MIXED NOISE REDUCTION

Marilena Stanculescu, Emil Cazacu

Politehnica University of Bucharest, Faculty of Electrical Engineering
Splaiul Independentei 313, Bucharest, Romania
marilenadavid@hotmail.com, cazacu@elth.pub.ro

Abstract: For real images corrupted by noise, the noise usually does not follow the gaussian model - for which filtering techniques such as Wiener filtering or wavelet reduction coefficients are efficient – or the impulse salt and pepper noise - for which statistical order filters are suitable. There is a considerable amount of literature about image denoising using wavelet-based methods. We implemented different noise removal algorithms in the wavelet domain. We also proposed a new filter and we compared its performance in terms of PSNR with some efficient known denoising methods.

Keywords: wavelet reduction coefficients, PSNR, filtering, Wiener filtering, denoising.

1. INTRODUCTION

Noise reduction and signal compression is still a challenging problem for researchers. When one uses algorithms in transformed domain, they become very attractive not only from theoretical point of view, but also from practical point of view due to the performances obtained as a result of their implementation using high speed microprocessors in signal processing domain. The use of transformed domains for the two types of applications mentioned above is justified by the existence of two important properties belonging to the orthogonal transform: signal energy compactation in a small number of coefficients in the transformed domain and their decorrelation. In this respect, the most used domain is the wavelet domain, especially due to the good time-frequency locality property and to the great variety of bases used for representation, giving good results for noise reduction and generating at the same time less artifacts than other cases.

For real images corrupted by noise, the noise usually does not follow the *gaussian* model - for which filtering techniques such as Wiener filtering or wavelet reduction coefficients are efficient – or the *impulse salt and pepper noise* - for which statistical order filters are suitable. The noise generated in real images can have different causes, so the global effect can be that corresponding to the superposition, in different ratios, of the two types of noises (gaussian and salt and pepper). For this reason, there are tested some types of filters in the wavelet domain, such as coefficient thresholding or empiric Wiener thresholding and the results are compared to the ones obtained using a cascade implementation of the *medfilt2* and *Wiener* filters from Matlab.

2. MIXED NOISE REDUCTION

Wavelet transform has the locality, multiresolution and compression properties, which make it a popular analyses tool for several signal processing applications. It compresses a signal into a very small number of coefficients. Given a signal corrupted by noise, the signal is mostly represented by large coefficients, whereas noise is distributed across small wavelet coefficients.

Wavelet domain is used in image processing domain because a wavelet transform applied to an image transforms the image into a multiresolution representation which permits an independent analyses of each sub-image and also it give a good time-frequency resolution which allows to see the sudden changes in an image, so it allows the implementation of spatial filters.

Classical scheme for noise reduction in the transformed domain is very much alike the one for compression in the transformed domain.

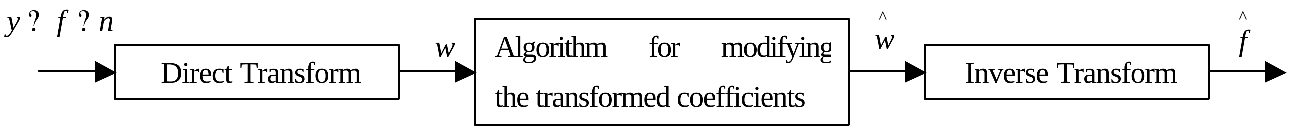


Fig. 1

Initial image	*Median* Filter	Wavelet filter *semisoft*	FMH3 filter followed by *semisoft*	Median filter *medfilt2*	*wiener2* filter	*Medfilt2* followed by *wiener2*	*Empiric wiener* filter with a pre-filter *FMH3*
6.7741 dB	22.5847 dB	26.1112 dB	25.6814 dB	22.6273 dB	21.0348 dB	25.7037 dB	27.5076 dB

Table 1. Values for PSNR obtained by filtering with a *median* pre-filter, *semisoft* wavelet filter and a cascade of the two filters for an image with mixed noise.

So, if the output of the median pre-filter is the input of an empiric wiener filter in the wavelet domain, one can obtain an improvement regarding both visual aspect and the PSNR. The scheme of this algorithm is depicted in Fig.2.

To eliminate the mixed noise, a first approach was to use a pre-filter before the wavelet reduction coefficients. The results proved that this approach is better than the one in which one uses each type of filter at a time.

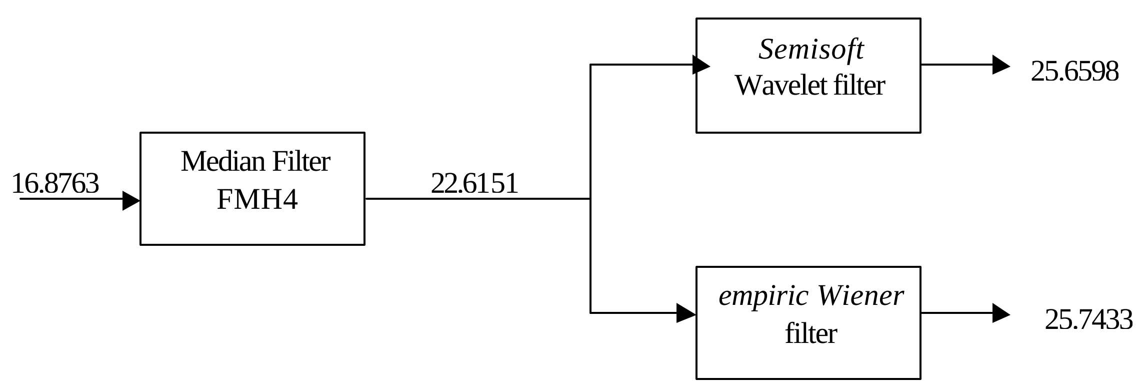


Fig. 2 Empiric Wiener filter with a pre-filter

The result obtained using an empiric filter in wavelet domain and a wavelet filter with a powerful pre-filter using an FMH4 filter, induces the idea that we can have an empiric Wiener filter in the wavelet domain which uses a hybrid-median pre-filter wit 4 iterations, the size of the window being increased for each iteration.

The scheme of this filter – called SUPER filter is presented in Fig.2. The results obtained by processing an image with SUPER filter are given in Table 2.

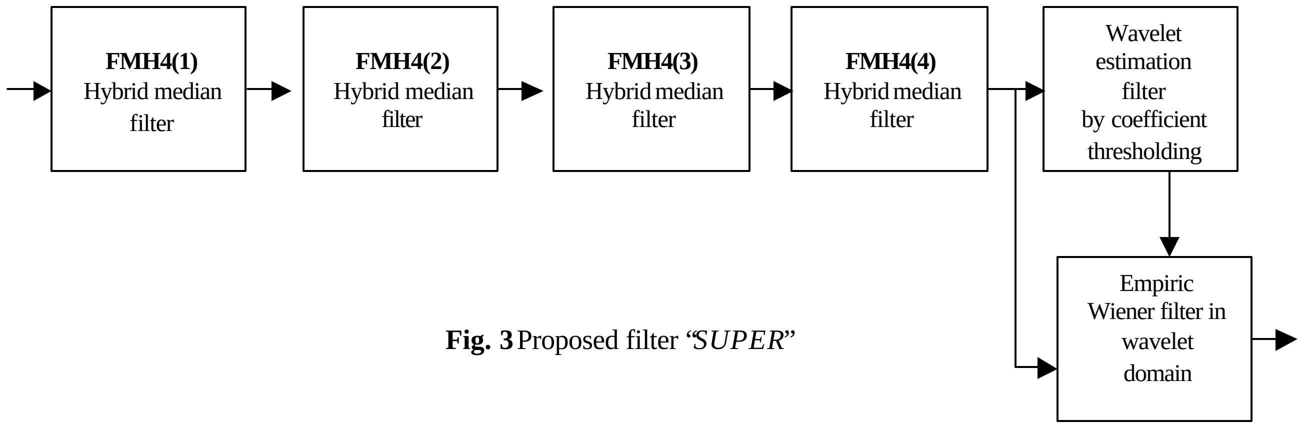
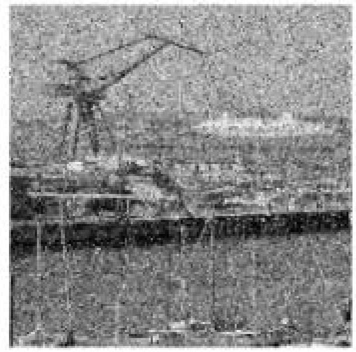


Fig. 3 Proposed filter "*SUPER*"

Image	Filter	*PSNR* (dB)	B_1 (dB)	B_2 (dB)	B_3 (dB)	B_4 (dB)	B_5 (dB)	B_6 (dB)
Port, without noise	Hybrid median	27.0064	19.0361	18.7434	16.4313	9.0261	5.0454	4.0342
	Wavelet estimation	24.8729	19.0347	18.7136	16.0180	7.3935	2.9448	1.5057
	empiric Wiener	25.5488	19.0425	18.7373	16.2685	8.1863	3.4978	2.1758
	medfilt2+winer2	22.0742	14.1992	15.0261	13.8746	8.3699	2.1614	-0.1027
Port, Gaussian noise media=0, variance=0.02	Initial	17.2147	19.0993	12.4552	7.8387	0.1408	-5.5118	-8.2158
	Hybrid median	21.4743	16.0868	10.8855	7.9364	2.8341	-0.6426	-2.4947
	Wavelet estimation	21.7193	16.0740	10.8834	7.6767	2.9583	0.6855	0.2265
	empiric Wiener	22.0917	16.0866	10.9014	7.9299	3.4188	0.8924	0.3803
	medfilt2+winer2	20.8692	15.0243	10.8268	7.4746	1.6706	0.3393	-0.2070
Port, salt&pepper noise *f* = 0.05.	Initial	18.4177	17.9925	10.5976	9.1360	1.5675	-3.8614	-6.9188
	Hybrid median	25.5926	17.6398	19.4311	13.5798	7.5289	3.6134	2.1210
	Wavelet estimation	23.8648	17.6393	19.4861	13.0801	6.2273	2.0069	0.6446
	empiric Wiener	24.4536	17.6494	19.4318	13.4999	6.8694	2.5196	1.1189
	medfilt2+winer2	21.9044	14.2967	14.5609	12.0489	6.9482	1.8691	-0.1412
Port, mixed noise, m=0, gaussian, variance=0.02 salt&pepper, f=0.05	initial	14.9753	16.4189	8.8050	4.5129	-2.5263	-7.7324	-10.4279
	Hybrid median	20.8860	17.7765	10.8763	6.0114	1.3049	-1.3331	-3.1857
	Wavelet estimation	21.3994	17.7465	10.8972	6.0864	2.1334	0.3375	0.1268
	empiric Wiener	21.7301	17.7961	10.8865	6.3554	2.4359	0.6152	0.2675
	medfilt2+winer2	20.6859	17.6836	9.7022	5.5420	0.3980	0.0978	-0.2363

Table 2. The result of applying the proposed filter upon the image Port, 256 x 256 pixel, 256 grey levels, without noise and corrupted by mixed noise.

a.



b.

c.

d.

Fig. 4 *Port* original image, composed noise

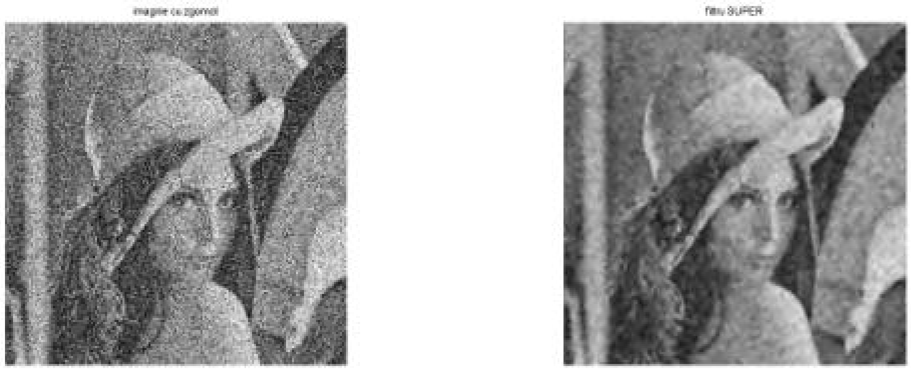
a. Original image.
b. Image with composed noise: gaussian and salt and pepper noise, *PSNR* = 14.9164 dB.
c. Image filtered using *medfilt2* followed by *wiener2*, *PSNR* = 20.7159 dB.
d. Image processed using *SUPER* filter, *PSNR* = 21.6560 dB.

The proposed filter was tested on very noisy images and the results obtained were better. The noise which was applied on the images is a composed noised consisting of one or more gaussian noises and one or more salt & pepper noises.

Fig. 5

a) *Lena*, 512 x 512 pixels, composed noise, *PSNR* = 14.8791 dB.

b) Filtered image using the proposed filter, *PSNR* = 27.4384 dB.

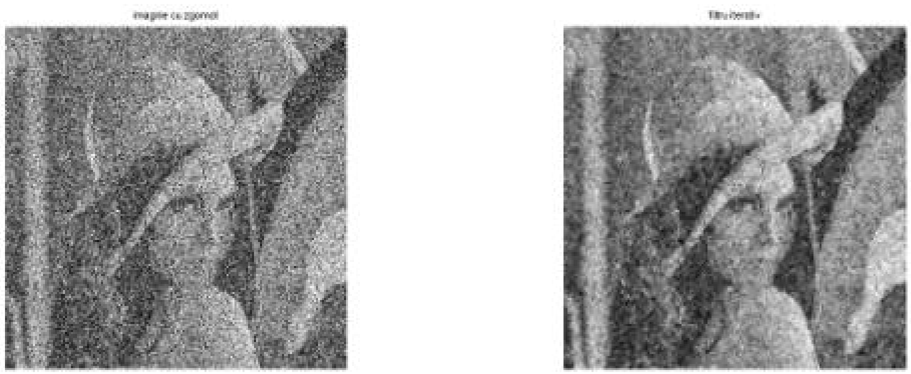


a. **b.**

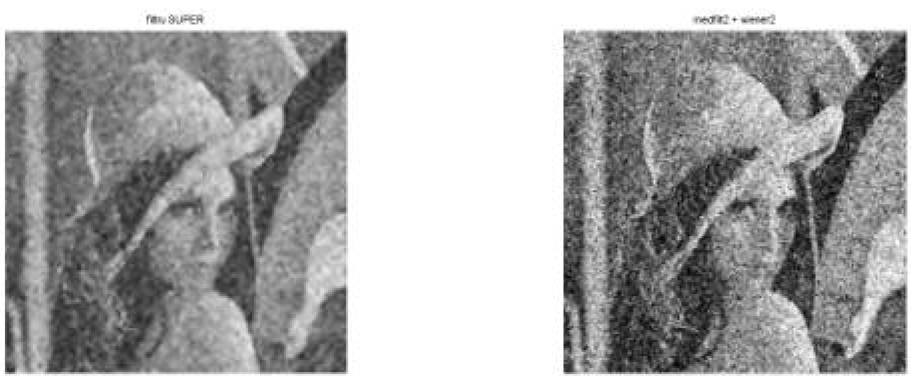
Fig. 6

a) *Lena*, 512 x 512 pixels, composed noise, *PSNR* = 10.7746 dB.

b) Filtered image using *SUPER* filter, *PSNR* = 23.8004 dB.



a. **b.**



c. **d.**

Fig 6. Images obtained by using the proposed filter an by cascading *medfilt2* and *wiener2* filters

a) Lena, 512 x 512 pixels, mixed noise, *PSNR* = 8.9819 dB.

b) Image obtained by an iterative estimation filter by wavelet reduction coefficient and an iterative pre-filter hybrid-median filter, *PSNR* = 21.5075 dB.

c) Image obtained using an empiric filter in the wavelet domain, *PSNR* = 21.6834 dB.

d) Image obtained by the succession *medfilt2* and *wiener2*, *PSNR* = 17.2398 dB.

3. CONCLUSION

The obtained results by using the proposed filter are better both considering the visual aspect and the PSNR. For images, which have better resolution, the filtering results are even better.

The proposed filter obtains better results than the case of the combination of *medfilt2* and wiener filters with about 4 dB in PSNR terms. Also, the visual quality of the images obtained using the proposed filter is better than in the case of the succession of the two filters.

4. BIBLIOGRAPHY

[1] ***Felix Abramovich, Yoav Benjamini***, Adaptive Thresholding of Wavelet Coefficients, *Computational Statistics and Data Analysis,* 22:351-361, 1996.

[2] ***J. Chou, M. Crouse, K. Ramchandran***, A Simple Algorithm for Removing Blocking Artefacts in Block-Transform Coded Images, *IEEE Signal Processing Letters, Vol. 5, No. 2., pg. 33--35 , Feb.* 1998.

[3] ***Ronald R. Coifman, Fazal Majid***, Adapted Waveform Analysis and Denoising, Adapted Waveform Analysis and Denoising, *Proceedings, International Conference ``Wavelets and Applications'', Toulouse, France (1992),* 1992.

[4] ***Ronald R. Coifman, Yves Meyer, Victor Wickerhauser***, Wavelet Analysis and Signal Processing, *M. B. Ruskai et al., ed., Wavelets and Their Applications, Jones and Bartlett, Boston, 1992, pp. 153—178*, 1992.

[5] ***Ronald R. Coifman, Mladen Victor Wickerhauser***, Wavelets, Adapted Waveforms, and De-Noising, http://citeseer.nj.nec.com/

[6] ***I. Daubechies***, The Wavelet Transform, Time-Frequency Localization and Signal Analysis, *IEEE Trans. on Information Theory, vol. IT-36, pg. 961-1005*, 1990.

http://www.ifp.uiuc.edu/~mihcak/paper.html

[7] ***Stephane Mallat, Wen Liang Hwang***, Singularity Detection and Processing with Wavelets, *IEEE Transactions on Information Theory,* 38(2):617--642, 1992.

[8] ***Jo Yew Tham, Li-Xin Shen, Seng Luan Lee, Hwee Huat Tan***, A Special Class of Orthonormal Wavelets: Theory Implementations, and Applications, *ICASSP '99, Pheonix, Arizona, U.S.*, March 1999.

[9] ***Jo Yew Tham, Li-Xin Shen, Seng Luan Lee, Hwee Huat Tan***, A New Multifilter Design Property for Multiwavelet Image Compression, *ICASSP '99, Pheonix, Arizona, U.S.*, March 1999.

[10] ***Saeed V. Vaseghi***, Advanced Signal Processing and Digital Noise Reduction, *Wiley & Teubner*, 1996

[11] ***Martin Vetterli, Cormac Herley***, Wavelets an Filter Banks: Theory and Design, *IEEE Transaction on Signal Processing, 40(9):2207--2232,* September 1992.

[12] ***Mladen Victor Wickerhauser***, Lectures on Wavelet Packet Algorithms, *INRIA, Roquencourt, France, Minicourse lecture notes,* 1991.