PHASE-SHIFT PLUS INTERPOLATION TIME-STEPPING METHOD FOR REVERSE TIME MIGRATION

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Reverse time migration (RTM), using the two-way acoustic wave equation is not a new concept. It was introduced in the late 1970's. But despite its advantages in depth imaging it was not used in practice due to its high computational requirements. Now, computer technology has improved and 3D prestack RTM is being used to address the imaging challenges posed by sub salt and other complex subsurface targets.

By using the full wave equation, RTM implicitly includes multiple arrival paths and has no dip limitation, enabling the imaging of complex reflectors. For poststack seismic data, RTM is performed by pushing the recorded wavefield backward in time into the subsurface with half of the velocity of the medium. At time t=0, the image time, the back propagated recorded wavefield is captured to construct the image. For prestack data, the RTM algorithm needs a different imaging condition. In prestack RTM, at each time step, a shot is forward propagated and the recorded data is similarly back propagated and the images are formed by crosscorrelating the source wavefield and the receiver wavefields to determine when a reflection event occurs. RTM can also be considered the inverse operation of forward modeling and the same numerical modeling code that is used for forward modeling can be used for RTM.

RTM is now computationally feasible but it is still expensive. One reason is that the most common implementations use small time steps to avoid numerical instability and reduce dispersion. This implies that 3D imaging using RTM for large seismic surveys, due to this sampling requirements, will either require filtering the data to remove the higher frequency data or the RTM code will require unacceptably long run times even with a cluster of computer. But, more recently, many new algorithms are being developed to overcome this problem.

In this paper we propose a new solution for the two way wave equation for reverse time migration (RTM). Using a pseudodifferential operator for time derivatives, computed directly from the two way wave equation, we obtain a time extrapolation operator in the space-wavenumber domain. The time-stepping method proposed can be implemented using an interpolation procedure based on the solution of the wave equation for the constant velocity case. The time advanced wavefields for several reference velocities are computed in the Fourier domain and then interpolated back in the space domain.

The proposed new method is a Fourier migration method for the two way wave equation for variable velocity media and it is conceptually very similar to the phase-shift plus interpolation method (PSPI) used commonly for one way wave equations. The feasibility of using this time-stepping method for RTM is demonstrated by the numerical synthetic examples and by studying its stability condition proprieties. Through the numerical examples, we show the applicability and robustness of this new method and also show that it can extrapolate wavefields with a much larger time step than commonly used.