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Non-Wiener filter, or Sharp Deconvolution in elimination of multiples

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Introduction

The problem of multiple suppression is of interest up to now despite of its long-standing. A new approach for attenuation of multiples in a "locally 1-D" environment is suggested, which is illustrated here with well-controlled processing of synthetic data. The method is based on a rigorous forward model and a non-Wiener filter design in the context of predictive deconvolution. Due to the linearity of the filter the method is of very low computational costs. The respective filter coefficients have quite definite physical sense: they are *primaries of a reflectivity series.* Therefore the method yields fairly good estimates of the reflection coefficients/acoustic impedance section **jointly** with elimination of multiples.

Method and application

The starting point of the method is the Lippmann-Schwinger equation with the proper chosen reference model:

$$\varphi \,=\, \varphi_{\downarrow} \,+\, \mathbf{G_0}\,\mathbf{V}\,\varphi \tag{1}$$

where $\varphi_{\downarrow}$ is *downward* wavefield in a reference media that is supposed to include the *free-surface* boundary conditions, but to be a *smooth approximation* of "locally 1-D" impedance section (no reflections: the concept that we exploited in [3], [4] to solve a 3-D nonlinear problem for reflected data). The $\mathbf{G_0}$ is the corresponding Green's function and $\mathbf{V}$ is the perturbation, induced by the difference between the smooth model and real impedance section with bounces. Note here, that the model given by eq. 1 holds neither a time-invariant source wavelet nor the very sharp frequency components of wavefields induced by precise periodic sentence of multiples (in contrary, e.g. to [1]). In time domain the eq. 1 gives the *convolution* of primaries of reflectivity series with the wavefield. Thus the respective inverse problem, i.e. the problem of *multiple suppression*, is the problem of the well-known **one-step** *predictive deconvolution.* This problem is solved on the base of **sharp deconvolution (SDec)** [2], which differs in two items from the conventional Wiener-filter:

- no stationarity of the involved records is assumed: just windowed segments are treated;
- the unknown filter coefficients is a priori *colored* random process but not the white noise: *prewhitening* is substituted by *precoloring* with a covariance operator being proportional to an estimate of an autocorrelator of the input records. This item is in fact an interpretation of a so called *self-adaptive regularization* **(SAR)** suggested us for general ill-posed problems [2].

The basis of self-adaptive regularization is the following criterion

$$\Delta(\mathbf{r}) \,+\, C(\mathbf{r}) \,\rightarrow \min \tag{2}$$

with $\Delta = ||\varphi_{\star} - \varphi||^2$ (weighted errors of prediction), $C(\mathbf{r}) \,=\, ||\mathbf{r}||^2_H$ (precoloring: αH^{-1} is the Fisher operator of the unregularized problem of prediction). The vector $\mathbf{r}$ stands for the designed/desired *primaries of the reflectivity series.*. In contrary to the conventional α-parameter regularization the relative SAR-solution does not contain the null-space components, which allows us to get very robust algorithms. The aim of SAR is to suppress all noise-induced high frequencies.

To restore the *informative* high-frequency components of the reflectivity image (bounces), which were lost while convolving with low-frequency wavelet and registration channel, we apply $\mathcal{E}$-analysis (*an Entropy of Image Contrast (EnIC):* [3], [4]). The value of the EnIC is minimal when the "image" of the earth's reflectivity is the most contrast, *sharp* (i.e. the image can be represented with the *minimal number of inherent parameters.*)

We illustrate the results of SDec-filter design with synthetic data. The corresponding phases of marine data processing simulation are displayed on the next page.

Conclusion

The suggested one-step method combines automatically predictive and spiking deconvolutions Sharp deconvolution has two advantages over conventional methods: it gives more *robust* & *high resolution* algorithms, which allows us to get not only multiples' attenuation but also reliable estimates of the upper part of the acoustic impedance section. The algorithms are very fast and thus feasible for industrial implementation.

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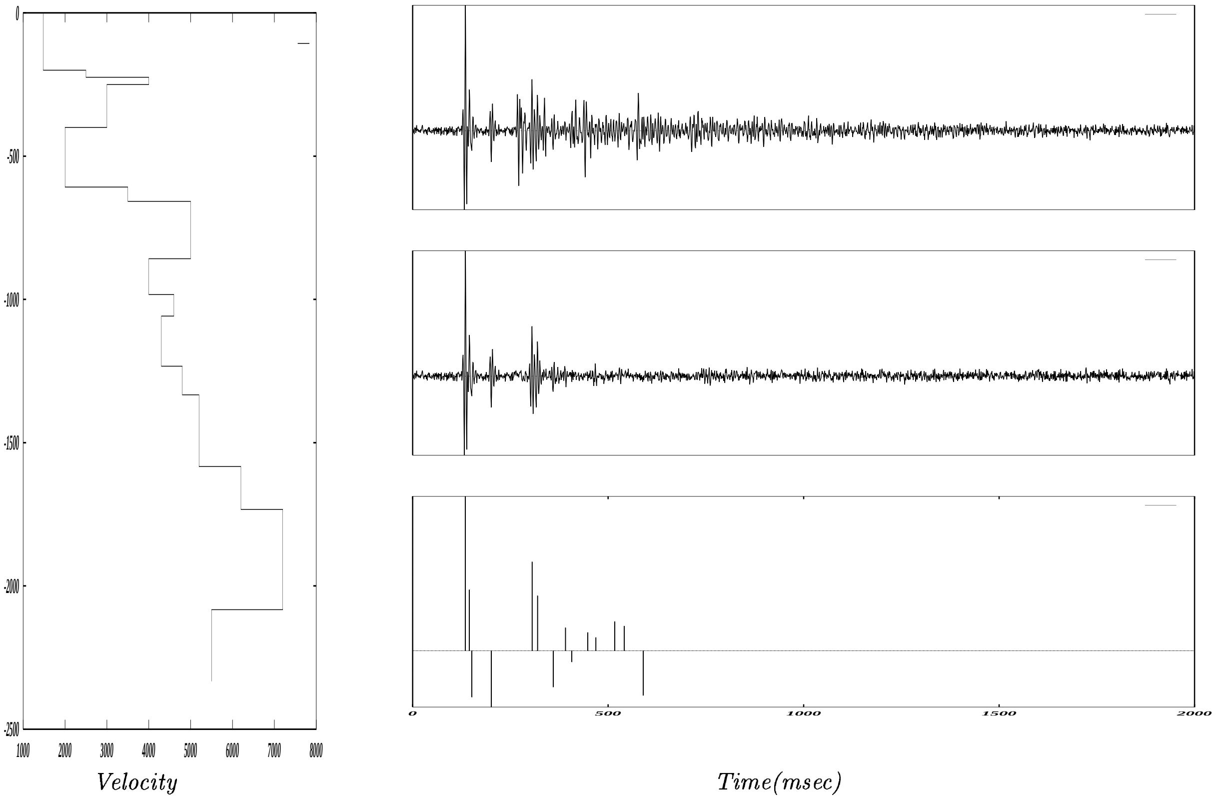

Fig. 1. The computer simulation of the marine data processing: multiple suppression with SDec-filter. `Left:` *velocity model;* `right (from the top to bottom):` • *input record with* **additive noise**; • *output;* • *true primaries of the impulse trace.*