Reducing FWI Dependence on Long Offsets for Deeper Velocity Model Updates

Reflections rather than diving waves and refractions push FWI deeper.

CONTRIBUTED BY PGS

There has been an increase in activity in recent years to reformulate FWI algorithms to deliver deep velocity model updates in a stable manner without relying on very long offsets. The PGS full waveform inversion (FWI) solution uses diving waves, refractions and reflections together to achieve this without artifacts or cycle skipping problems. This enables better inversions for robust ranking and more reliable de-risking of prospects.

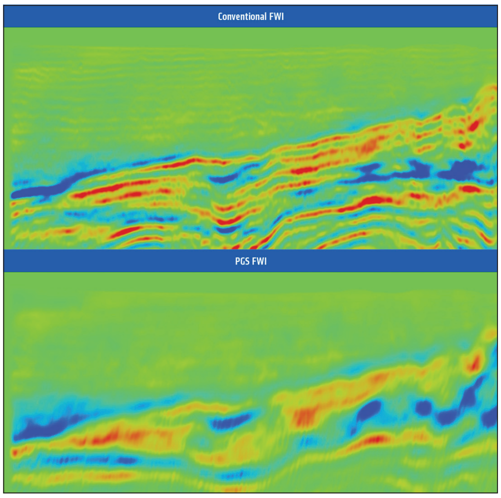
Traditional methods

Although well-established as part of the velocity model-building flow, most successful applications of FWI to date have been limited to shallow water environments. This can be attributed to the fact that typical implementations rely heavily on refracted energy or diving waves. Put together with the offset limitations that exist in seismic data, streamers and nodes alike, it follows naturally that shallow settings lend themselves easiest to being addressed by FWI as they are better sampled by refractions. FWI inverts for the velocity model by solving a nonlinear inverse problem minimizing the difference between modeled data and recorded field data. The matching is quantified by the residuals of a least-squares objective function, and the model update is computed as a scaled representation of its gradient.

Using reflections

To move beyond the typical limitations outlined above, PGS has reformulated its FWI algorithms to include reflected energy to retrieve long-wavelength updates. The fundamental idea is to compute a gradient in which undesired reflectivity, i.e., migration isochrones, are eliminated, and the full wavefield can be used in FWI to produce high-resolution velocity models that accurately predict refractions and reflections. This is a key step when using these velocity models for depth migration and imaging.

PGS FWI separates the low from the high wavenumber components in the gradient so that long-wavelength velocity updates are delivered at depths greater than the penetration depth of the diving waves. In this implementation of FWI, these improvements to the physics of FWI are complemented by the introduction of new and robust regularization schemes to stabilize the solution to the inversion step, therefore improving the mathematics of the implementation.



FWI velocity model updates are shown using conventional FWI (top) and PGS FWI (bottom). Most of the high wavenumber detail in the upper velocity model update is false due to artifacts of the migration isochron. The lower velocity model update is generated using PGS FWI and is the correct representation of the geology. (Image courtesy of PGS)

Looks can be deceptive

The figure compares the results of a velocity model derived using a more traditional implementation of FWI versus the new PGS implementation (lower). The difference is remarkable. While it is inviting to view the upper result as containing spectacular resolution and thereby "fit for direct interpretation" in the manner wherein reflectivity seismic images are interpreted, nothing could be farther from the truth. Most of the high wavenumber detail in the upper velocity model update is false, artifacts of the migration isochron problem. The lower velocity model update is the correct representation of the geology in this location.

In short, the new velocity model-building solutions are able to provide high-resolution velocity models from records containing diving waves and reflections without the migration imprint caused by conventional FWI.

Another well-known challenge to FWI is cycle skipping, which also contributes to high wavenumber velocity model artifacts such as those in the upper part of the figure. In addition to the better imaging condition, PGS is also making progress with sophisticated regularization schemes used to elegantly avoid cycle skipping during FWI.

Better resolution, shallow or deep

It is also worth noting that reflection FWI does not only contribute high-resolution deep velocity model updates. Some areas such as those affected by seafloor rugosity or very shallow geological heterogeneities may derive more benefit to shallow velocity model-building using reflections rather than diving waves and refractions.

Please visit booth 2122 to learn more about PGS FWI. ■

SYSTEM
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more than 250,000 cableless channels that can be laid out in the highly variable geometries that are common in today's high-density surveys.

A typical RT3 configuration consists of tens of thousands of ultra-lightweight and ultra-low power recording units (Motes) that communicate via radios to a grid of ground relay units (GRUs) that transport the seismic data in real time to the fully interactive central recording system. RT3 incorporates all of the relevant industry-proven RT2 features, including real-time data quality control and Hybrid Radio Telemetry (where any Mote that becomes stranded from the radio network will temporarily become an autonomous node until radio connectivity is restored). The RT3 radio network is completely self-organizing, requiring minimal resources during deployment.

The Mote weighs less than 1 kg (2.2 lb), further reducing the weight differential between a cabled system and a cable-free system. It is available in two models, one with an internal high-output geophone and the other with a standard connector for an external string of geophones.

The GRU delivers significantly higher seismic data throughput than any cabled system on the market. It is a full duplex transceiver that significantly reduces line latency and increases the number of receivers supported in a line segment. Sustained throughput is approximately 20+ Mbps with a "burst" rate of up to 55 Mbps. Legacy cabled systems historically operate at 8 or 16 Mbps.

A newly designed central recording system includes a spread manager that provides three independent views of the spread, including continuous seismic energy and ambient noise levels. A parameter management system simplifies operations, and the spread health dashboard provides the user with a quick and consolidated means of reviewing and fixing user-addressable system problems. The system automatically engages the required receivers for production while leaving other parts of the spread in a monitored low-power state.

"RT3 is a game-changing technology that will enable the great majority of seismic contractors around the world that currently enjoy the benefits of real-time seismic systems to finally decommission their old cabled systems and replace them with a real-time cable-free system," said Mick Lambert, president and CEO of Wireless Seismic. "The significantly reduced weight and cost of RT3 will make ultra-high channel count projects much more cost-effective, especially for the rapidly emerging requirement for high-density seismic surveys."

Visit Wireless Seismic at booth 915 during the SEG to take a look at the RT3 seismic acquisition system. ■

MEXICO
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The WesternGeco Perdido reimaging project ties the U.S. Gulf of Mexico Alaminos Canyon protraction area to the offshore Mexico Perdido area by incorporating 36,000 sq km (13,900 sq miles) of reimaged data. The portfolio incorporates all existing 3-D WAZ data as well as additional NAZ seismic data. To image the deep Paleogene subsalt structures and diapiric salt and shales in the area, a processing flow is being employed that integrates well data, gravity and magnetics to better constrain the modeling process.

Regional reimaging onshore Mexico

A new onshore program in partnership with Seitel involves the reimaging of approximately 25,000 km (15,534 miles) of 2-D seismic data from CNH's data library covering both conventional and unconventional onshore lease blocks in the areas of Burro Picachos, Burgos, Chicontepec, Veracruz and Sureste as well as the under-explored Chihuahua province.

Multiple vintage seismic datasets are also being reimaged. The workflow employs the latest refraction statics and signal processing solutions. This has significantly improved signal-to-noise ratio and produced superior imaging of main targets, enabling the first consistent regional seismic images throughout the large onshore areas. Final products over the prolific fields of the Chicontepec, Burgos and Sureste basins are now available.

To learn more about these and other multiclient projects, please visit booth 535, where information on the programs will be presented daily. ■