Multichannel Seismic Reflection Data Processing: Multiple Attenuation of Line 250 at the Coast of Southern California Using Hyperbolic Radon Transform

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Abstract. Multichannel seismic reflection data processing of line 250 at the Coast of Southern California has been done by using Echos®. The purpose of this research is to separate multiple reflections from the primary reflection. Multiple reflections yield dramatic effect especially on marine seismic survey. Multiple reflections in marine seismic data is the noise caused by waves that trapped in a layer of sea water or rock layers. One of geophysics exploration problem is removing multiple reflections from primary reflection. Multiple reflections often destructively interfere with the primary reflection making interpretation difficult, so it’s needed to get seismic section free from multiple reflections. There are some methods to attenuate the multiple reflections, one of them is Hyperbolic Radon transform. Hyperbolic Radon transform method works by transforming the data from time-offset domain into the Radon domain. Primary reflection and multiple reflections can be separated into Radon domain. In the end of this research, seismic section before and after multiple attenuation using hyperbolic Radon transform were compared. Based on the result of processing, it can be concluded that hyperbolic Radon transform is effective to attenuate multiple reflections at 0.24-1.25s TWT. But, it can eliminate some of data and makes seismic section seen unclear.

1. Introduction
Seismic data processing is one of the major steps in the exploration process, alongside the acquisition and interpretation of seismic data. Energy sources are used to acquire seismic data to generate elastic waves which are reflected back to the receivers on the surface by subsurface structures. Examples of a simple seismic data acquisition geometry, with one source and a pair of receivers is show in figure 1. In seismic data acquisition, primary reflections are those that reflected only once at a certain subsurface interface before they arrive at the receivers. These primary reflections provide information such as velocity and subsurface structural identification [2].

However, in addition to primary reflections, receivers also record reflections which have been reflected between subsurface reflectors (or the surface) more than once before being received on the surface. It yields multiple caused by high impedance contrast at the boundary between layer. Multiple reflection has taken into account as a dramatic effect especially on marine seismic surveys [2].
Multiple reflections have been long time considered a noise in marine seismic data, as multiple reflections might interfere the data processing affecting the interpretation of subsurface image [3]. Hence, the multiple need to be attenuated to get the seismic data free from multiple. Multiple attenuation method that used in this research is hyperbolic Radon transform. Hyperbolic Radon transform method works by transforming the data of the time-offset domain into the Radon domain. Primary reflection and multiple reflections will be separated in Radon domain. Our objective is to test the Radon Transformation due to its robustness in removing the multiple of marine seismic data set. In the further discussion, we also compare the result with the conventional f-k filter.

![Figure 1. Seismic data acquisition geometry and primary reflections [2].](image)

2. Methodology
Seismic data records were stored in a raw format and have to be processed using standard routines before it can be used for interpretations [5]. The data have been processed using the software Echos® from Paradigm, Houston, Texas, USA. The seismic data have been previously preprocessing and sorted according to Common Mid Point (CMP). Figure 2 shows standard processing flow chart for this research.

![Figure 2. Processing flow chart for seismic data processing line 250.](image)
2.1. Pre-processing

Pre-processing consists of filter, deconvolution, filter f-k and muting. Filter was performed using FILTER module. During the process of filtering, unwanted signal frequencies that are recorded with the reflection events can be removed by allowing only a band of usable frequencies to pass [1,7]. Deconvolution was performed using DECONA module. Deconvolution was aimed at improving temporal resolution by compressing the basic source wavelet to approximately a spike and suppressing reverberating wave trains [1,7]. The f-k filter was performed using FK-FILT module [1]. The f-k filter process used to remove noise that has same frequency but has different wave number. Muting is performed using MUTE module [1]. Muting process used to remove noise on first break.

2.2. CMP Sorting

In CMP sorting was performed using SORT module [1]. The data were transformed from shot-receiver to midpoint offset coordinates. This is CMP sorting, which requires field geometry information. The required coordinate transformation was achieved by sorting the data into CMP gathers. Each individual trace is assigned to the midpoint between the shot and receiver location associated with that trace. Those traces with the same midpoint location are grouped together, making up a CMP gather [7].

2.3. Velocity Analysis and NMO Correction

Velocity analysis was performed using VELDEF module [1]. It provides an interactive option to select best fitting hyperbola defined by RMS velocity. Picking of velocity was assisted by a semblance of coherent trace energy [4]. The result of velocity analysis used to Normal Move-Out correction (NMO correction). The arrival time of reflections from a single event from the subsurface depends on the travel path of the signals. For a reflection from a point located in the subsurface with a constant velocity, the time difference between a given offset and zero offset in called Normal Move-Out (NMO) and can be calculated as equation 2.1.

\[
\Delta t = t(x) - t(0) = \frac{x^2}{2v^2t_0^2}
\]

where \(x\) is offset distance of receiver from source, \(v\) is velocity through the layer and \(t_0\) is total travel time for a round trip at zero offset [4].

2.4. Hyperbolic Radon Transform Method

Radon filtering suppresses non coherent noise for the full velocity range, and coherent noise such us multiple reflections, outside the velocity filter range. The hyperbolic velocity filter is based on the velocity function provided by the user. Radon filtering can be done at any stage of pre-stack processing prior to NMO. It is most often run with the data prepared for input to a stacking program [1].

A reflection point on a horizontal layer generates a hyperbolic event on a CMP gather. In order to map the hyperbolic event to a focus point in Radon domain, the hyperbolic Radon transform over the CMP gather is defined as equation 2.2.

\[
u(t, q) = \sum_{x} d(t = \sqrt{t^2 + qx^2}, x)
\]

where \(q = \frac{1}{v_{norm}}\), the summation path is defined by \(t = \sqrt{t^2 + qx^2}\) which implies a hyperbolic curve.

2.5. Stacking

After applying NMO correction with velocity function for primary reflection, traces of the same CMP will be stacked together. The primary associated signals are enhanced by summation over offsets while random noise is attenuated, since primaries are flat on NMO corrected gathers. If several random noise was stacked together, there will be same cancellation because they will be out of phase
with each other. After that, there will be a stacked seismic section which can be interpreted and analyzed using many parameters [6].

3. Results and Discussion

Multiple attenuation method that used in this research is hyperbolic Radon transform. Theoretically, hyperbolic events in the time-offset domain to a point in the Radon domain. Because the multiple reflections have different velocity to those primary reflections which are not associated with the multiples, they are mapped to different regions in the Radon domain, multiple-free data can be reconstructed back to the time-offset domain using inverse Radon transform [2].

After multiple attenuated, stacking was performed and then seismic section before and after multiple attenuation process were compared and analyzed. The result from the process is multiple-free seismic section. Multiple-free seismic section is shown in Figure 3b. The results has been review and show us that the filtering process is not completely removing the noise. This issue could be triggered because of the quality of our data is not good. However, for the interpretation, the noises has been reduced and did not affect the main signal. So the signal to noise ratio is not decreased.

Figure 3 shows a comparison of seismic section before and after multiple attenuation using hyperbolic Radon transform. Figure 3a shows the stacked seismic section without any multiple attenuation. Here are two multiples visible. They are visible at 0.24-1.25s TWT. Figure 3b shows the stacked seismic section after multiple attenuation was performed using hyperbolic Radon transform. Multiples can be attenuated with hyperbolic Radon transform. So, the advantage is Radon transform method can attenuate multiple reflections. But, it can eliminate some of data that makes seismic section seen unclear.

![Figure 3](image)

Figure 3. (a) Result of seismic section before multiple attenuation, (b) Result of seismic section after multiple attenuation is performed using hyperbolic Radon transform. Black arrow indicates multiples.

This radon transform has performed adequately in removing the multiples in marine data set. However, compare to conventional f-k filter, the result is better. The limitation of our study is the
quality of our data set that should be effective for low resolution data. We strongly recommend that in the future study, more complex data set should be tested with this method.

4. Conclusions

Based on multichannel seismic reflection data processing of line 250 at the Coast of Southern California that has been performed using Echos®, it can be concluded that hyperbolic Radon transform is effective to attenuate multiple reflections at 0.24-1.25s TWT. But, it can eliminate some of data that makes seismic section seen unclear.

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