A GPR NOISE REMOVAL METHOD BASED ON STATIONARY GRAPH PROCESS

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Clutters and background noise are common types of coherent noise that severely compromises the B-scan image analysis on ground penetrating radar (GPR) survey. Existing background removal techniques, such as the Mean Subtraction (MS) [1], Background Matrix Subtraction (BMS) [2], Singular Value Decomposition (SVD) can remove horizontal clutters in B-scans but have limited capabilities in reducing noise caused by the soil heterogeneity [3]. This study proposes a method for clutter and noise reduction in GPR B-scans based on stationary graph process, which can remove both the horizontal clutters and noise caused by soil heterogeneity. The key to the method is to reduce the power of the noise from the power of the raw data.

In this approach, B-scans without hyperbolae are recorded and treated as noise images, and B-scans with hyperbolae of different sizes and at different positions are recorded as the combination of valuable signals (reflection pattern of targets) and noises. The sizes of all the images are kept as the same. A set of 100 B-scan image samples with hyperbolae patterns is considered as $\{x_r\}_{r=1}^{100}$, and a set of 10 noise image samples is considered as $\{y_r\}_{r=1}^{10}$. Every image is represented by a vector x_r and y_r. We consider the images x_r , y_r to be realization of a graph process, in another word the images are stationary in the shift given by its covariance [4], here the covariance is approximated by the sample covariance $S = \hat{C}_x = V\Lambda_c V^H$. The process above is named the graph shift operator (GSO). We tested both sample covariance of the B-scans with and without hyperbolae $\{\hat{C}\}_x^{(j)} = V_x^{(j)}\Lambda_c^{(j)}V_x^{(j)H}$, $\{\hat{C}\}_y^{(j)} = V_y^{(j)}\Lambda_c^{(j)}V_y^{(j)H}$, and found they can be (approximately) diagnosed by V, which indicates the process is stationary. Then, a Winer filter, a counterpart of the graph process, is used to reduce the noise. An image with hyperbolae and clutters is considered as a vector $\boldsymbol{x}$, and we obtain the clutter filtered version $\tilde{x}_k^{W\,ie} = ((p_k - y_k^2)/p_k)\,\tilde{x}_k$, where p_k is the power of the image $\boldsymbol{x}$, y_k^2 is the noise power, $\tilde{x}_k = V^H\boldsymbol{x}$ is defined as graph Fourier transform (GFT). Power used here is the eigenvalues of the sample covariance $\hat{C}_x$ (image with hyperbola and clutters) and $\hat{C}_y$(noise only). The vector represents the filtered image is $\tilde{\boldsymbol{x}} = V\,\tilde{x}_k$. By transferring $\tilde{\boldsymbol{x}}$ to matrix of original image size, we can get the B-scan after noise reduction. In this work, we use signal-to-noise ratio (SNR), which is the ratio of the sum of amplitude of the hyperbolic regions to the sum of the amplitude of the noise regions, to evaluate the noise reduction performance. As the proposed method not only attenuate the horizonal clutters but also reduce other noise, the method produces an SNR value of 80 which is higher than the result through existing methods such as SVD, MS, and BMS, whose SNR values are approximately from 20 to 25. The preliminary results demonstrate that the proposed methodology yields efficiently reduction of horizontal clutters and improves the SNR of the B-scan images.

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