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The migration of prestack slant stack with PSPI

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ABSTRACT

Prestack slant stack migration is implemented with both one-pass and two-pass phase shift plus interpolation (PSPI) to migrate seismic sections with lateral velocity variations. I compared impulse responses of operators with different sets of velocities to test the accuracy of the migration operator. This algorithm can handle lateral velocity variations very well.

INTRODUCTION

The migration of the slant stack of a common midpoint gathers is a method that makes no assumptions that deteriorate with wide offset angles, steep dips, or vertical velocity variations. Events of different dips that intersect are equally well imaged. Hence, Keho and et al (1992) use such migrated $\tau - p$ seismic data to do AVO processing.

Ottolini (1982) proposed the equations for and some applications of common midpoint slant stack migration. The migration can be implemented with either FK or the phase shift algorithm.

Gazdag (1984) provided an unconditionally stable method, phase shift plus interpolation (PSPI), taking lateral velocity variations into account.

This paper describes my use of two different PSPI algorithms to implement common midpoint migration of prestack slant stack for velocity variations with depth and also for lateral velocity variations. The migrated sections can be stacked to obtain a migrated image or left unstacked for for AVO analysis.

MIGRATION OF COMMON MIDPOINT SLANT STACK

The migration of common midpoint slant stack is accomplished by the following steps.

1) Construct the slant stack section, transform the CDP gather from the (t, y, h)

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domain to the (τ, y, p) domain by the $\tau - p$ transformation.

2) Sort the data into a constant p section.

3) Migrate the constant p section.

4) Do inverse $\tau - p$ transformation and stack the section, or do amplitude analysis.

SLANT STACK TRANSFORMATION

We first have to transform the wavefield in CDP gather from the (x, t) domain to the (τ, p) domain. Let $d(x, t)$ be the wavefield and $u(\tau, p)$ be the transformed slant stack wavefield (Claerbout, 1985) so that

$$u(\tau, p) = \int d(x, \tau + px)dx \tag{1}$$

where

$\tau = t - px$

p : *slant parameter*

x : *offset*

A lot of care needs to be taken to construct a high-quality slant stack CMP gather, several methods exist to achieve this (Kostov, 1990) . The causes of poor quality are probably due to very coarse offsets and missing offsets beyond the ends of the cable. Those missing offsets must be interpolated or extrapolated before slant stack transformation .

MIGRATION EQUATION FOR COMMON MIDPOINT SLANT STACK

According to Ottolini (1982), the DSR equation for the downward continuation of common midpoint slant stack is

$$\frac{\partial u}{\partial z} = \frac{-i\omega}{v}\left[\sqrt{1-(Y+pv)^2} + \sqrt{1-(Y-pv)^2}\right]U \tag{2}$$

where

$$Y = \frac{vk_y}{2\omega}$$

The solution of equation (2) is

$$U(\omega, z+\Delta z, k) = U(\omega, z, k)\exp\left\{\frac{-i\omega}{v}\left[\sqrt{1-(\frac{vk_y}{2\omega}+pv)^2} + \sqrt{1-(\frac{vk_y}{2\omega}-pv)^2}\right]\Delta z\right\} \tag{3}$$

We can use this equation to obtain the wave extrapolation for constant velocity. Velocity variations in depth are easily accommodated by varying the velocity v with depth z in equation (3).

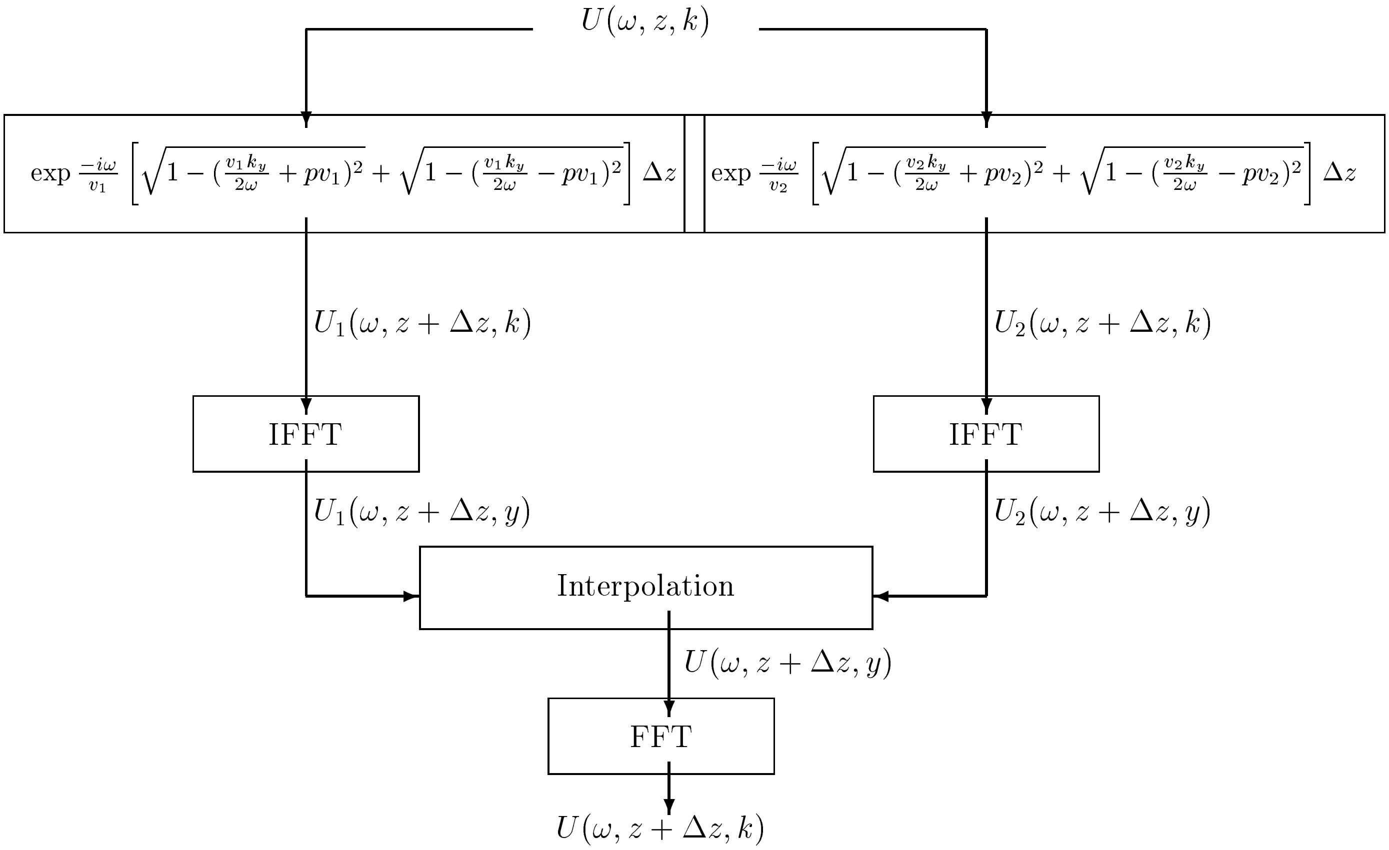

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Figure 1: Computational flow chart of prestack slant stack migration with one-pass PSPI.

IMPLEMENTATION FOR LATERAL VELOCITY VARIATIONS

I used two different algorithms to implement one-pass and two-pass PSPI respectively.

One-pass PSPI

By using the PSPI algorithm(Gazdag and Sguazzero, 1984), the wave extrapolation with lateral velocity variations can be implemented. I first use v_1 and v_2 to do the wave extrapolation separately, then inverse Fourier transform the wave field to the space domain. Then I interpolate the wavefield between $U_1(\omega, z + \Delta z, y)$ and $U_2(\omega, z + \Delta z, y)$. Finally, I do the Fourier transform again to complete the next Δz wavefield extrapolation in the same way. Figure 1 is a computational flow chart of this process.

Two-pass PSPI

As an alternative to downward continuation and interpolation of the source and receiver at the same time, we can also finish the prestack slant stack migration with

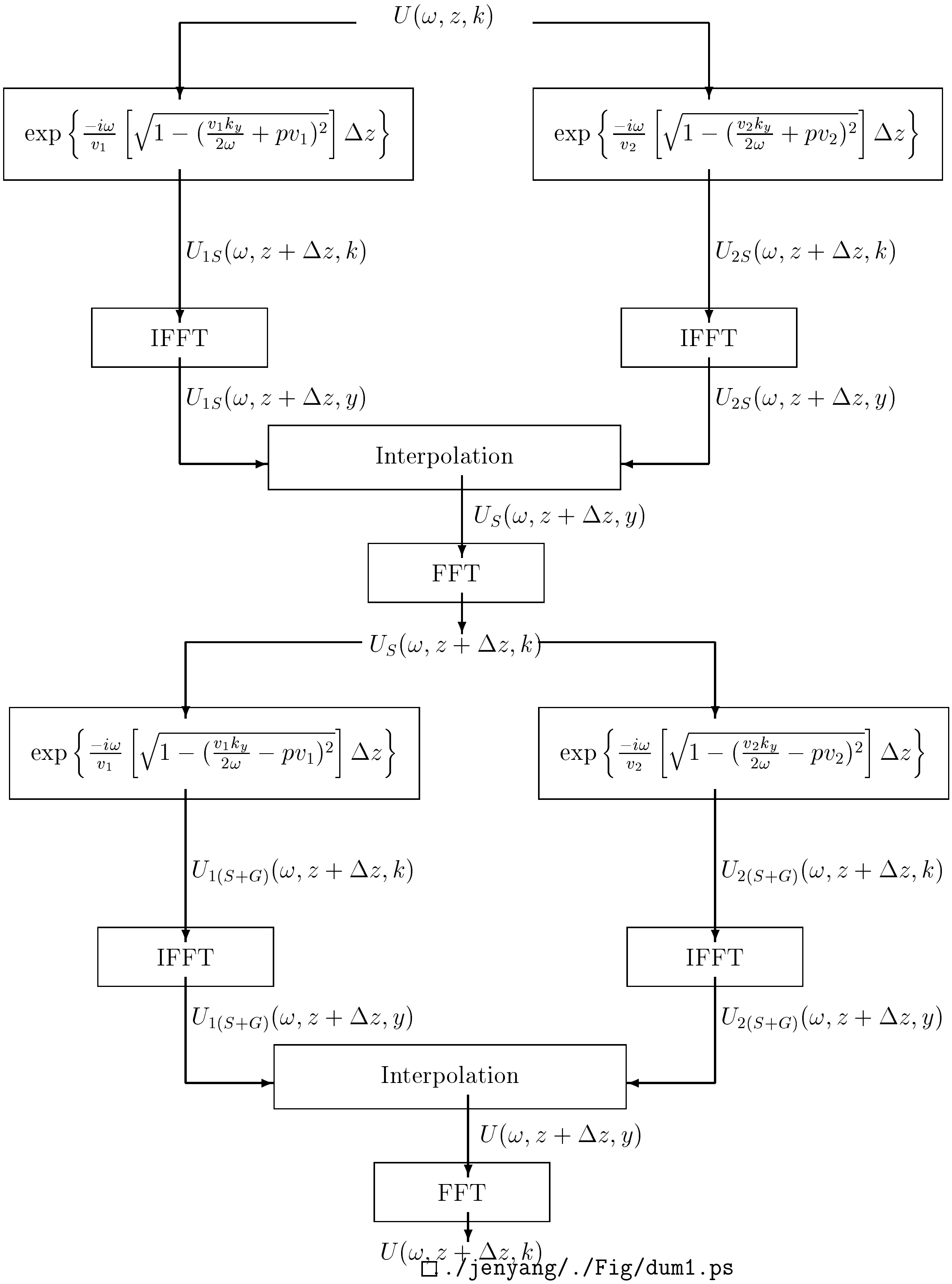

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Figure 2: Computational flow chart of prestack slant stack migration with two-pass PSPI.

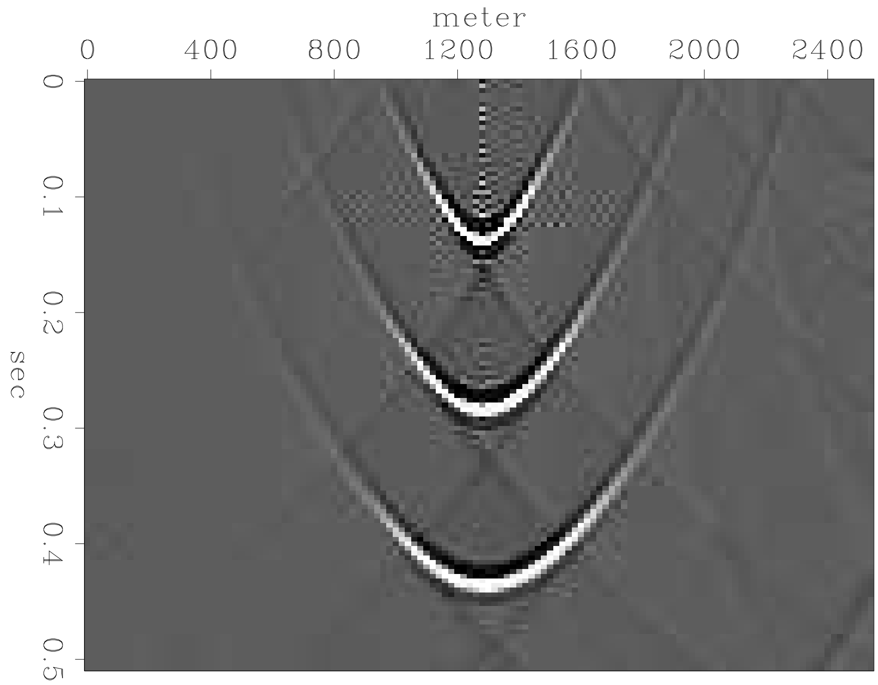

Figure 3: The impulse response of prestack slant stack migration with PSPI; p=.00021 s/m with $v_1(z) = 1500 + 0.5z$ m/s, and $v_2(z) = 2500 + 0.5z$ m/s. jenyang-fig1 [ER]

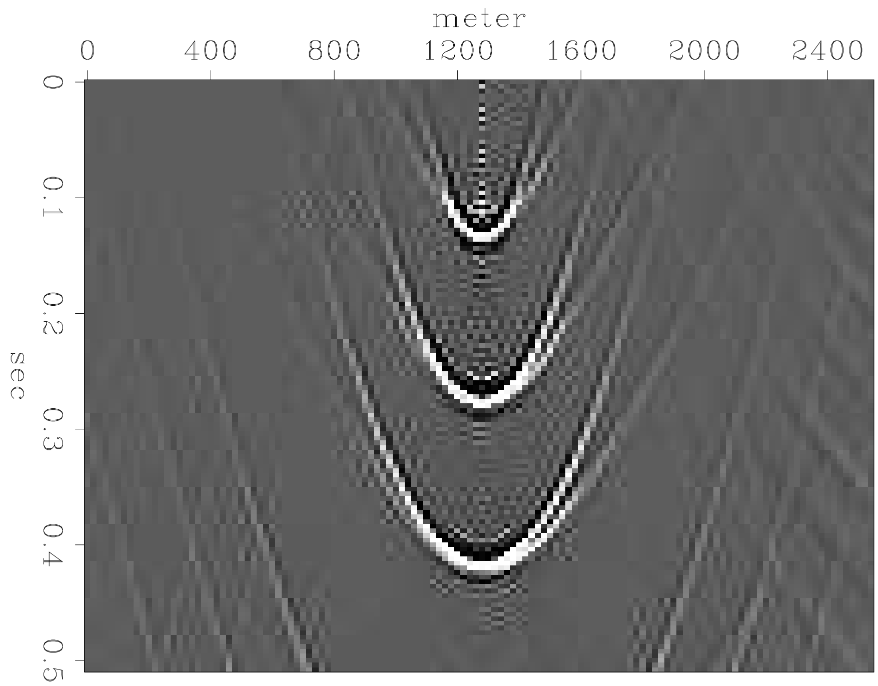

Figure 4: The superposition of the impulse response of $v = 2000$ m/s and $v_1(z) = 1500$ m/s at $y = 0$ m and of $v_2(z) = 2500$ m/s with $y = 2560$ m by PSPI. jenyang-fig2 [ER]

PSPI by splitting into two pass. Its implementation is illustrated in the steps shown in Figure 2. The U_{1S} and U_{2S} are the wavefields extrapolated by v_1 and v_2 separately for the source. After the interpolation, we get U_S. Then wavefields are downward continued separately for the receiver by v_1 and v_2. By interpolating the wavefield between $U_{1(S+G)}$ and $U_{2(S+G)}$, we can complete the whole wave extrapolation.

DISCUSSION OF RESULTS

Figure 3 shows the impulse response of prestack slant stack migration with PSPI, with $p = .00021$ s/m, $v_1(z) = 1500 + 0.5z$ m/s at $y = 0$ m, and $v_2(z) = 2500 + 0.5z$ m/s at $y = 2560$ m. The skewed impulse responses are caused by the velocity variations in depth and in lateral variation.

To test the accuracy of the PSPI operator, I used $v_1(z) = 1500$ m/s at $y = 0$ m and $v_2(z) = 2500$ m/s at $y = 2560$ m to simulate the response of $v = 2000$ m/s at $y = 1280$ m. Figure 4 shows these two impulse responses together. The impulse response with a wider aperture is from the PSPI, and the other is the response with $v = 2000$ m/s. The bottom of the responses coincide very well, even with the velocity discrepancy. By increasing the velocity discrepancy, we get Figure 5, with $v_1(z) = 1000$ m/s and $v_2(z) = 3000$ m/s. The bottom of the responses are no longer coincident, and the discrepancy gets worse as the depth increases.

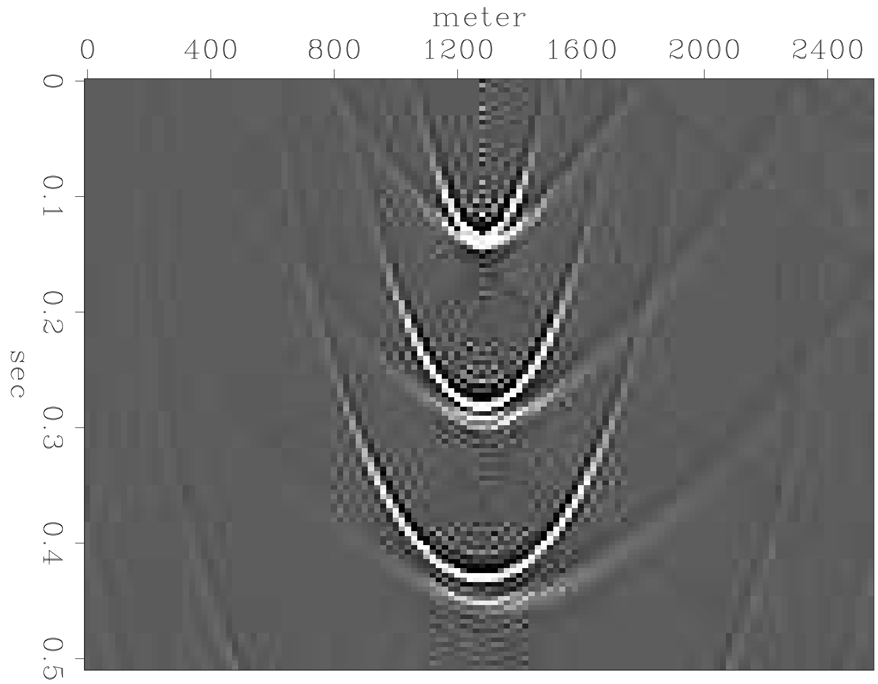

Figure 5: The superposition of the impulse response of $v = 2000$ m/s and $v_1(z) = 1000$ m/s at $y = 0$ m and of $v_2(z) = 3000$ m/s at $y = 2560$ m with PSPI. jenyang-fig3 [ER]

CONCLUSION

Prestack slant stack migration was implemented with the PSPI algorithm using two reference velocities. This algorithm can handle lateral velocity variations of up to 25 percent. I used both one and two-pass PSPI. The impulse responses of two-pass PSPI are similar to that of one-pass method; however the two-pass method has slightly better accuracy.

After the prestack slant stack migration, the seismic events are lined up at the correct position. It is easier and more accurate to analyze the AVO either in the v(τ, p) domain or in the (τ, x) domain. A good forward and inverse slant stack transform package is necessary to preserve the amplitude.

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