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# The inverse-scattering sub-series for the removal of free-surface and internal multiples: Status, open issues and plans

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## Introduction

The industry trend to deepwater has raised the bar on seismic effectiveness due to a confluence of higher cost and technical challenges. Imaging beneath complex overburdens, e.g., salt, basalt, or karsted sediments, are high economic priority for hydrocarbon exploration and production and represent technical challenges without an immediately available effective response.

A prerequisite for the imaging of primaries is the removal of multiples. Traditional multiple elimination techniques typically assume a 1-D earth, or periodicity of multiples, or move-out differences, or they require: velocity analysis, or interpretive intervention, or event picking. However, the level of technical challenge represented by the types of plays described above cause traditional methods to bump-up hard against their assumptions with a concomitant degradation or cessation of effectiveness.

## A response to the challenge

The inverse-scattering multiple attenuating sub-series for free-surface and internal multiples is a direct response to this tough and important challenge. The sub-series for attenuating free-surface and internal multiples (Weglein et al. 1997, Carvalho et al. 1992, Araujo et al. 1994, Matson and Weglein 1996, Coates and Weglein 1996) were described and exemplified for towed streamer and multi-component ocean bottom and on-shore data. These multiple attenuation sub-series have excellent convergence properties, assume absolutely no information concerning the subsurface, require no velocity analysis, no event picking, nor interpretive intervention, and they have demonstrated effectiveness on field data (Carvalho et al 1992, Carvalho and Weglein 1994, Matson et al. 1999).

Imagine predicting and subtracting all the multiples from a salt body, while preserving all primaries, with no information about the salt structure, nor what is above the salt, i.e., no velocity, nor any other cause or influence on these multiples. Many considered this absolutely impossible in 1990, considered it somewhat understandable by 1997, and today it is considered eminently reasonable, when production strength codes routinely apply those algorithms and fulfill that promise. Another wave-theoretical technique, the feedback method, was pioneered by Berkhout (1982) and developed by Verschuur et al. (1992) and these two methodologies were compared (e.g., Berkhout et al., 2000 and Weglein et al., 2000). The inverse-scattering methods were the first and remain the only comprehensive method for eliminating all multiples from a heterogeneous earth with absolutely no subsurface information or user intervention of any kind.

A useful method for attenuating internal multiples was developed independently by E.Landa et al. (1999). Although it requires event picking, it shares the timing prediction apparatus for the selected multiples whose primaries it has picked with the more complete and general inverse scattering internal multiple procedure. As we mentioned, the inverse scattering internal multiple method predicts the timing and amplitude of all internal multiples, at all depths at once, with absolutely no need for event picking nor interpretive interference. The Landa method is a cost-effective solution when the primaries from the reflectors generating the internal multiples are identifiable. This is also true for the feedback approach to internal multiples. However, under highly complex conditions, e.g., with hard to identify and/or interfering events, highly heterogeneous media, diffractive or corrugated reflectors, or small amplitude salt internal multiples proximal to small amplitude subsalt primaries, the wave-theoretical generality and power of the inverse scattering free-surface and internal multiple prediction methods stand alone.

All inverse-series applications require a good estimate of the source signature in the water, which is achievable under many circumstances (Verschuur et al. 1992, Carvalho et al. 1992, Carvalho and Weglein 1994, Matson, 2000) and new techniques are being investigated and developed (e.g., Weglein et al. 2000, Manin and Spitz, 1995). The latter direct wavelet prediction and pattern recognition subtraction techniques are motivated by the need to go beyond the current energy minimization standard for complex and subtle free-surface and internal multiple subtraction and the problems presented by 3-D out of plane multiples to 2-D algorithms, respectively. The near future will see closer to true 3-D data acquisition and 3-D implementation of the algorithms, mitigating some of the impediments to reaching the full potential of these demultiple concepts.

**Money and influence: Assumptions move from the subsurface to the measurement surface.**

No amount of money can impress, induce or influence a 1-D algorithm to understand a diffraction or to sympathize with a complicated multidimensional wavefield. However, money can affect the completeness of seismic acquisition and thereby allow multidimensional algorithms, designed to address a complex and largely unknown subsurface (albeit with greater demands on a complete and sampled wavefield on the measurement surface) to reach their inherent capability for providing added value. The development of more complete, realistic and costly demultiple and imaging algorithms empower the petroleum industry to allow those interested in spending more to achieve greater reliability and reduced risk, to have a new choice with a better chance at getting more. More realism and completeness are aligned with greater reliability and reduced risk.

The industry trend is to develop new methods with fewer unrealistic assumptions about the subsurface and replace them with greater demands on the definition and completeness of the seismic experiment.

**Summary**

In this talk, we will briefly trace the evolution of the inverse scattering demultiple concepts and algorithms and exemplify them with synthetic and field-data examples. We will discuss their relationship to the important feedback methods, and describe issues that need to be addressed or that require further attention. The recent application of the feedback method to land data by Kelamis and Verschuur is noteworthy. Among the outstanding issues that will be discussed are: 3-D, wavelet estimation, near trace and cross-line interpolation and extrapolation, and deghosting. Candidate methods for addressing several of these impediments to effective multiple removal will be described.

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