Robust, Automatic, Continuous Velocity Analysis
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Summary
Velocity analysis is one of the key steps in the processing of seismic data. Accurate velocities give rise to an optimal stack response, improved reliability of AVO attributes and can also be used as a predictor of geopressure. Consequently, a robust, fully automatic, continuous velocity analysis technique is highly desirable. Starting from the work of Swan (2001) we extend his method for routine use in a production processing environment. We illustrate the success of our new method with results from two case studies.

Introduction
Manual velocity picking is an expensive task, even when the sampling of the velocity field is an order of magnitude less than that of the seismic data. To make matters worse, it is well known that dense picking grids are required to reduce velocity interpolation errors between analysis locations, leading to even longer turnaround times.

An automatic, continuous velocity analysis method has been published recently (Swan, 2001). This technique uses attributes derived from an AVO analysis of pre-stack CMP gathers to construct a residual velocity indicator (RVI). Under certain assumptions the RVI isolates the velocity effects from the true AVO ones and a velocity correction can be estimated. The RVI is significantly more sensitive to velocity variations than a standard semblance estimate. Application of this method can flatten the gathers and improve stack and AVO results. However, we have found that it is unstable in some areas, sometimes causing more problems than it solves. Through a series of examples, we show how the robustness of the method can be improved, allowing its automated use in production processing.

Methodology
In the methodology of Swan (2001) AVO analysis occurs at every CMP and every time sample and, after time and space averaging of the complex form of the AVO attributes, a continuous RVI estimate is calculated. This RVI value is used to update the velocity field and subsequent moveout correction. AVO analysis can be repeated on these revised gathers and another RVI value calculated – this process is iterated until convergence occurs.

To study this process we apply it to a line of high quality marine gathers that are muted to an incidence angle of 25°. The results from one gather are shown in Figure 1a after 0, 2, 4 and 6 iterations. This gather lies between two manually picked locations, so the moveout correction may suffer from velocity interpolation errors, as well as errors due to manual mis-picking. There are areas where the flatness of the gather has improved (black arrows). However, there are also areas where the gather has not been improved, or has even been made worse (green arrows). These effects are a time variant function of the iteration number, so early stopping of the process is not possible.

Stability
The theory behind the Swan technique uses a number of assumptions in its derivation, with perhaps the most important being: constant velocity and consistent AVO behaviour in the analysis window, and the short offset approximation for moveout and AVO analysis (see Swan 2001 for more details). These, and other, assumptions are often invalid in real data – this adds noise and instability to the iteration process, even for high quality data, as Figure 1a demonstrates. Monitoring convergence criteria allows us to have a data driven number of iterations and hence avoid, or at least reduce, these instabilities. In Figure 1b we repeat the analysis using this extension to Swan’s original method. These gathers are now flat everywhere, highlighting the benefits of the method while reducing the side effects.

Marine Case Study
AVO gradient results from a central North Sea dataset are shown in Figure 2a. This section was obtained by fitting Shuey’s 2-term AVO equation to the pre-stack gathers after a 500m manual velocity analysis. There is considerable energy in this section, mainly associated with the geological structures. Are these genuine measurements of AVO effects in the gradient, or artificial ones caused by the gathers not being flat? Figure 2b shows the corresponding section after application of our extended Swan method (12.5m × 4ms grid). The flatness in the gathers is improved significantly by our new method, causing a dramatic reduction in energy on the gradient section, especially in areas associated with the structure. This indicates that a great deal of the energy in Figure 2a was spurious and gives us increased confidence in the reliability of our new results – the true AVO effects are now much easier to detect.

Land Case Study
Final stack results from an onshore Netherlands dataset are shown in Figure 3a. This section was obtained after a 400m manual velocity analysis. Figure 3b shows the corresponding stack after application of our extended Swan...
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method (25m $\times$ 4ms grid). There are many areas, indicated by the arrows, where the stack response has been improved by this technique. Also, a sharpening of the stack response is generally observed throughout.

Conclusions

The automatic, continuous velocity analysis of Swan (2001) can flatten pre-stack CMP gathers in small areas of data. However, we find this technique to be unstable in production processing. We have developed measures to improve the robustness of this process and demonstrate their effectiveness using two case studies.

References


Figure 1: Comparison of a pre-stack CMP gather after 0 (the input velocities), 2, 4 and 6 iterations of: (a) the original Swan (2001) method, and (b) the extended Swan method.
Figure 2: Comparison of AVO gradient sections calculated after: (a) 500m manual velocity picking, and (b) the extended Swan method. Note the dramatic decrease in energy associated with the geological structure in (b) caused by the gathers being flatter.
Figure 3: Comparison of final stack sections calculated after: (a) 400m manual velocity picking, and (b) the extended Swan method. The arrows indicate areas where the extended Swan method has improved the stack response.