APPLICATION OF MATLAB IN SEISMIC INTERFEROMETRY FOR SEISMIC SOURCE LOCATION AND INTERPOLATION OF TWO – DIMENSIONAL OCEAN BOTTOM SEISMIC DATA.

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Abstract: - Seismic survey is a program for mapping geological structure by observation of seismic wave. Creating seismic wave with artificial sources and observing the arrival time of the waves reflected from acoustic impedance contrasts or refracted through high velocity members. Real-time vertical seismic profile (VSP) imaging provides information ahead of the drill bit that confirmed the well trajectory. A key objective was to determine the best location for the seismic source while drilling. Geological bodies like salt causes ray bending which leads to higher amplitude reflections between sediment layers and causes multiple rays scattering in the data collected. Conventional source location and interpolation methods heavily rely on the accuracy of the velocity models. In this paper interferometric techniques will be use to extract multiple scatter information in ocean bottom seismic data which will provide reliable results without knowledge of the velocity models. The sparse ocean bottom seismic data are interferometrically correlated with the model – based Green’s functions for the sea floor model. This generates densely recorded ocean bottom seismic traces. Local matching filter will be applied to reduce the artifacts in the interpolated data. To mitigate the artifacts in the interferometry correlation results, an anti – aliasing theory developed will establish a fundamental criterion for numerical application of seismic interferometry to any seismic data. Mathematical Time Revisal Mirror models will be developed in MATLAB to determine the position of seismic source by comparing the phases of signals at the output terminals. Simulation will also be run using the data generated to plot a two dimensional ocean bottom seismic profile (OBS). Hence seismic interferometry can be applied during exploration for hydrocarbon and during down hole drilling to provide reliable information about complex geology.

Key words: Seismic, Interferometric, Modeling, Simulation, Green’s function, Redatumed, Anti-aliasing theory.
1. INTRODUCTION.

Seismic interferometry is an exciting new field in geophysics that utilizes multiple scattering events to provide unprecedented views of the Earth’s subsurface structures. In this paper, MATLAB codes was use to illustrate important ideas which generate synthetic traces and invert these to determine the Earth’s reflectivity structure. These principles were reinforced by deriving rigorous mathematical models of seismic interferometry. The mathematical models were applied to both synthetic data and field data to produce interferometric imaging applied in geophysics for exploration seismology. Correlating a pair of recorded seismic traces with one another and summing the resulting correlogram for different shot records is the basic processing step of seismic interferometry. This typically results in a new trace with a virtual source and receiver location known as a redatumed trace. The redatumed trace simulates a trace as if a real short and receiver were at the new datum. The redatuming procedure has been used by the exploration geophysics community since the early 1970s. One of the traces in the correlation pair is computed by a numerical procedure such as ray tracing while the other trace is naturally recorded. Ray tracing or more generally numerical modeling, uses an imperfect model of the Earth’s velocity distribution which leads to defocusing errors in model based redatuming. In contrast, seismic interferometry is free of such problems because it only uses recorded traces in the correlation. This freedom also allows one to utilize all of the events in the trace, including higher order multiples and coherent noise such as surface waves, leading to enhanced resolution, illumination and the signal to noise ratio in the reflectivity image. Hence MATLAB cod was use to generate synthetic traces, redatum OBS data by summed cross-correlations and invert the redatumed traces for the Earth’s reflectivity structure. The benefits of redatuming VSP sources to a lower datum are follows. Better image resolution because, the VSP sources are redatumed to be closer to the target. Redatuming to a deeper level avoids defocusing errors due to an incorrect estimate of the over burden’s migration velocity $v(x)_{over}$. The $v(x)_{over}$ model is not needed because the extrapolation operators $G(A|x)$ for $X_eS_o$ in the equation are naturally obtained from the VSP data. The purpose is to redatum vertical seismic profile (VSP) data so that both the source and receivers were below the complex overburden and could be closer to the target body. The VSP-SWP was derived and correlation transform for a linear acoustic medium of constant density,

2. Problem Formulation.

Mathematical modeling: $G(A|x)$ and $G(B|x)$ are interpreted as the traces recorded in the horizontal well at A, $B_eS_{well}$ were generated the near surface point source at $X_eS_o$. This interpretation of $G(B|x)$ was reversed by reciprocity $G(B|x) = G(x|B)$ to say that the source is at the interior point B and excites waves that propagate to the near - surface boundary points at x. The correlation – reciprocity equation is shown below:
The integrands are labeled VSP because the kernels, \( G(B|\mathbf{x}) \) or \( G(A|\mathbf{x}) \), can be interpreted as VSP data. The sources are located at \( \mathbf{x} \) along the dashed boundary \( S_0 \) and the geophones are buried at \( A \) and \( B \) along the horizontal well at \( S_{\text{well}} \). The left hand side of this equation is SWP because it represents the single well profile data obtained from shots and receivers along the well. The SWP data \( G(B|A) \) can be used to image reflectors around the well without suffering from the distorting effect of an unknown velocity between the well and surface. The ray diagram for interferometic interpolation of sparse OBS data is shown in the figure below and this scheme can be formulated with the reciprocity equation of the correlation type with two states. Consider two states, one is the acoustic field associated with multilayered model shown in the figure below, where \( G(x|A) \) is interpreted as the acoustic wave field excited by an interior harmonic point source at \( A \) and recorded at \( x \). The other state is the acoustic field in the sea-floor model, which only consists of water layer free surface, and a sea floor below which is a homogeneous medium with the same velocity and density of layer 1. The Green’s function associated with this new state is defined as \( G_o(x|B) \), and does not contain reflections from any interface below the sea floor.

The Helmholtz equations satisfied by these two Green’s function are:

\[
(\nabla^2 + k^2) G(x|A) = - G(x - A) \quad \text{Eqn. 1}
\]

\[
(\nabla^2 + k_o^2) G_o(x|B) = - G(x - B) \quad \text{Eqn. 2}
\]

Where \( k = w/\nu(\mathbf{x}) \) for the multilayered model and \( k_o = w/\nu_o(\mathbf{x}) \) for the sea-floor model. The Laplacians can be weighted by Green’s functions to give the following identities:

\[
\nabla \cdot [G(x|A) \nabla G(x|B)] = \nabla \cdot [G(x|A) \nabla G_o(x|B)] = - G(x|A) \quad \text{Eqn. 3}
\]

\[
\nabla \cdot [G_o(x|B) \nabla G_o(x|B)] = \nabla \cdot [G_o(x|B) \nabla G(x|A)] = - G_o(x|B) \quad \text{Eqn. 4}
\]

Instead of defining the integration volume over the entire multilayered model, the volume is restricted to the ocean layer where both the sea-floor model and multilayer model agree. Subtracting and integrating the above equation over the ocean volume yields the reciprocity equation of correlation type for two different states:

\[
G(B|A) - G_o(A|B) = \int_{S_o} [G(x|A) \frac{\partial G(x|B)}{\partial n_x} - G_o(x|A) \frac{\partial G_o(x|B)}{\partial n_x}] d^2x
\]

Where \( S_o \) is the boundary along the sea floor and the integration along free vanishes because both Green’s functions are zero there. The contributions from the infinite
vertical boundaries to the left and right of the boat will be ignored. The reciprocity equation of correlation type for two different states can be used for the interpolation or extrapolation of traces. Applying the far-field approximation to the above equation yields the scheme for interpolating sparse OBS traces:

\[ G(B/A) \approx 2i k \int_{\Omega} G(x/A) G(x/B)^* dx^2 + G(B/A)^* \quad \text{Eqn. 6} \]

Where, \( G(x|B) \) is the Green’s function for a water layer model and \( G(x|A) \) is the OBS Green’s function for the actual earth model. Here A and B positions are, respectively, just below the free surface and above the sea floor, and \( S_s \) is the boundary along the sea floor and integration along the free surface vanishes because both Green’s functions are zero there. The equation above shows a virtual OBS trace obtained by correlating the real OBS trace \( G(x|A) \) are the Green’s function of the water layer model \( G_0(x|B) \), and summing over all real OBS receivers. The contributions from the vertical boundaries at infinity to the left and to the right of the boat will be ignored (Wapenear and Fokkema, 2006). To reduce artifacts only down going waves was use in the Green’s function \( G_0(x|B) \) and \( G(x|A) \). To mitigate artifacts associated with the far-field approximation and the summation along a discrete recording interval in a limited recording aperture size, a local time – domain matching filter is applied to the virtual OBS traces obtained with equation 6 is shown in figure 2. The Anti-aliasing condition for interferometric interpolation: Assume that only the primary and first order multiple reflections are correlated then;

\[ \mathcal{O}(A,B,x_i) \approx C(A,B,x_i)e^{i(TAx_i-TBx_i)} \quad \text{Eqn. 7} \]

Where \( C(A,B,x_i) \) denotes the geometrical spreading term, \( TAx_i \) denotes the multiple travel time in the water layer from the virtual receiver B to \( X_i \). In this case we arrive at the anti-aliasing condition:

\[ (TAx_{i+1}-TBx_{i+1})-(TAx_i-TBx_i)<\frac{T}{2} \quad \text{Eqn. 8} \]

Where \( TAx_{i+1} \) is the multiple reflection travel times, \( TBx_{i+1} \) is the primary reflection travel time, and \( T=2\pi/\nu_0 \) is the dominant period of the data. Rearranging equation gives:

\[ (TAx_{i+2}-TAx_i)-(TBx_{i+1}-TBx_i)<\frac{T}{2} \quad \text{Eqn. 9} \]

If we make the plane wave assumption events we have: \( TAx_{i+1}-TAx_i \approx \Delta x/V_{Xm}(x_i) \), and \( TBx_{i+1} - Tbx_i \approx \Delta x/V_{Xp}(x_i) \) where \( \Delta x \) is the recording interval and \( V_{Xm}(x_i) \) and \( V_{Xp}(x_i) \) are respectively the horizontal apparent velocities for the multiple and primary events at receiver location \( x_i \). Then equation is written as

\[ \Delta x \left( \frac{1}{V_{Xm}(x_i)} - \frac{1}{V_{Xp}(x_i)} \right) < \frac{T}{2} \quad \text{Eqn. 10} \]

The equation can be used as the anti-aliasing criterion for interferometric interpolation. This formula is easily generalized to the anti-aliasing criterion for the correlation of any pair of different events.

3. Problem Solution.
3.1 DISCUSSION.
Geological message of figure 2, interpolation shows that from depths of 4500 m to 6000 m is a bank-edge with sag. This have shelf-edge reef, with very good porosity overlying sediments probably
carbonate prone. The depths of 6000 m to 8000 m is a reflection – free mound which shows patch reef or pinnacle reef, drape shows flanking sediments more compatible probably shale. Figure 1, shows computed and theoretical trace g(A,t|B,0) for the two-layer model result computed by MATLAB program. There is a phase shift problem in the predicted wavelet because the theory is for 3D yet the integral implementation is over a 2D line. This model synthetic seismograms and interferometrically transform SSP 1st-order multiples into primaries. Interferometric redatuming works under far field approximation but has errors. Errors increase as reflector approaches free surface. The dashed lines correspond to the analytic response of a point source and the solid lines correspond to the numerical solution by applying Green’s theorem to shot gathers recorded along the horizontal surface AB. Figure 3, shows the data collected from Canada with zero offset vertical profile interpolation and migration velocity. This shows that the one without the velocity component is clear then the one with the velocity component.

4. CONCLUSION.
Hence MATLAB for technical computing can be applied to seismic interferometric by using Green’s function leading to super resolution of the image. A major benefit of seismic interferometric is that source receiver array, after interferometric redatuming becomes closer to the imaging target. This means that the distorting effects of the uninteresting part of the medium are avoided leading to better image resolution of the target. No velocity model or statics are needed for the redatuming because the data act as natural wave field extrapolator. This gives a very clear image which can show the formation of the earth and possible hydrocarbon deposited in that part of the subsurface. I there for recommend the use of MATLAB in seismic interoperation for exploration in the oil and gas industry.

REFERENCES.