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Comparison of the MM algorithm and least squares deconvolution method for the recognition of thin layers

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Extended Abstract

Summary

Deconvolution problems involve estimating an unknown input when the signal and the response of an LTI system are known and lead to wavelet compression and increase the temporal resolution. However, in practice, the output signal is noisy. For some systems, the deconvolution problem is simple, but for the non-invertible or almost non-invertible systems, the problem is more complex. The use of the exact inverse of the systems leads to the amplification of the noise. The reflectivity sequence is the representation of the layers of the earth. The resulted compression leads to a high-resolution image of the earth. The outcomes exhibit that the reflection coefficient significantly improves after application of the MM algorithm on synthetic and real data, compared to the least squares and the frequency spectrum methods after the application of the algorithm.

Introduction

On the observed and measured data at the surface, the properties of the lower layers can be obtained using an inversion operation. Deconvolution can be used to calculate the coefficient of reflectivity of the Earth. The sparse spiking deconvolution calculates the coefficient of reflectivity by minimizing the L1 norm.

Absorption is a function of frequency, and the earth acts as a low-pass filter, reducing the amplitude of higher frequencies than the lower frequencies. Therefore, where absorption occurs, the dominant frequency in the spectral range goes to lower frequencies, and an increase in wavelength are expected .

In fact, the time width of the wavelet that is propagated through the earth, increases after it is received again at the surface. It can lead to a reduction in temporal resolution. If the compressed wavelet in the time domain is desired, the width of the frequency spectrum should increase. Wavelet compression could lead to an increase in the temporal resolution of the layers.

Methodology and Approaches

Least squares method

One of the general methods of solving inverse problems is to minimize the energy of X:

$$\arg\min_x \|x\|_2^2$$

where $y = Ax$ and the solution of $\|x\|_2^2 = \sum_{n=0}^{N-1} |x(n)|^2$ is written as below:

$$x = A^H (AA^H)^{-1} y$$

In the above equation A^H is the transpose of the complex conjugate of the matrix A. When y is noisy it is not desired to solve the inverse problem exactly. In this case, the approximate solution of $y = Ax$ is to minimize the cost function

$$\arg\min_x \|y - Ax\|_2^2 + \lambda \|x\|_2^2$$

The solution of the above equation is written as below:

$$x = (A^H A + \lambda I)^{-1} A^H y$$

Each equation system is looking ahead to the solution system of linear equation in signal processing; the equation could be significant since y and x are long signals (or pictures). For an efficient algorithm, a fast and efficient method to solve the system of equations is necessary. In most cases, the system of equations has properties and structures that the fast resolution method can be used. For example, sometimes the Fourier transform can be utilized; otherwise, the repetitive algorithms should be employed.

Sparse solution

Another solution of inverse problems is to minimize the summation of the absolute value of x:

$$\arg\min_x \|x\|_1$$

where y=Ax, $\|x\|_1$ is the L_1 norm. This equation is called basis pursuit or BP.

Unlike the least squares problem, the BP problem cannot be solved explicitly. The solution of the BP problem is obtained using numerical iterative algorithms. When y is noisy, it is not logical to solve the inverse problem. In this case, the minimization of the cost function makes it possible to obtain the approximate solution:

$$\arg\min_x \|y - Ax\|_2^2 + \lambda \|x\|_1$$

This equation is called basis pursuit denoising or BPD.

Results and Conclusions

In the MM algorithm, there are two different parts in the cost function, and the existence of standards or norms L1 and L2 can improve deconvolution. Least squares method as a common method does not have the ability to increase data compression. Least squares method only smoothes the data, and this is a disadvantage of this method. After applying the MM algorithm, the physical attributes on the real section are shown, and this algorithm leads to significant improvement in spectral phases and amplitudes.