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An AVO-Friendly Noise-filtered Stretch-Free Reflection-based Multimodal Optimisation based Non-hyperbolic Approach to Moveout Analysis and Stacking (A Showcase of Results)

Hamish Wilson - PhD - School of Earth Sciences

Supervisors: Lutz Gross and Andrew Garnett

Introduction

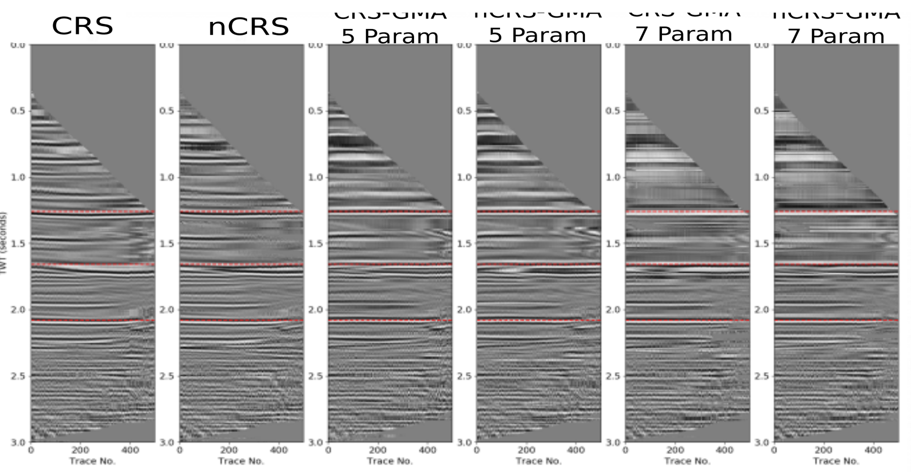
Moveout Analysis and stacking are two quintessential steps in seismic processing. Traditional Moveout analysis does not take into account anisotropy, lateral heterogeneity, AVO/AZ anomalies, and applies muting at large offset to depth ratios. Not utilising a moveout approximation that adequately describes the non-hyperbolicity of the moveout provides insufficient insight into the kinematic characteristics of the subsurface and degrades the quality of the stack. AVO/AZ anomalies augment the location of optimal moveout parameters in the moveout analysis process and reduces the quality of the stack. Large offset-to-depth ratios remove potentially insightful data from the moveout analysis process and reduce the fold of the stack. Conversely without this mute, traditonal moveout analysis would be hampered by moveout stretch which would hamper the frequency content of the stack. The content of this poster showcases techniques developed during the course of my PhD to address the aforementioned limitations of moveout analysis and stacking.

Proposed Moveout Approximation

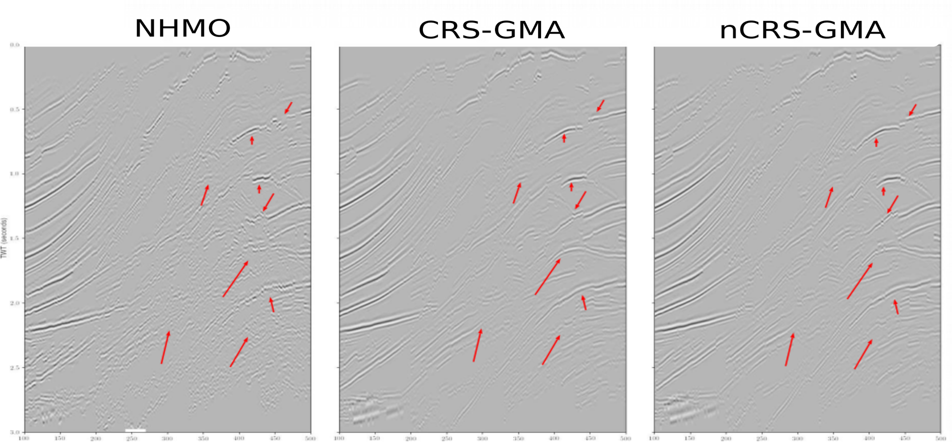
CRS-based approximations as opposed to CMP-based approximations use adjacent CMP locations in the moveout analysis process. This is an attractive feature as it increases the number of traces used in the moveout analysis and stacking process. This comes at the cost of additional parameters in the moveout approximation. Traditional CRS-based approximations do not account for anisotropy. In my PhD I develop the nCRS-GMA. The nCRS-GMA was developed to do nonhyperbolic moveout analysis with CRS gathers in the presence of anisotropy an lateral heterogeneity (Wilson 2019).

$$t(\Delta m,x)^2 = f^{(d)}(\Delta m) + \frac{x^2}{V_{nmo}^2} + \frac{Ax^4}{V_{nmo}^4\left(\frac{Bx^2}{V_{nmo}^2} + f^{(d)}(\Delta m) + \sqrt{f^{(d)}(\Delta m)^2 + \frac{2Bf^{(d)}(\Delta m)x^2}{V_{nmo}^2} + \frac{Cx^4}{V_{nmo}^4} - \hat{g}^{(\Delta m,x)}(\Delta m,x)}\right)} + \frac{A\hat{g}^{(\Delta m,x)}(\Delta m,x)}{(B^2-C)\left(\frac{Bx^2}{V_{nmo}^2} + f^{(d)}(\Delta m) + \sqrt{\frac{2Bf^{(d)}(\Delta m)x^2}{V_{nmo}^2} + \frac{Cx^4}{V_{nmo}^4} + f^{(d)}(\Delta m)^2 - \hat{g}^{(\Delta m,x)}(\Delta m,x)}\right)}$$

Proposed CRS-based moveout Approximation that, dependending on choice of g^hat is either nCRS-GMA or CRS-GMA.



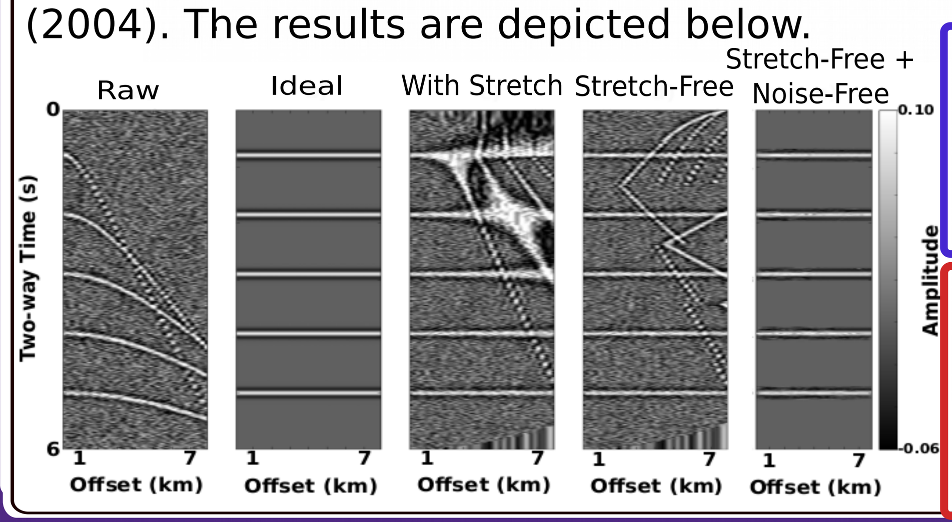
Comparison of Corrected CRS-gathers using Traditional (Müller 2003 , Fomel & Kazinnik 2012) and Proposed nCRS-GMA and CRS-GMA approximations

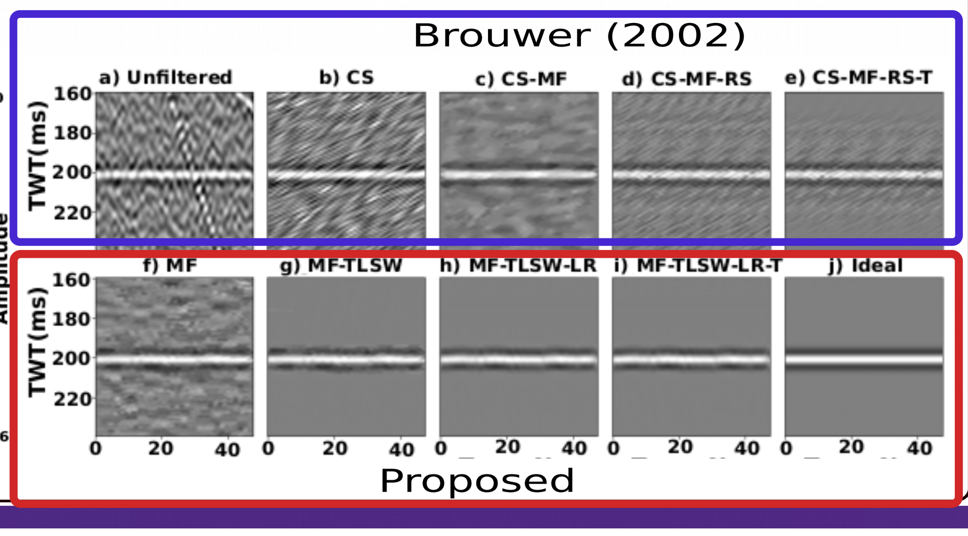


Comparison of stacks using CMP-based GMA (NHMO) (Fomel & Stovas 2010) and Proposed 5-parameter nCRS-GMA and CRS-GMA approximations

Stretch and Noise Removal

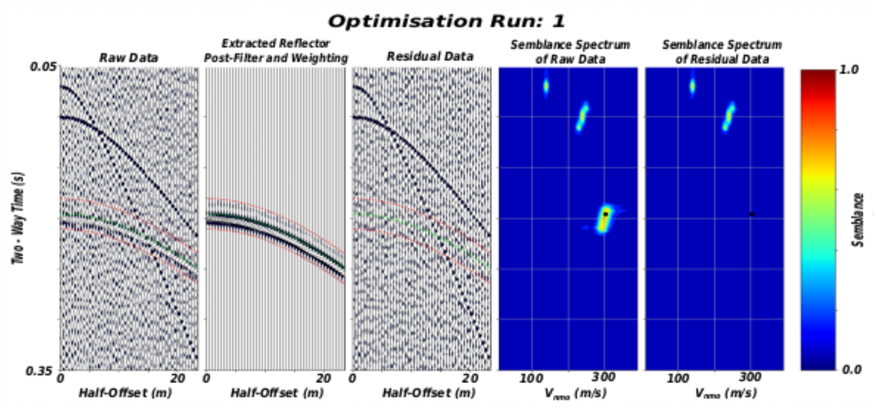
To remove stretch and any artefacts and noise associated with this stretch removal we propose a median-filter, local-similarity, rank reduction, thresholding technique. This is inspired somewhat by the approach of Brouwer (2002) that use cyclic sampling and median filtering to remove said noise. To remove stretch, we develop a stretch-free distribution function for the nCRS-GMA approximation which is an extension of the work of Perroud (2004). The results are depicted below.



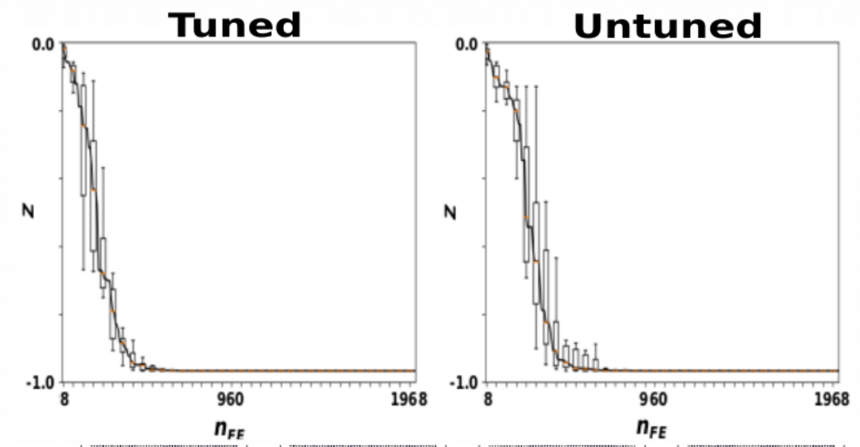


Proposed Multimodal Moveout Approach

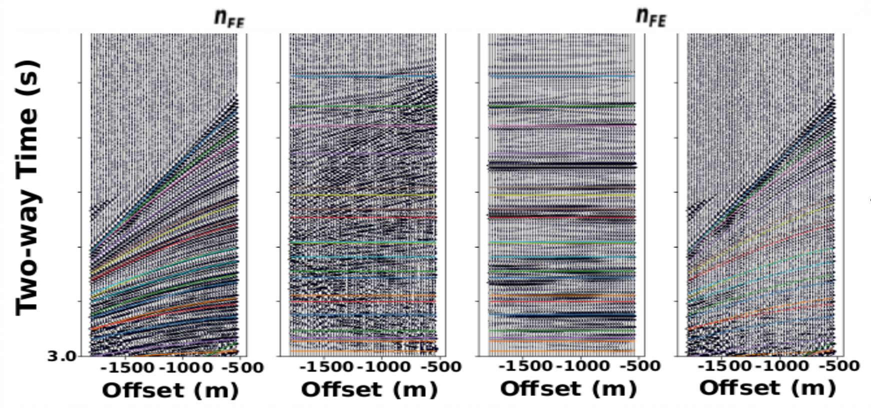
To Find optimal moveout parameters, we developed a sequential-niching inspired multimodal moveout analysis technique which is completely data-driven. This technique uses a layer-block elimination technique to change the CRS-gather on each iteration (Wilson 2019). The filtering and removal of stretch on each block is done using the proposed stret and noise removal process. the residual data is used on each iteration to update the cost function (semblance). An example is shown in the figure below.



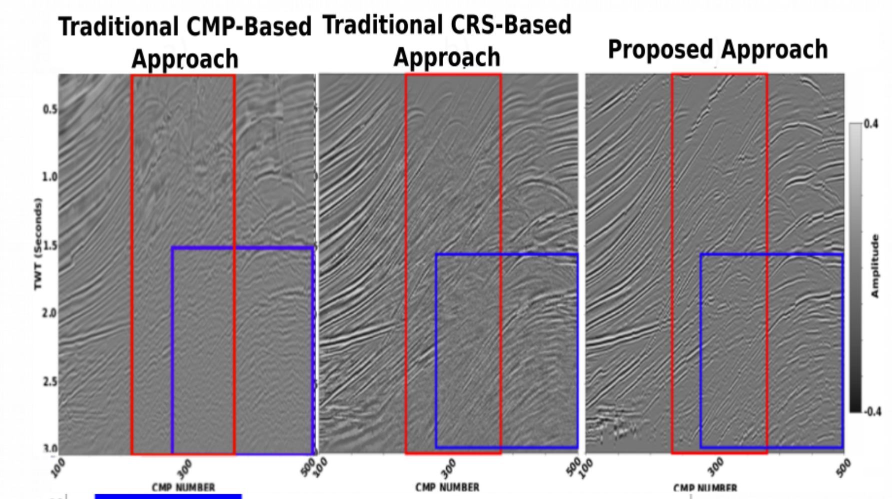
First iteration of proposed sequential multimodal algorithm.



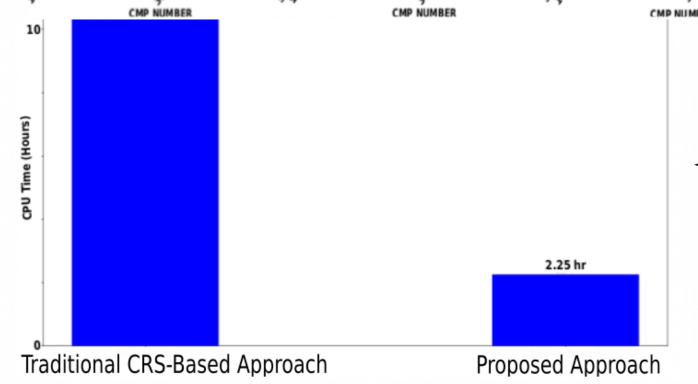
Optimisation curves using Tuned control parameters vs untuned control parameters for base optimisation algorithm (in our case this is CMAES (Hansen 2001))



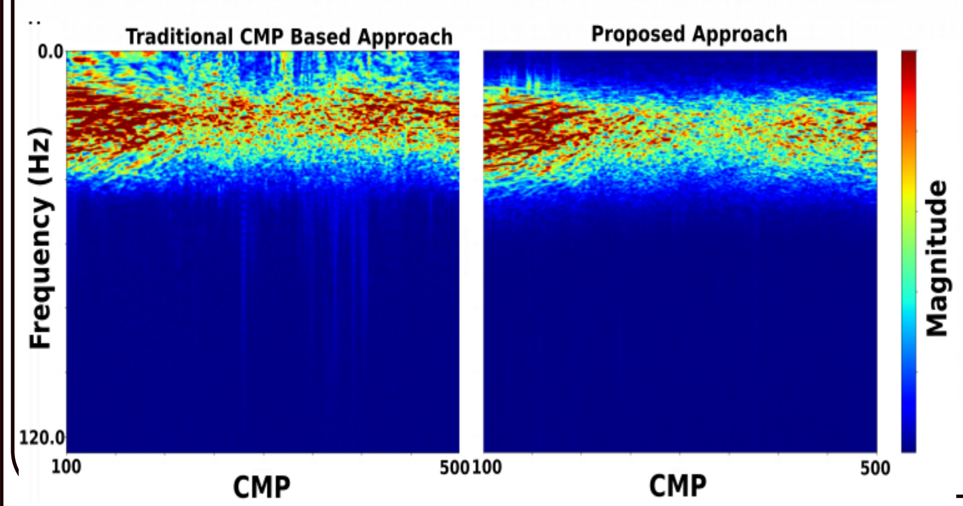
Comparison of moveout corrected gathers using proposed method with and without filtering on layer blocks



Stack Comparison of Traditional CMP-based moveout analysis (velocity analysis) with no stretch-mute, Traditional CRS-based approach (Barros 2015) and the proposed approach.



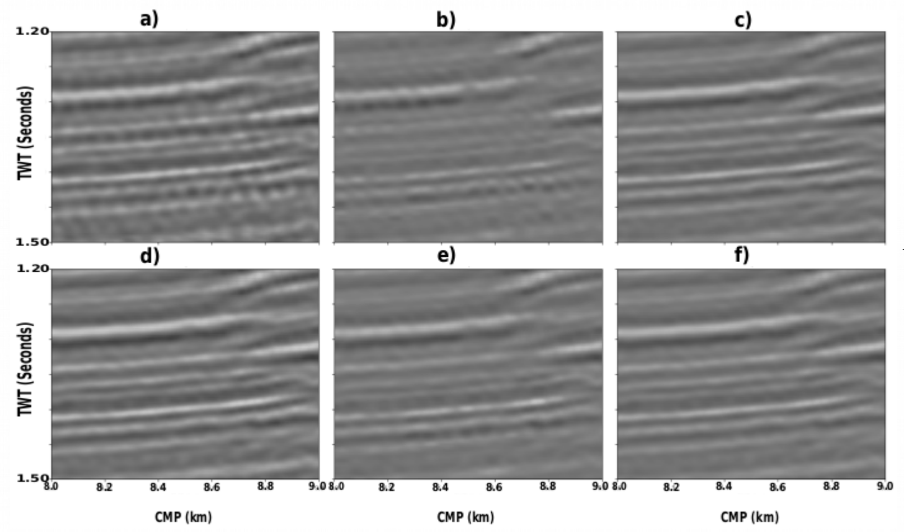
Comparison of aggregated computational time between Traditional CRS-based approach (Barros 2015) and the proposed approach.



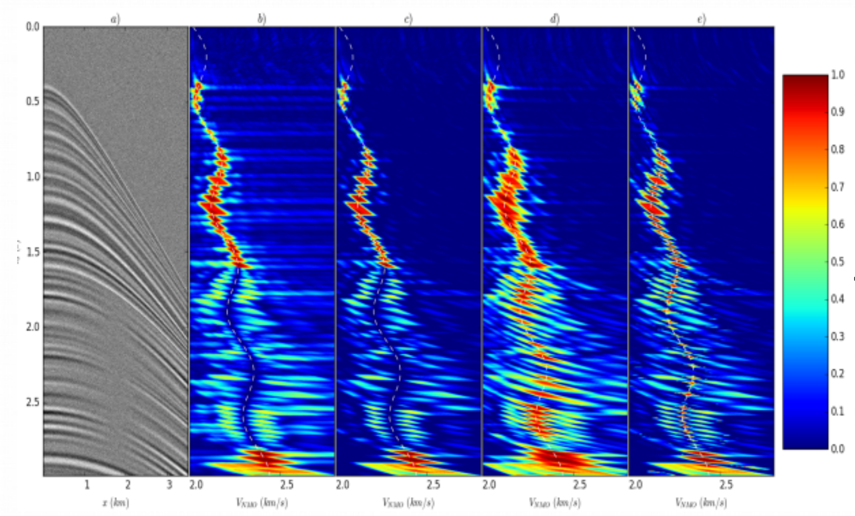
Comparison of 2D Frequency spectra between Traditional CMP-based approach with no stretch mute and the proposed approach.

Stacking and Moveout Analysis in the Presence of AVO Anomaly

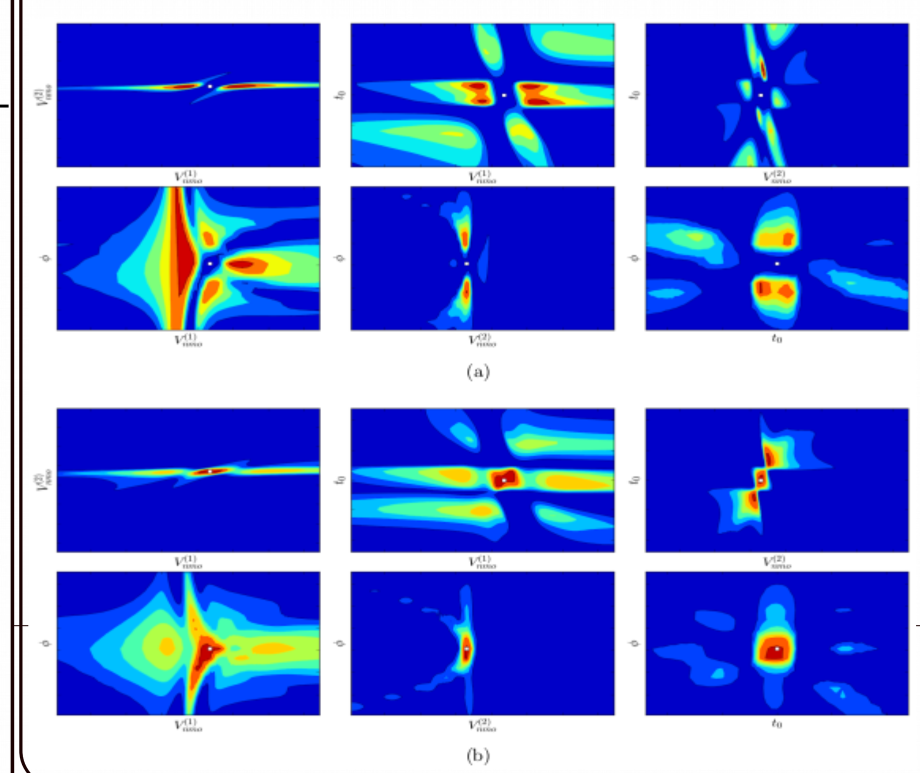
In the presence of AVO/AZ anomalies, the moveout analysis and stacking processes can be erroneous particularly if a polarity reversal is associated with said AVO anomaly. In my PhD, I developed a technique of detrending the data before utilising it in the stacking and moveout analysis processes. This involves removing the AVO trend from the data. Below is showcased some of the results of applying detrending to weighted stacking and weighted semblance in moveout analysis.



a) is conventional stacking of data affected by an AVO anomaly, b) is using SNR weighting for the data affected by an AVO anomaly. c) is the AVO- Local similarity weighted stacking proposed by Deng (2016). d) is the detrended version of a), e) is the deterended version of b), f) is the detrended alternative to c)



a) is a CMP gather with an AVO anomaly with a polarity reversal, b) is traditional semblance, c) is the velocity weighted semblance of Luo & Hale (2012), d) AB-detrended version of c), and e) is an AK-detrended version of c)



El case: Semblance panels/slices for combinations of moveout parameters (with all other parameters fixed to their true values) where the white marker represents the true location of the parameter set calculated using; a) The velocitysensitivity weighted semblance operator, and b) the AK-weighted velocity sensitivityweighted semblance operator.

References

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