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NOISE REMOVAL IN MULTICHANNEL IMAGES*

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ABSTRACT

An adaptive filtering method, the Windrow-Hoff algorithm, for enhancing multichannel signals against additive noise has been investigated. It removes noise from multichannel images containing correlated signal components but uncorrelated noise components. Its potential application is the enhancement of multichannel microwave satellite images as a preprocessing step for the extraction of geophysical parameters.

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I. Introduction

In recent years multichannel image analysis has been given a fair amount of attention. One common example of multichannel image processing is the multispectral data analysis in the field of remote sensing. Multispectral images are obtained from aircraft or spacecraft that overfly a region of interest on the earth's surface taking multiple-frequency measurements. Examples of such multichannel imaging instruments are the Scanning Multichannel Microwave Radiometer (SMMR) aboard Nimbus-7 and Seasat 1, and the Thematic Mapper (TM) aboard the Landsat-D satellite.

In this paper, we present some study results of applying an adaptive filter to enhance (remove noise from) multichannel images against additive noise. The method is an extension of the adaptive filtering by Windrow and Hoff [1]. The main objective of this type of filter is to cancel noise between channels, thus increasing the signal-to-noise ratio. The filter makes use of two or more input channels containing correlated image data but uncorrelated noise. The output is an estimate of the Wiener solution (least mean square) of the signal in a given channel. One of the most significant features of this method is its adaptability allowing the signal and noise characteristics from channel to channel to be unknown.

In the study, the adaptive filter is used to remove additive random noise from synthetic multichannel images containing correlated signal components when both the signal and noise statistics are assumed to be unknown. In one case the filter is applied to multichannel time-sequence images and in another case non-temporal multichannel images are used.

II. The Noise Cancelling Filter [3,4]

The basic element of the adaptive filter is the adaptive linear combiner, shown in Fig. 1. Multichannel image measurements x_{ij}, where i is the channel number and j is the time index, are input to the combiner. Each measurement is weighted by a weighting coefficient W_i and the projects are summed to form an output signal y_j given as

$$y_j = \sum_{i=1}^{N} W_i \; x_{ij} = W^T X_j \qquad (1)$$

where

N is the total number of channels,
$W^T = [w_1, w_2, \ldots w_N]$, and
$X_j = [x_{1j}, x_{2j}, \ldots x_{Nj}]$

The mean square error between the output y_j and a reference signal d_j is given by

$$E[e_j^2] = E[(d_j - y_j)^2]$$
$$= E[d_j]^2 - 2P^T W + W^T R W \qquad (2)$$

where

$P = E[d_j X_j]$ is the cross correlation, and
$R = E[X_j X_j^T]$ is the autocorrelation matrix.

The optimal weights W^* is obtained by solving the gradient equation,

$$\frac{\delta E[e_j^2]}{\delta W} = -2P + 2RW = 0 \qquad (3)$$

and the solution is a matrix form of the Wiener-Hopf equation [2]:

$$W^* = R^{-1} P \qquad (4)$$

The optimal weights minimizing the error would require *a priori* knowledge of the correlation matrices which are usually not available in practical situations. Adaptive filtering is an alternative method to find an approximate solution of the Wiener-Hopf equation. A simple iterative procedure, the so-called Widrow-Hoff Least Mean Square algorithm [1], is an attractive adaptive filtering method. It is based on the method of steepest descent and does not require explicit measurements of correlation between channels. The algorithm starts with an arbitrary initial weighting vector and the weights are updated adaptively based on both the error signal and the input data by the following equation:

$$W_{j+1} = W_j + 2\mu e_j X_j \qquad (5)$$

where μ is a parameter indicating the rate of convergence and stability. After convergence, the output y is a best least square estimate of the reference signal d, where d can be considered as the underlying signal in a chosen input channel that one wants to enhance.

Let us consider a simple two-channel adaptive noise cancelling filter. Channel one contains an image signal s_1 plus noise n_1 and channel two contains $s_2 + n_2$. The two signals are related (relationship unknown), and the noises are assumed to be uncorrelated with each other. If channel one is considered to be the reference signal $d = s_1 + n_1$, after convergence of (5), the difference between the filter output y and the reference response d is minimized. In other words, the filter output y is a best estimate of $d = s_1 + n_1$. Since n_1 is uncorrelated with $s_2 + n_2$, the output y is a best estimate of s_1 rather than $s_1 + n_1$; thus, the noise has been removed.

III. Experiments and Results

A set of synthetic time-sequence multichannel images were generated. Image signals between channels are correlated, and their characteristics correspond to the Scanning Multichannel Microwave Radiometer (SMMR) radiative transfer model. Time sequences of the synthetic SMMR images were created using the Markovian model. Random noise was added to these images to simulate noisy microwave satellite data.

The adaptive filter was extended to handle image signals and applied to enhance the synthetic images. Figure 2 shows the noise cancellation results of two of the channels. Original noisy imagaes with a 16.0 mean square error (MSE) were enhanced, with the resulting MSE reduced to 2.09.

If time-sequence images are not available, non-temporal, multichannel images can be converted to one-dimensional data for the adaptive filtering. Figure 3 shows some of the results of non-temporal, multichannel noise cancelling.

References

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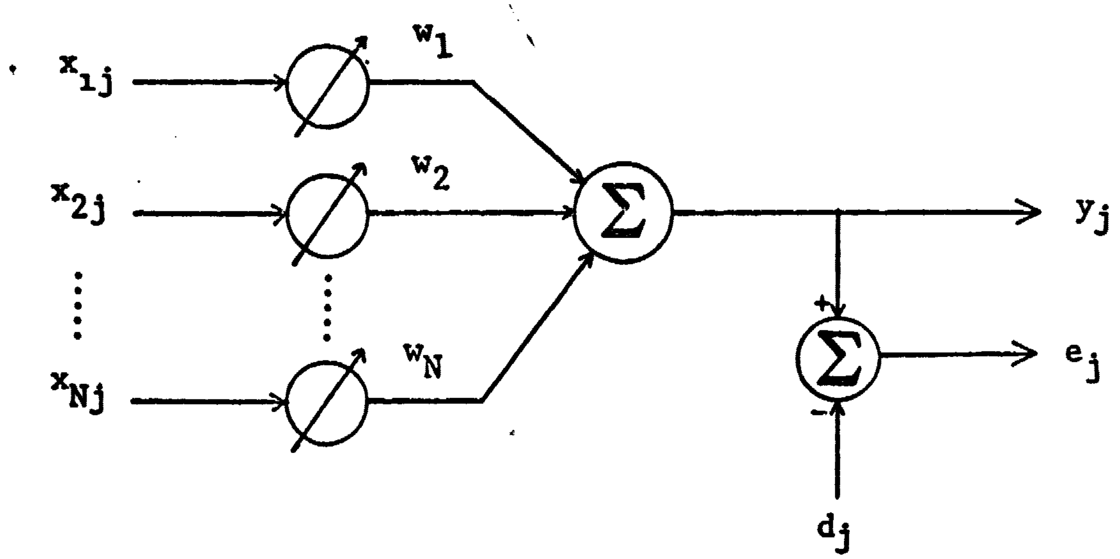

Fig. 1. A multichannel adaptive signal enhance. The filter output y is an estimate of d [3].

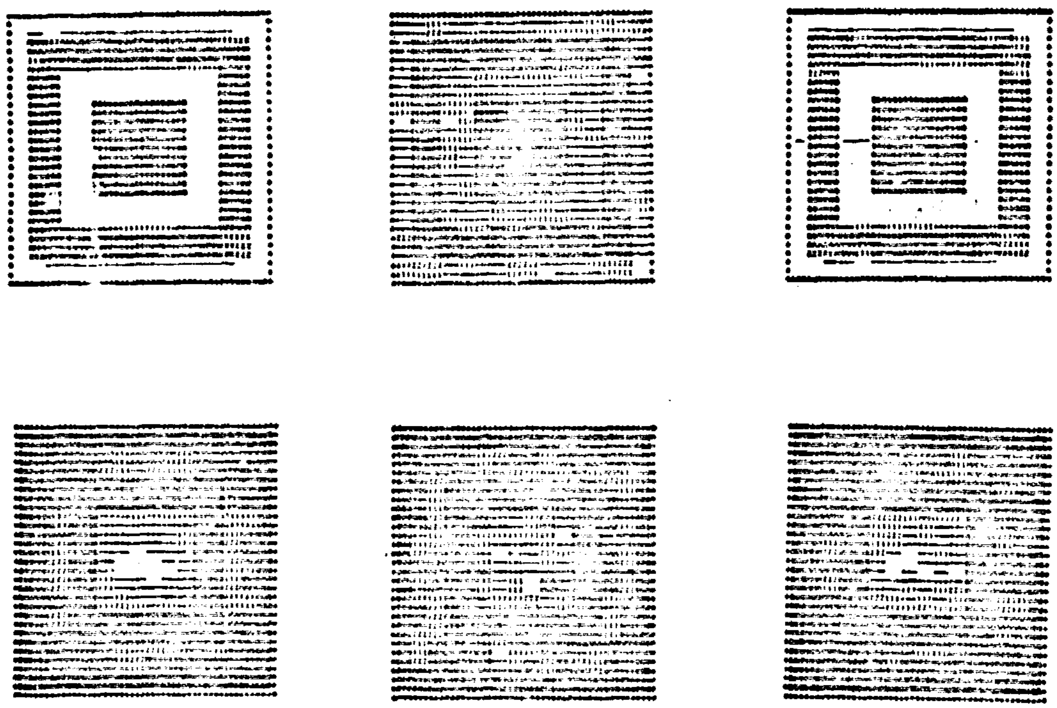

Fig. 2. Noise cancellation of time-sequence multichannel images:

(a) ideal image,
(b) noisy image with MSE = 16.0, and
(c) enhanced image with average MSE = 2.09.

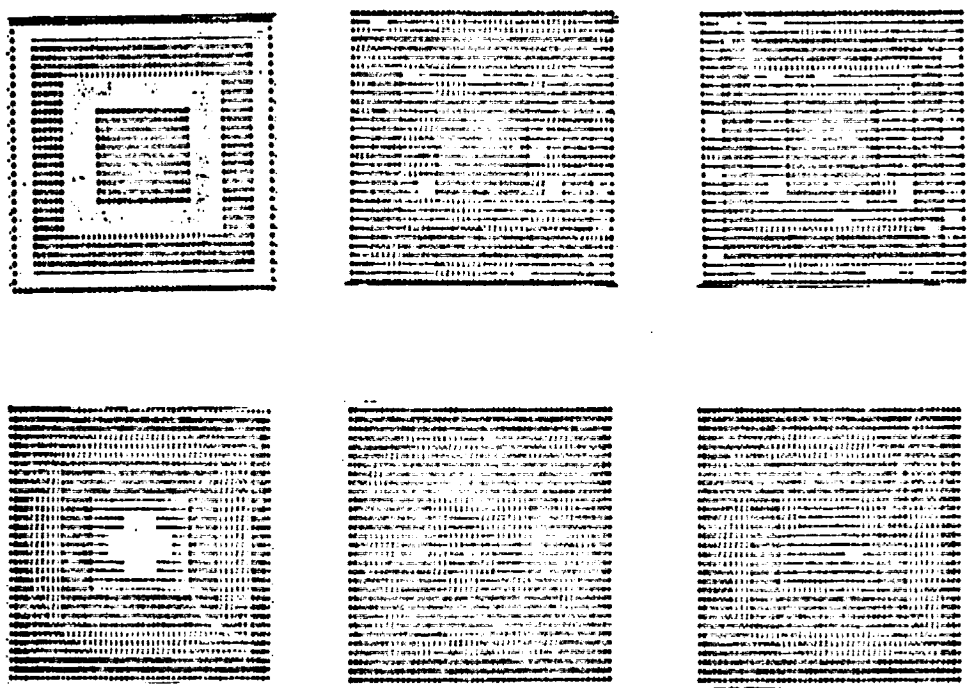

Fig. 3. Noise cancellation of non-temporal, multichannel images:

(a) ideal image;
(b) noisy image with MSE = 16.0, and
(c) enhanced image with average MSE = 8.10.