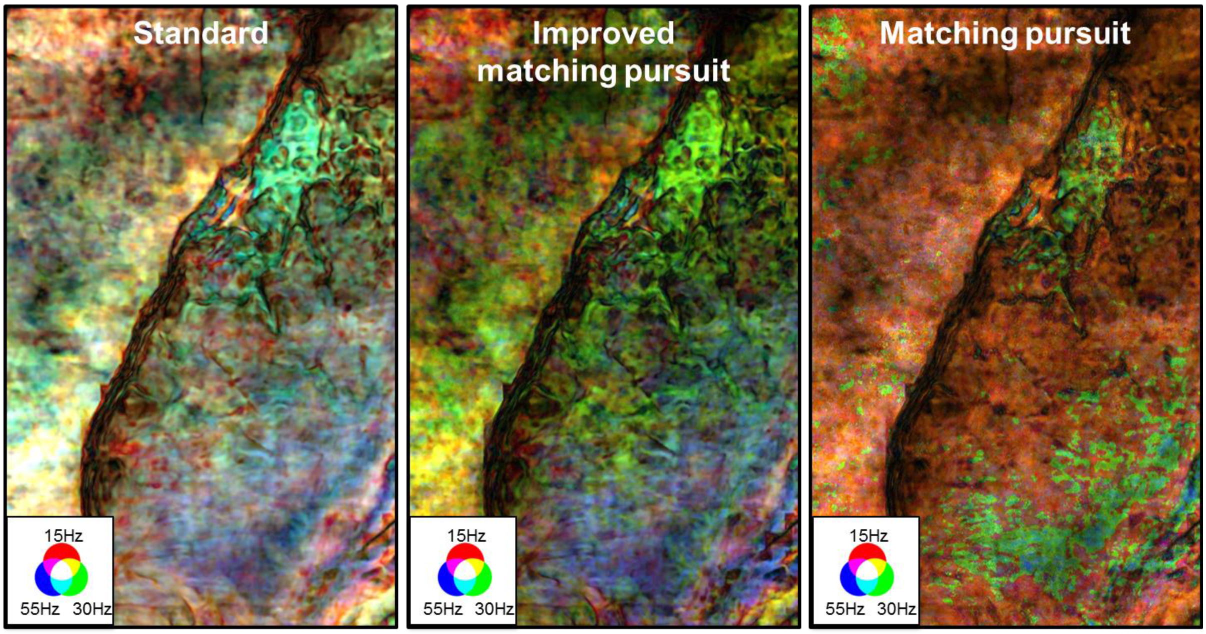

__Figure 4__ RGB blends draped on a horizon. The blends were created using standard (left), matching pursuit (right) and improved matching pursuit based (centre) frequency decomposition methods. The frequency resolution of the new method is much better than that of the existing method (note the lack of red spikes) and is comparable to that of the standard frequency decomposition technique.

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Conclusions

A new, highly tuneable, matching pursuit based frequency decomposition method has been developed to respond to the challenges of broadband seismic data. It shares the best qualities of the existing approaches: it is largely sensitive to thin, finely separated events, provides an improved lateral consistency and a good frequency resolution. These achievements can enhance the quality and reliability of further analyses, such as seismic facies classification and sub tuning thickness interpretation (cf. McArdle and Ackers 2012).

Acknowledgements

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References

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