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ELIMINATING IMPULSIVE DISTURBANCES USING ADAPTED WEIGHTED MEDIANS

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Abstract – The idea of adaptive weighted median filtering of disturbed signals is presented in the contribution. The disturbance is assumed to be impulsive, hence linear filters are not a suitable tool for elimination of such pulses. After a short review of literature concerning weighted medians and their properties a piecewise linear process is analyzed and optimum weight vectors of the median filter are determined.

Keywords: Nonlinear filtering, weighted median, impulsive disturbance

1. INTRODUCTION

Filtering out disturbances from transmitted or recovered measurement signals is one of the most important tasks of analog and digital signal processing for many decades. Removing of specific disturbances, having form of separate pulses (impulsive disturbances), requires specific algorithms because of very wide spectra of such pulses. The use of median procedures, especially of weighted medians, seems to be particularly effective in such filtering procedures. According to the applied algorithm, signal samples, which include disturbances, should be eliminated and replaced by some values resulting from neighbouring nondisturbed samples. The idea of such filtering and some examples of median parameters resulting from the signal shape will be presented below.

2. WEIGHTED MEDIAN ALGORITHMS

All steps of pulse elimination procedures (prewhitening, elimination, inverse filtering etc.) were discussed in [2] and an illustrating example for simple median operation was given there. It has been observed that certain functions of the linear filtering blocks can be taken over by nonlinear ones, in our case by the median operator. A theoretical background of this idea was presented some years ago in [1]. It was shown there also that a simple combination of weighted medians, for instance a linear function of two weighted medians, has a definite frequency response. There was recommended for instance the following operator

$$\tilde{y}(n) = \alpha_1 y_1^{WM}(n) + \alpha_2 y_2^{WM}(n) \qquad (1)$$

where $y_1^{WM}(n)$ and $y_2^{WM}(n)$ are Weighted Median (WM) smoothers defined by

$$y_i(n) = MED\lfloor \mathbf{w_i} \bullet \mathbf{x} \rfloor \qquad (2)$$

where
$\mathbf{w_i} \bullet \mathbf{x} = [\ w_{i1} \bullet x(n) + \ldots + w_{iN} \bullet x(n)\ ]$,
$\bullet$ - operator of repetition.

The corresponding MATLAB procedures and facilities enabling us to study algorithm properties in a very "comfortable" way, were discussed in [2].

A specific, very interesting goal is to characterize the weighted median sliding windows by the use of harmonic linearization. The problem was treated in a very extensive way in [1], some additional examples are given in [4], but it seems to be still open.

3. THE SHAPE OF DISTURBED SIGNAL AND MEDIAN PARAMETERS

The filtering properties of weighted medians depend on parameters α_1, α_2 and $\mathbf{w_i}$, their values can be optimized with respect to the difference between the original and the filtered signal, for different signal shapes. Two examples for different typical shapes of signal and median filtering are given in Figs. 1 and 2. It can be seen that a certain compromise between the elimination of disturbing pulse and the signal distortion should be found (parameter values are identical for both examples in order to illustrate the necessity of optimization – especially in case II – Fig.2).

4. ADAPTING WEIGHTS OF MEDIAN FILTER

As it can be easily shown the accuracy of filtering (measured as rms value of the difference between the original and the filtered signal) depends on the local shape of the signal. It is proposed to chose some optimum value of $\mathbf{w_i}$ for given values of local derivatives of the signal. In order to illustrate the situation optimum values of weights were determined for different slopes of linearly increasing signal or dif-

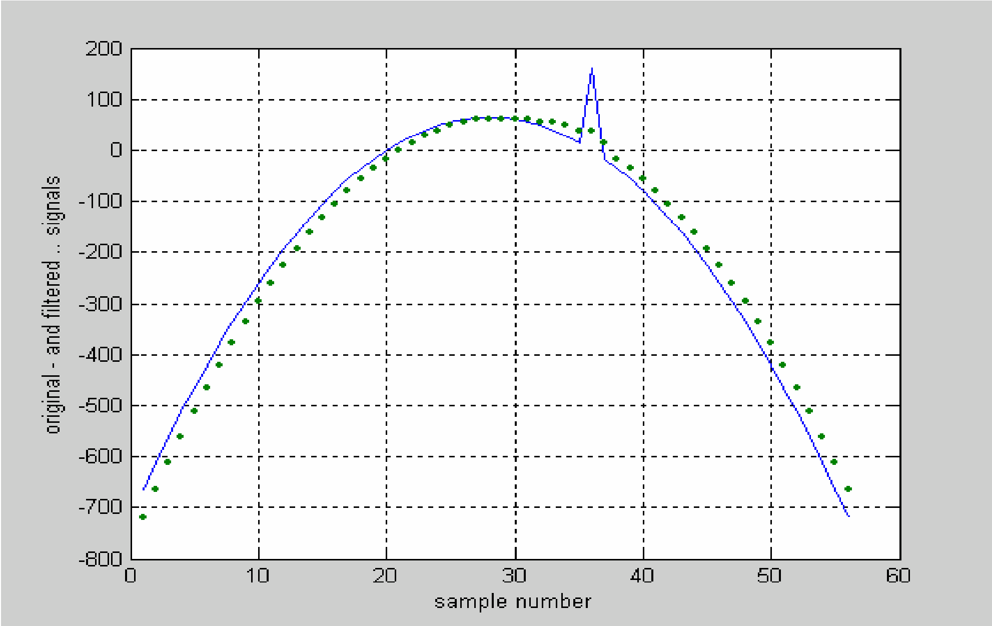

Fig. 1 Measurement signal I

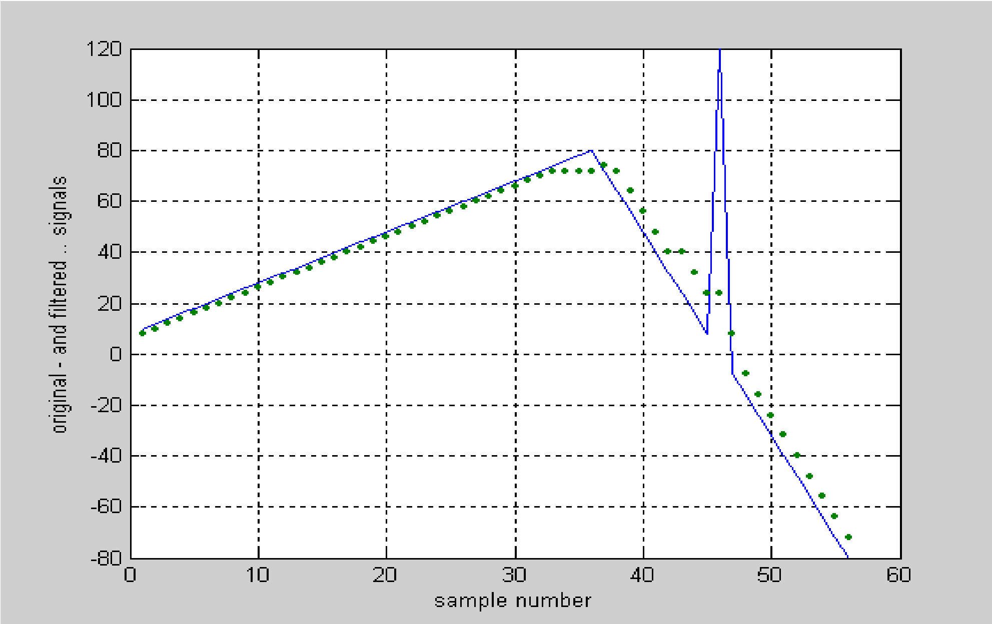

Fig. 2 Measurement signal II

Table 1 Optimum median weights for different signal slopes

Slope coeff.	g5o	g4o	G3o	g2o	g1o
-15	1	5	4	1	1
-10	1	2	3	1	1
-5	2	9	3	1	1
0	2	7	1	1	1
5	8	2	8	2	1
10	8	2	8	2	1
15	2	3	5	1	1

ferent derivatives (see Table 1). In case of signal as shown in Fig. 3 the slopes have to be detected and the vector of weights switched over according to the table. The slope coefficients should be quantized, of course, because of practical reasons. Several examples of enlarged piecewise signal for different slopes are given in Figs. 4, 5 and 6.

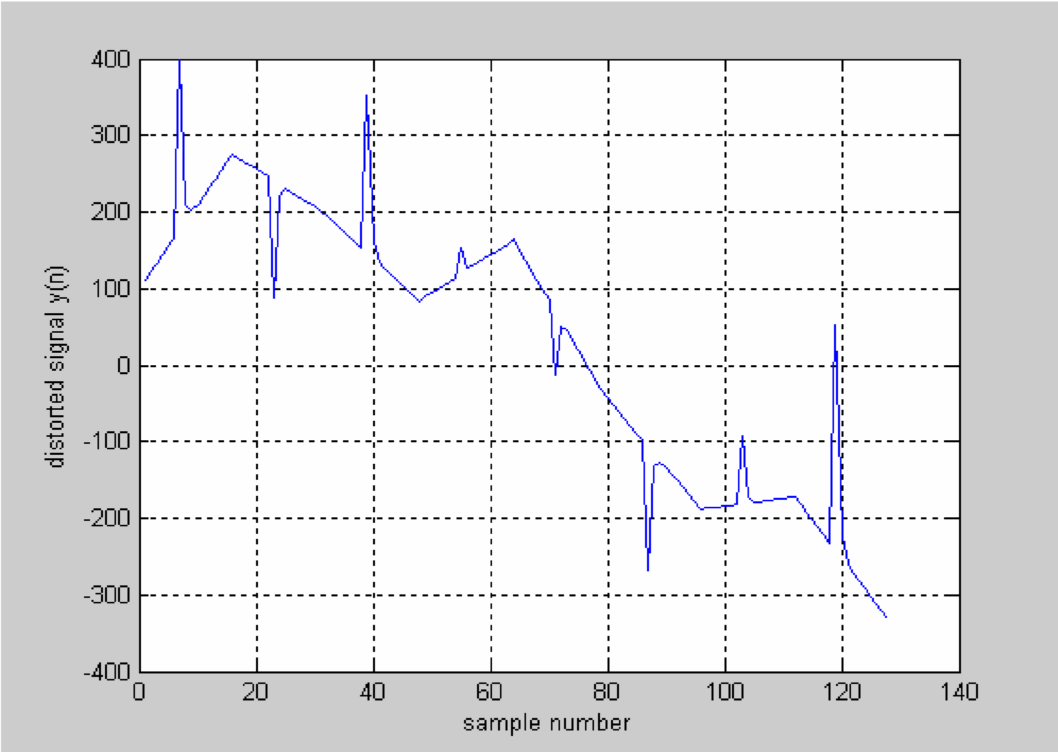

Fig. 3 Piecewise linear distorted signal

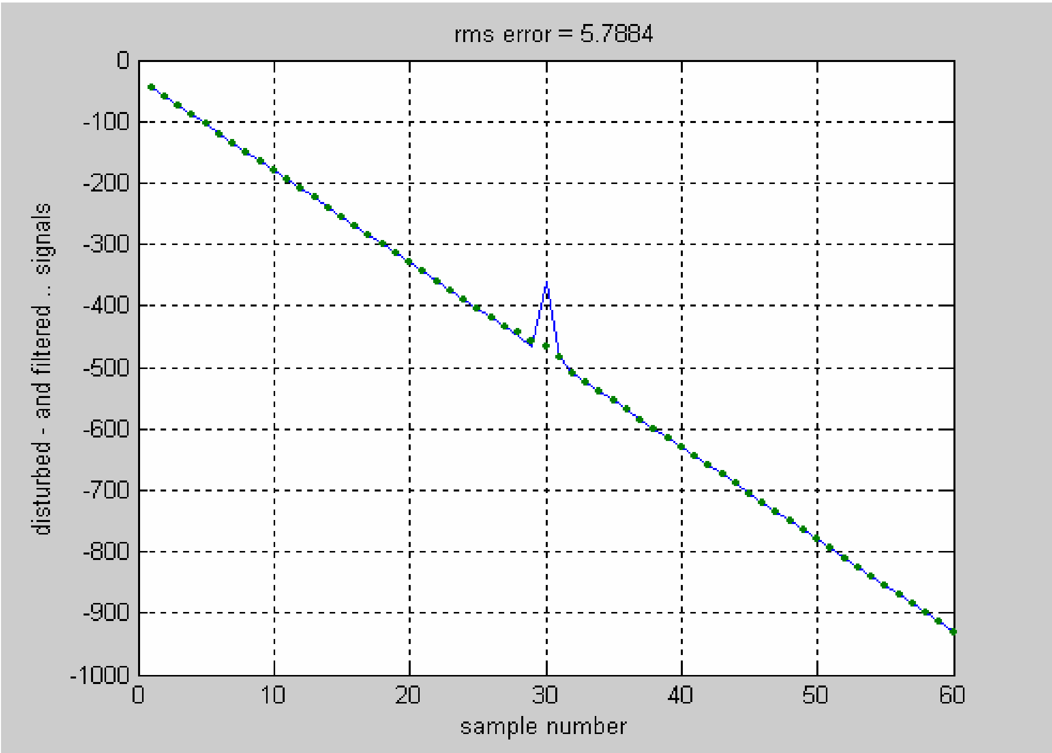

Fig.4 Enlarged distorted and filtered signals for slope tg=-15

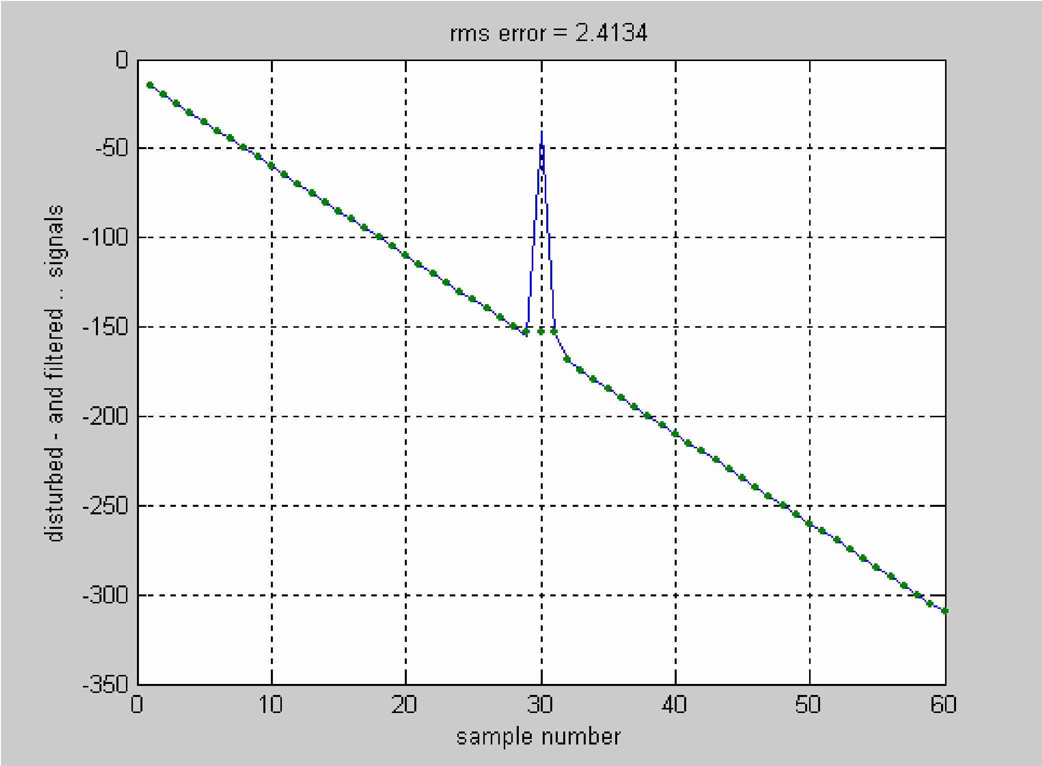

Fig.5 Enlarged distorted and filtered signals for slope tg=-5

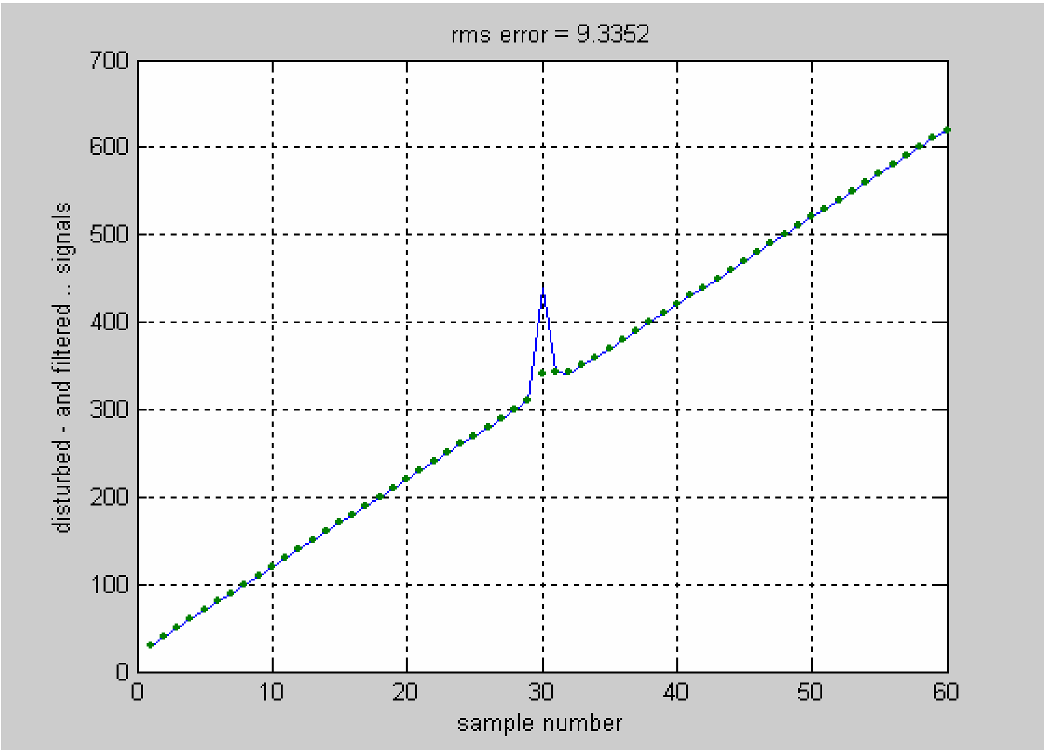

Fig.6 Enlarged distorted and filtered signals for slope tg=10

5. CONCLUSIONS

Weighted medians can be used as filtering algorithms for typical measurement signals in case of impulsive disturbances. Nevertheless their parameters must be adapted to the shape of filtered signal. Some simple solutions of the problem are given in the full text of paper. It is possible to apply different weights to different subintervals of the signal in order to achieve the above mentioned compromise between filtering and shape distortion.

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