(a)	(b)
(c)	(d)

Figure 5: All the filters use 5 × 5 window. (a) output of the GVDF filter, (b) output of the DDF filter, (c) output of the hybrid filter, and (d) output of the adaptive hybrid filter.

Table 1: NMSE ($\times 10^{-2}$) for the image "Lena"

	VMF		GVDF		DDF		Hybrid		Adaptive Hybrid	
noise model	3×3	5×5	3×3	5×5	3×3	5×5	3×3	5×5	3×3	5×5
Gaussian	0.769	0.627	0.629	0.537	0.819	0.653	0.711	0.562	0.629	0.517
gauss./Impuls.	0.790	0.632	0.634	0.549	0.841	0.665	0.731	0.569	0.657	0.535
Impulsive	0.151	0.303	0.162	0.314	0.152	0.309	0.155	0.309	0.151	0.304
Original image	0.143	0.296	0.156	0.309	0.152	0.306	0.148	0.305	0.144	0.299

II Conclusion

In this paper a new VM-VDF hybrid filter is presented to process multichannel signals, e.g. color images. Two structures are proposed, a non adaptive approach and an adaptive one. These filters were used to restore color images corrupted with different types of noise. Their performance was evaluated and compared against some well known vector filtering techniques. Simulation results show the effectiveness of these filters in (a) removing different types of noise from color images, and (b) preserving important image details such as edges. Some filtered images are presented in figure 5 for visual assessment.

The proposed structure allows the parallel implementation of the filter, wich reduces the execution time considerably.

References

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Figure 3: Original RGB image "Lena".

Figure 4: Noisy image corrupted with Gaussian ($\sigma = 20$) with 2% Salt and pepper in each channel.

GVDF[1] filter is V_{GVDF}.

It is obvious from this figure that the direction of the output vector V_{GVDF} of the GVDF is shifted away from that of BVDF V_4, which represents the least error estimate of the angle location. This shifting introduces an additional error to the direction of the output vector, i.e., to the hue of the output sample in the case of color images.

In our approach, we try to remove the distortion introduced by the effect of the second stage on the direction. This is accomplished by estimating the direction and the magnitude independently and then combining them to get the overall output of the filter V_{out}. This output vector will have the direction of the BVDF, which is the best estimate of the direction of the original vector under the condition that it should be the direction of one of the input vectors. As for the magnitude processing, two methods are adopted, an adaptive way and a non adaptive one. The result is a new nonlinear multichannel filter which combines the "good" properties of both the Vector Median and the Vector Directional filters.

The proposed filter is different from the directional-distance filters (DDF) introduced by Damianos et al [5]. DDF filters are derived by simultaneous minimization of the functions that define the VMF and the VDF. The performance of the proposed filters are compared to those of the DDF filters for the color image "Lena" corrupted with different noise distributions, see Table 1.

I-1 Proposed structure

As mentioned above, the goal here is to get the most accurate estimation of the direction of the original input vector; while smoothing the noise. For that purpose, we propose the following filter structure.

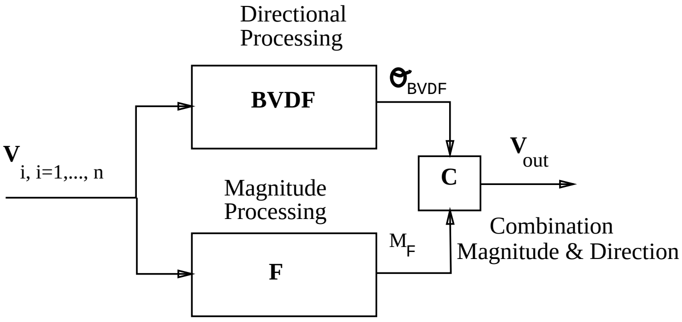

Figure 2: New filter structure for multichannel signal processing

The structure presented in Figure 2 is formed of three blocks, **BVDF** block for directional processing, **F** block for magnitude processing, and the **C** block which combines the output of the two previous blocks to form the overall output vector.

The first two blocks may be executed in parallel since the only required input for both is the set of vectors in the filter window. The magnitude processing can be achieved by any scalar or vector filtering technique. In the simulations we used the VMF for the non adaptive approach and in the adaptive one we used the VMF and the mean filter.

I-1-a Filtering algorithms

1- Non adaptive algorithm

In this algorithm only the VMF is used as magnitude estimator.

$$V_{out} = \begin{cases} V_{VMF} & if \quad V_{BVDF} = V_{VMF} \\ \frac{V_{BVDF}}{||V_{BVDF}||}||V_{VMF}|| & otherwise \end{cases} \tag{1}$$

2- Adaptive algorithm

$$V_{out} = \begin{cases} V_{VMF} \quad if \quad V_{BVDF} = V_{VMF} \\ else \begin{cases} V_{out1} \text{ if } \sum_{i=1}^{N} ||V_i - V_{out1}|| < \sum_{i=1}^{N} ||V_i - V_{out2}|| \\ V_{out2} \quad otherwise \end{cases} \end{cases} \tag{2}$$

Where

$$V_{out1} = \frac{V_{BVDF}}{||V_{BVDF}||}||V_{VMF}||,$$

and

$$V_{out2} = \frac{V_{BVDF}}{||V_{BVDF}||}||V_{av}||.$$

In the adaptive hybrid filter case, both magnitudes (M_{av}) of the average vector and (M_{VM}) of the VMF output are computed.

Hence, the magnitude of the output vector will be that of the mean vector in smooth regions and that of the VMF near edges so that edges are preserved while noise is smoothed more effectively than in the non-adaptive scheme. A more efficient impulse removal technique is presented by the authors in [4].

I-2 Simulation results:

To access the performance of the hybrid filter under different noise conditions, image "Lena"was corrupted with various noise distributions: Gaussian ($\sigma = 20$), Gaussian ($\sigma = 20$) contaminated with 2% of impulses in each channel, Impulsive (2%) in each channel.

Table 1 shows the NMSE results for image "Lena". From these results it can be concluded that the VM-VDF hybrid filter preforms in most cases better or as good as the GVDF. It can be observed that for the filter window of 5 × 5 the performance of the hybrid filter is always better than those of the GVDF and the DDF.

In addition, we present the results of filtering the image "Lena" by (a) the $GVDF^1$, (b) the DDF, (c) the hybrid filter and (d) the adaptive hybrid filter, in the case of Gaussian ($\sigma = 20$) with 2% Salt and pepper in each channel. to illustrate qualitatively the filtering results. From these images, it can be seen that the Hybrid filter preserves better the fine details and edges yielding a better image quality.

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[1] The GVDF here is the VDF followed by the α-trimmed mean filter.

VECTOR MEDIAN-VECTOR DIRECTIONAL HYBRID FILTER FOR COLOR IMAGE RESTORATION

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ABSTRACT

In this paper we propose a new approach for multichannel signals and image processing. This new scheme is similar to the VDF's [3] approach, in the way it decomposes the filtering process into direction estimation and magnitude estimation of the output vector. While the VDF performs these two stages sequentially; our filtering approach may execute the two stages in parallel. This parallel structure eliminates the distorting effect of the magnitude processing stage on the direction estimated in the first step. And it reduces the required time of the overall processing to the time corresponding to the most demanding task. A further speedup factor is gained over the VDF approach, since our algorithm does not use sorting at any stage. Simulation results show the effectiveness of the proposed scheme in color image restoration.

I Introduction

Multichannel signals have been for a long time processed using techniques developed for single-channel signals. The latter fail to use the inherent correlation between channels and thus produce most often suboptimal results. On the other hand, multichannel techniques utilizing the correlation between the components would be more effective. A major contribution to the field of multichannel signal processing, are the vector median filters (VMF's) [1]. VMF's can be derived as the maximum likelihood estimators for multidimensional exponential distribution; or using vector order statistics. In the latter the ordering criterion is the sum of the distances between the vectors in the filter window. But when directional data is considered MLE estimators are not very appropriate [2].

Considering the multichannel signal samples as vectors, which can be uniquely characterized by their direction and magnitude, Trahanias et al. [3] defined the VDF's, using the sum of angles between the vectors as the ordering criterion.

Vector directional filters proceed to the elimination of the vectors with atypical directions in the vector space. The output of the VDF is a set of vectors with similar directions. These vectors have to be further processed by a single-channel filter; since VDFs do not process vector magnitudes.

Vector directional filters (VDFs) eliminate the vectors with atypical directions in the vector space, so the estimation of the direction can be as accurate as possible. Assuming that the output vectors given by the VDF have almost the same direction, these vectors are further processed by any single channel filter to smooth the noise in the filter output. As a result, the second stage of the filter which does not take into account the direction of the input vectors, will distort the output direction while smoothing the noise. Since the assumtion, that the VDFs' output vectors have almost the same direction, does not hold near edges and specially in the presence of impulsive noise.

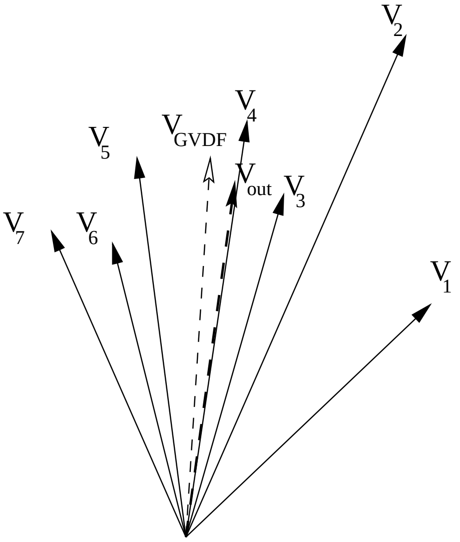

Figure 1: Comparison of the GVDF and the hybrid filters' output vectors

An illustration of this effect is given in Figure 1, for the case of a two-channel one-dimensional signal. Given the input vectors set $\{V_1, V_2, ..., V_7\}$; the output vector of the BVDF filter is the vector most centrally located, here it is the vector V_4. Therefore, the output of the