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GPR Random noise attenuation using Savitzky-Golay filter in the dual-tree complex wavelet domain

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Extended Abstract

Summary

Ground penetrating radar (GPR) data, like other geophysical methods, always has unwanted energies or noise. Noise attenuation is one of the most important steps in the processing of Geophysical data before interpretation. Different methods have been proposed to attenuate the Gaussian noises of GPR data. Each of these methods has its limitations and advantages. In this study, for the first time, Savitzky-Golay (SG) filter in the dual-tree complex wavelet domain (DTCWT) have been used to attenuate the Gaussian and non-Gaussian noises of GPR data. Synthetic data results in the presence of Gaussian noise have indicated the poor performance of the soft and non-negative Garrote thresholding methods in the complex wavelet domain in such a way that the downward and damping trend of the frequency spectrum of the thresholding methods indicating the loss of the signal in the high-frequency range. In other words, when the noise is attenuated, the signal is also lost. On the other hand, applying the SG filter has indicated that the original shape of the signal has not been restored in the synthetic and real GPR data. For further investigation, the SG filter with the same wavelet field parameters in the presence of Gaussian and non-Gaussian noise has been applied to synthetic and real GPR data. The application of the designed SG-DTCWT algorithm on the GPR data has led to more reliable results in terms of signal retention and noise attenuation.

Introduction

The basis of the GPR system is the transmission of high electromagnetic energy in the ground and the reception of the reflected energy with different electromagnetic impedances related to the differences in permittivity, conductivity, and permeability of the target and the underground environment. The wide bandwidth of frequencies around the antenna central frequency means that the target signals are generally covered by noise and clutters; Thus, without applying any processing methods, there will be difficulty in identifying the signal from the noise. To achieve the high resolution of the GPR image with minimum signal loss, this research explores the dual-tree complex wavelet transform (DTCWT) (Kingsbury, 1998), Savitzky Golay (SG) time-domain filtering (Savitzky and Golay, 1964), and the combination of these two domains to prepare better results in the suppression of the noise of the GPR signal in the presence of Gaussian and non-Gaussian noises.

Methodology and Approaches

The algorithm of de-noising using the DTCWT method includes the following steps:

- Decomposing the signal using analysis filter banks of the proposed method to prepare the wavelet coefficients,
- Estimating a thresholding value to threshold the wavelet coefficients by one of the thresholding functions
- Combining the new coefficients by synthesis filter banks of the DTCWT method to reconstruct the de-noised signal.

Moreover, the proposed approach is highlighted in the following steps:

- DTCWT is applied to the noisy GPR signal to obtain the detailed subbands,
- The SG filter is applied to each subband separately,

- The reverse of DTCWT using non-negative Garrote thresholding is applied to the sub-bands.

Results and conclusion

This paper focuses on the attenuation of Gaussian and non-Gaussian random noises from the GPR data using time-frequency analysis methods. First, the SG time-domain filter and DTCWT method have been applied to synthetic data polluted by Gaussian and non-Gaussian noises. The synthetic results have indicated the superiority of the soft and non-negative Garrote thresholding methods in the DTCWT domain compared to the SG method, and the weakest result is related to the application of the time domain SG filter in the presence of non-Gaussian noise. However, matching the frequency spectrum of thresholding methods demonstrate that the signal is lost in the high-frequency ranges. For further investigation, the SG filter with the same wavelet field parameters in the presence of Gaussian and non-Gaussian noises has been applied to synthetic and real data. The SG-DTCWT approach has a more logical noise reduction response than the DTCWT method. The algorithm proposed in this research confirms the success of the new approach concerning the application of the time-domain SG filter within the framework of the complex wavelet transform. Since the random noise in the GPR data does not follow the Gaussian distribution, the SG-DTCWT algorithm can be a reliable method of noise attenuation.