Vertical elliptic operator for efficient wavefield extrapolation in TTI media

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Advanced imaging algorithms, such as reverse time migration (RTM), rely on accurate and efficient forward and backward extrapolation of waves in time. Solving the full anisotropic/elastic wave equations is computationally expensive. Therefore, (Alkhalifah, 2000) proposed the acoustic anisotropic wave equation for transversely isotropic (TI) media by setting the shear-wave velocity along the symmetry direction to zero. The equation shares the same dispersion relation with that of the quasi-P (qP) wave in elastic TI media.

Recently, Xu and Zhou (2014) proposed a novel approach to solve the acoustic anisotropic wave equation. They obtain a new equation by decomposing the pseudo-differential operator into two numerically solvable operators: a Laplacian operator and a scalar operator. This approach would require solving an equation similar to the acoustic isotropic wave equation, thereby significantly reducing the computational load. The approach improved the kinematic match of later arrivals as opposed to the effective isotropic based approximation (Alkhalifah et al., 2013), nevertheless, the amplitude distortion was evident in the obtained RTM images (Tang et al. 2014).

To improve the amplitude accuracy, Xu et al. (2015) modified the original decomposition, such that the pseudo-differential operator is now decomposed into an elliptic differential operator and a scalar operator. For a transversely isotropic media with vertical symmetry axis (VTI), this would mean solving a vertical elliptically anisotropic (VEA) differential operator. However, for a tilted transversely isotropic media (TTI), the decomposition would yield a tilted elliptically anisotropic (TEA) differential operator. It is worth noting that there is a significant cost difference between solving the TEA and VEA wave equations. This cost difference is associated with mixed partial derivatives arising in the wave equation when tilt is non-zero.

We propose an alternate strategy by decomposing of the pseudo-differential operator into a VEA differential operator and a scalar operator, even when the TI medium exhibits non-zero tilt. In essence, we solve a VEA-like wave equation at each time step, therefore, the cost is equivalent to the isotropic decomposition. We observe that the amplitude match is slightly inferior to the TEA case; however, the cost is significantly lower. Therefore, the proposed decomposition yields a much improved cost versus efficiency trade-off. Furthermore, the wavefield solution does not contain shear-wave artifacts and therefore does not require costly noise-filtering operations.

References

Alkhalifah, T., 2000, An acoustic wave equation for anisotropic media: *Geophysics*, 65, 1239–1250.

Alkhalifah, T., X. Ma, U. Waheed, and M. Zuberi, 2013, Efficient anisotropic wavefield extrapolation using effective isotropic models: Presented at the *75th EAGE Conference & Exhibition incorporating SPE EUROPEC 2013*.

Tang, B., S. Xu, and H. Zhou, 2014, RTM with pure quasi-P wave equation: Presented at the *76th EAGE Conference and Exhibition 2014*.

Xu, S., and H. Zhou, 2014, Efficient and accurate algorithm for quasi-P wave propagation: Presented at the *76th EAGE Conference and Exhibition 2014*.

Xu, S., B. Tang, J. Mu, and H. Zhou, 2015, Elliptic decomposition of quasi p-wave equation: accepted, *77th EAGE Conference and Exhibition 2015*.