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Multiparametric traveltimes: Concepts and applications

Presented by Martin Tygel, University of Campinas, Campinas SP, Brazil

ABSTRACT

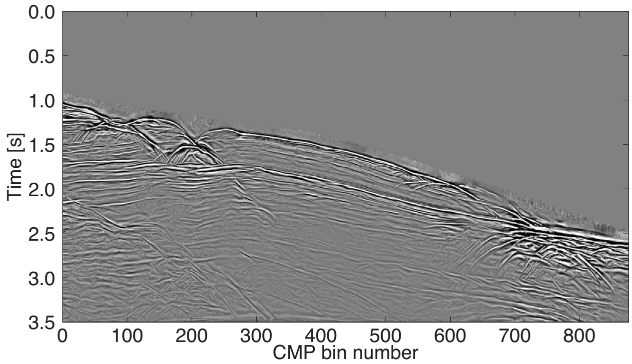
Traveltime stacking is one of the most fundamental tools in the processing of multicoverage seismic data. The most popular stacking traveltime is the normal moveout (NMO), upon which the celebrated common-midpoint (CMP) method is based. Established in the 1960s, the CMP method remains as an obligatory step in any seismic processing sequence. The NMO stacking traveltime depends on a single parameter (the NMO velocity) and is performed on individual CMP gathers, thus depending on offset only. In spite of its well-recognized good properties, such as a valuable zero-offset (ZO) stacked section and an NMO-velocity field, NMO stacking can be seen to have two main drawbacks: The first one is that it employs only a fraction (CMP gathers) of the multicoverage data and, as a consequence, takes no advantage of the redundancy contained in the full data. The second one is the fact that it delivers a single parameter (NMO velocity), not much information extraction from the huge and costly seismic data.

In the 1980s, in response to the demands of seismic processing in anisotropic media, multiparametric nonhyperbolic moveouts came into play. Still dependent on offset only, such moveouts mainly were applied to transverse anisotropic media with a vertical axis of symmetry. Moveout extensions for more complex anisotropic media are available in recent literature, being a topic of active ongoing research.

A vigorous attempt to overcome the limitations of offset dependent moveouts came about in the late 1990s by the introduction of multiparametric moveouts depending on both midpoint and offset coordinates and also fully in 3D. Moreover, the parameters introduced in the new traveltimes were seen to be very useful for other imaging purposes, such as, e.g., time migration, separation of reflections and diffractions, time-to-depth conversion, tomography and, more recently, data regularization.

In this lecture, I discuss the multiparametric traveltimes that are the most natural extensions of the classical single-parameter NMO and time-migration moveouts. More specifically, these are the 3D hyperbolic (second-order Taylor polynomial) mainly designed for reflections and double-square-root (sum of two hyperbolic moveouts), mainly designed for diffractions. Both traveltimes are defined for varying midpoint and half-offset coordinates.

Besides a brief discussion of the traveltime expressions and interpretation of their parameters, various applications on the above-mentioned topics are presented. Finally, perspectives and actual challenges of the multiparametric traveltime approach to seismic imaging are commented.



BIOGRAPHY

Martin Tygel received his BSc in physics (1969) at the State University of Rio de Janeiro and MSc in mathematics (1973) at the Catholic University of Rio de Janeiro. After being awarded by a fellowship of the Brazilian Council of Research and Technological Development (CNPq), he obtained the MSc (1976) and PhD (1979) in mathematics at Stanford University. He has taught at the Federal University of Rio Grande do Norte (1979–1981) and the Federal University of Bahia (1981–1983), being responsible there for the mathematical disciplines at the joint graduate program in geophysics together with Petrobras. In 1984, he joined the University of Campinas (Unicamp), where he is located until today. Prof. Tygel has also been a Humboldt scholar (1985–1987) in Hannover (Germany), and also a visiting professor at the Universities of Karlsruhe (Germany) (1990) and Trondheim (Norway) (2007–2008). In 2002, he received the Conrad Schlumberger Award of the European Association of Geophysicists and Engineers. In 1997, Prof. Tygel was one of the founders of the Wave Inversion Technology (WIT) Consortium. In 2001, he founded the Computation Geophysics Laboratory at the Department of Applied Mathematics at Unicamp, and in 2013, he founded the High Performance Geophysics (HPG) Lab at the Center of Petroleum Studies also at Unicamp. The latter has a special emphasis in integrating geophysics results with high-performance computing (HPC) so as to optimize their most direct practical application.

Besides his scientific activities which include three books and more than 200 publications in international journals and proceedings of international congresses, Prof. Tygel has a long experience in carrying out projects which involves academia and the oil industry. His research interests are in methodologies and algorithms of seismic processing, imaging, and inversion that have a sound basis on wave propagation and find practical application to exploration and monitoring of hydrocarbon reservoirs.

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