NMO Correction for PS-Wave

Pablo Machado Barros (Cenpes-Petrobras)
André Bulcão (Petrobras)
Bruno Pereira Dias (Petrobras)
Claiton Pimentel de Oliveira (Petrobras)
Djalma Manoel Soares Filho (Petrobras)
Gustavo Catão Alves (Petrobras)
Tiago Ilipronti Girardi (Cenpes-Petrobras)
Ubiratan Jose Furtado (Petrobras)
Luis Fernando Mendes Cury (Cenpes-Petrobras)

NMO Correction for PS-Wave

Please, do not insert author names in your submission PDF file

Abstract

Normal moveout (NMO) correction is a procedure applied in seismic data processing, usually associated with the problem of stacking pre-migrated data and/or conducting velocity analysis. The NMO equation used in the industry, $t = \sqrt{t_0^2 + x^2/V_{rms}^2}$, derived by Dix (1955) [1], applies a small offset approximation for a horizontally layered-Earth model as a way of approximating the two-way zero offset travel time from source to receiver. It is based on the root mean square (rms) velocity of each layer, which incorporates information from layers above it and has been successfully applied in industry for decades as a simple yet effective method of estimating layer velocities. However, as acquisition technology has advanced, longer offset data has been acquired, making the small offset approximation used in NMO Dix equation no longer valid. Castle (1994) [2] derived an upper bound limit, $x < \sqrt{2}.(depth\,of\,reflector)$, for the radius of convergence of this equation and all analytic NMO correction formulas based on the Taylor series of time *t* as a function of offset *x* (such as the *shifted hyperbola model* [2]):

$$t = c_1 + c_2x^2 + c_3x^4 + c_4x^6 + \cdots$$

The practical implication of this is that NMO-corrected data outside of this limit (shallow regions with large offsets) is critically stretched. The traditional approach to dealing with this problem is muting, i.e. deleting entire regions of stretched data before stacking.

In this work we propose a new method for NMO correction, based on the layered Earth-model of homogeneous and isotropic horizontal layers and on the assumption that reflections can happen inside any layer. An equation for the two-way zero offset travel time is analytically derived and numerically solved in such a way that no small offset approximation is used, which means that data stretching is avoided for large offsets. A consequent benefit of the method is the possibility of adapting the velocities of each layer in such a way that we can calculate the travel times of converted PS waves using the P velocity for the incident wave and the S velocity for the reflected one. This can be used to obtain a good estimation of the S velocity near the water bottom, which can be used as input to velocity model building in elastic FWI simulations, helping its convergence as the very slow velocity of S wave near the water bottom gives rise to numerical difficulties related to the necessity of refinement of the mesh there.

As a validation we applied this method to synthetic data from ocean bottom nodes and performed stacking, comparing the results of the usual Dix NMO formula with it. As expected, data stretching is avoided, allowing full use of the data for stacking. The numerical solution is much more expensive than the simple application of the Dix NMO equation, but is still cheap by current computing power standards, making the use of the small offset approximation meaningless nowadays. However, a not foreseen difficulty arose: regions of the data of large offset present multiple events, i.e., rays that reflect at different layers and arrive at the same time. This means the corrected position of an event would be more than one place, and a fraction of the amplitude should be separated for each of them. This was not implemented, here the amplitude was equally split among them. As an extension of this work, the relative amplitudes of the multiple events could be estimated using *Zoeppritz* equations (approximating densities by Gardner's relation), as all incidence and reflections angles for all transmitted and reflected rays are known, but considerably increasing the computational cost.

[1] Dix, C. H., 1955, *Seismic velocities from surface measurements*, GEOPHYSICS, vol 20, p68.

[2] Castle, R. J., 1994, *A Theory of Normal Moveout*, GEOPHYSICS, vol 59, p983.