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DETECTION AND CANCELLATION OF IMPULSIVE DISTURBANCES USING MATLAB PROCEDURES

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Abstract – The paper deals with detection and elimination of impulsive disturbances, by the use of nonlinear algorithms based on weighted median filtering. The MATLAB procedures are applied here; they are used also in prewhitening and smoothing of the disturbed signal which can be a sequence of measurement data corrupted by pulses of different origin. The use of algorithm is illustrated by an example.

Keywords: Impulsive disturbance, nonlinear transform, median algorithm.

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 MATLAB procedures, especially for testing of algorithms, seems to be particularly effective in this case.

Generally, in most cases the following properties of the disturbed signal must be taken into consideration: correlation of signal samples, pulse shape, as well as power variations of the signal and disturbances. The most popular approach consists mainly in some nonlinear and linear operations and uses old concepts derived from analog methods [1]. Alternatively the idea of "median window" applied to a short sequence of samples has become a practical solution and will be discussed in the contribution. Also the weighted median and a simple linear combination of two medians will be used because of its specific frequency characteristic.

2. ALGORITHM OF FILTERING

According to the applied algorithm signal samples, including disturbance, should be eliminated and replaced by some values resulting from neighbouring nondisturbed samples. As it was mentioned in [2], such operation is realized only with respect to short sequences of pulses so the disturbed signal must be prewhitened in order to convert the "fuzzy" pulses to approximately Dirac pulses. Designing a pulse eliminating algorithm or circuitry must include therefore the following elements:

- mathematical model of disturbing pulses,
- determining the prewhitening filter structure,
- determining the median parameter,
- determining the inverse filter structure (compensating prewhitening operation).

All these steps were discussed in [3] 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 [4]. It was shown there 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

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

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

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

where $\mathbf{w_i} \bullet \mathbf{x} = \lfloor\ w_{i1} \bullet x(n) + \ldots + w_{iN} x(n)\ \rfloor$,

• - operator of repetition.

3. ILLUSTRATING EXAMPLE

The above described method is illustrated by a simulation including generation of contaminated signal and disturbance elimination procedure. The original nondisturbed signal (which can be a sequence of measurement results} as well as the disturbing pulses are obtained using the *rand* function, and subsequently "coloured" in corresponding difference equations. The proper filtering algorithm includes prewhitening and calculation of medians by the use of the following procedure:

```
y2=0.859*(1.53*median(ypr1)-
   0.633*median(ypr2));
```

where `ypr1` was created according to the procedure:

```
K1=9; % length of the median interval
W1=[4 1 1 1 2 1 1 1 0];  % weight vector
for p=1:(N-K1+1),
    for j=1:K1,
       ypr(j,p)=y(p+j-1);
    end;
end;
m=1;
r=size(W1);
for i=1:r(2),
    for j=1:W1(i),
        ypr1(m,:)=ypr(i,:);
        m=m+1;
    end;
end;
```

A similar procedure was applied in order to generate the `ypr2` sequence, except weight vector which has now the form

```
W2 = [0 1 1 1 2 1 1 1 4]
```

i.e. is an inverted sequence vector with respect to `W1`.

It results from the above procedure that rows of `ypr` are repeated in `ypr2` and `ypr2` so many times as it is indicated by elements of weight vectors. Simultaneously the two-dimensional matrix `ypr` consists of columns being sections of `y(n)`, cut out by a sliding K1 or K2-length window.

It must be added that the original process x(n) was shaped from a uniformly distributed sequence of samples x1(n) by the following difference equation

$$x(n) = x1(n) + 0.9x(n-1) \qquad (3)$$

and disturbed by a sequence of pulses as shown in Fig.1. The sum y1(n) of signal x(n) and disturbance z(n) was prewhitened by

$$y(n) = y1(n) - by1(n-1) \qquad (4)$$

(the resulting signal for $b=0.4$ is shown in Fig.2). Finally, after median operations the filtered sequence was transformed "inversely"; the sequence $y3(n)$, shown in Fig.3 together with original signal $x(n)$, was calculated as

$$y3(n) = y2(n) + 0.54\,y3(n-1) \qquad (5)$$

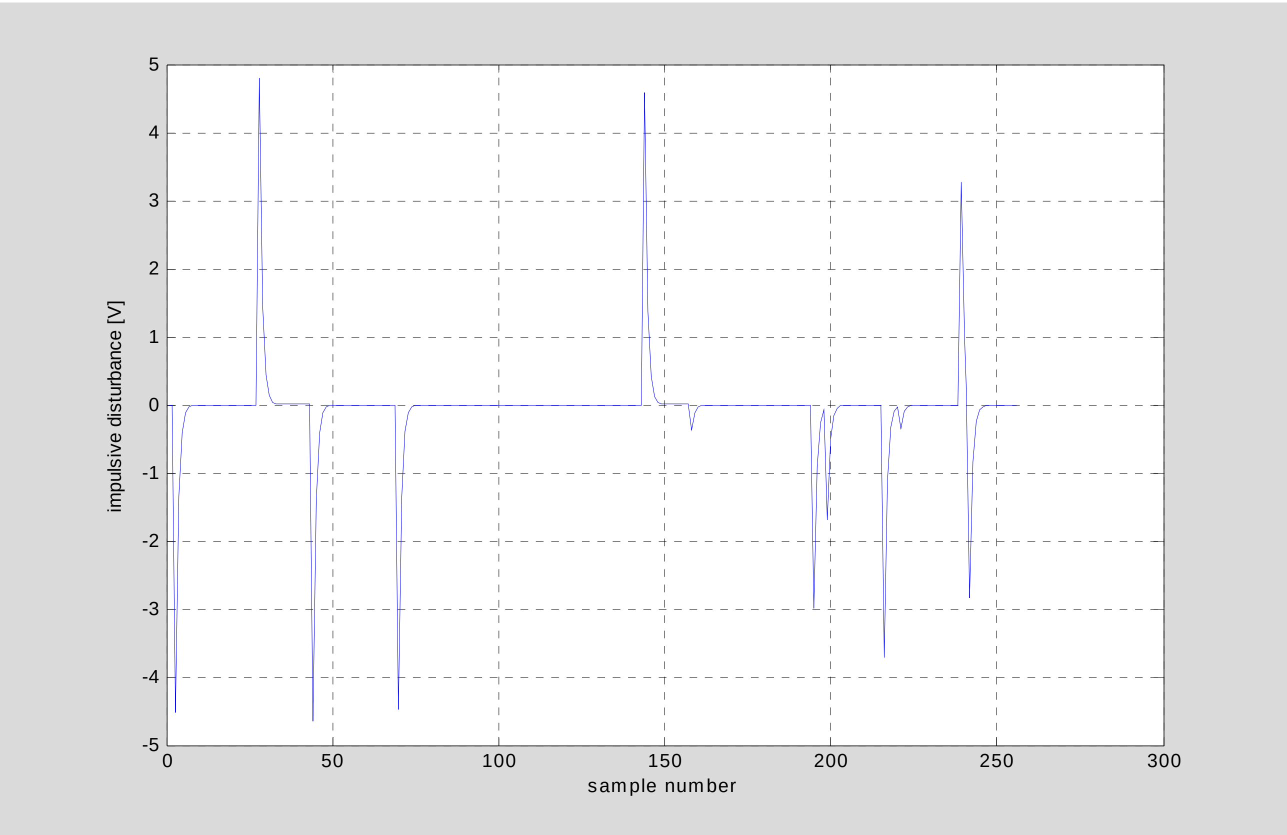

Fig. 1. Impulsive disturbance

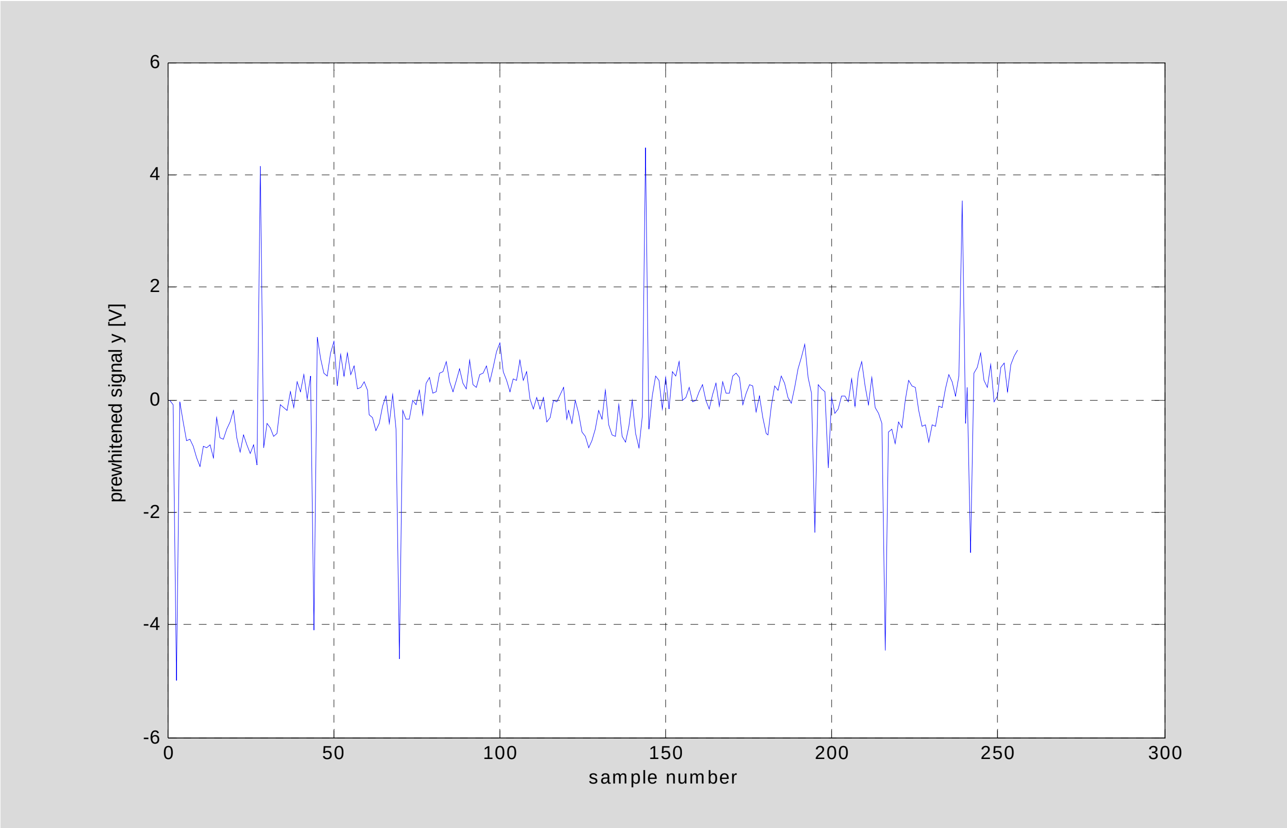

Fig. 2. Prewhitened signal

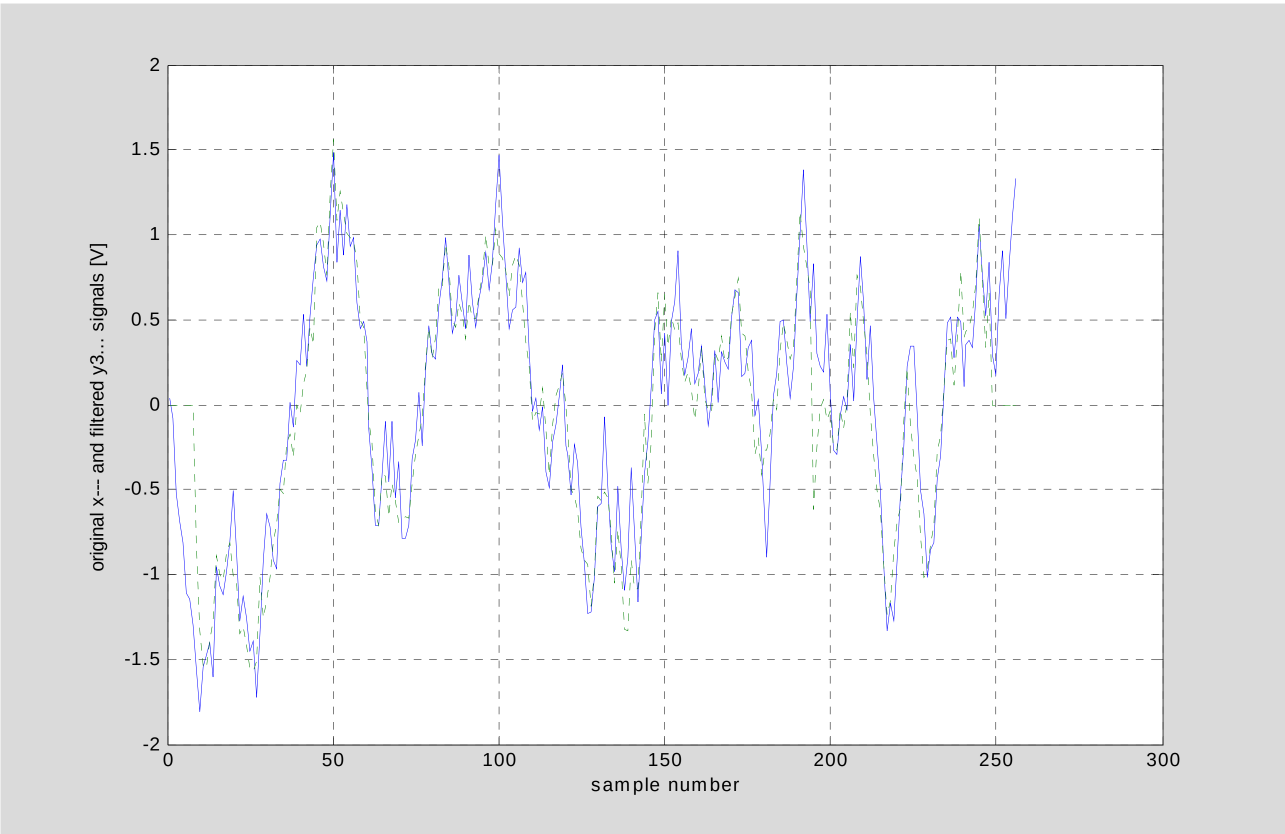

Fig. 3. Original x ----- and filtered y3 ······· signals

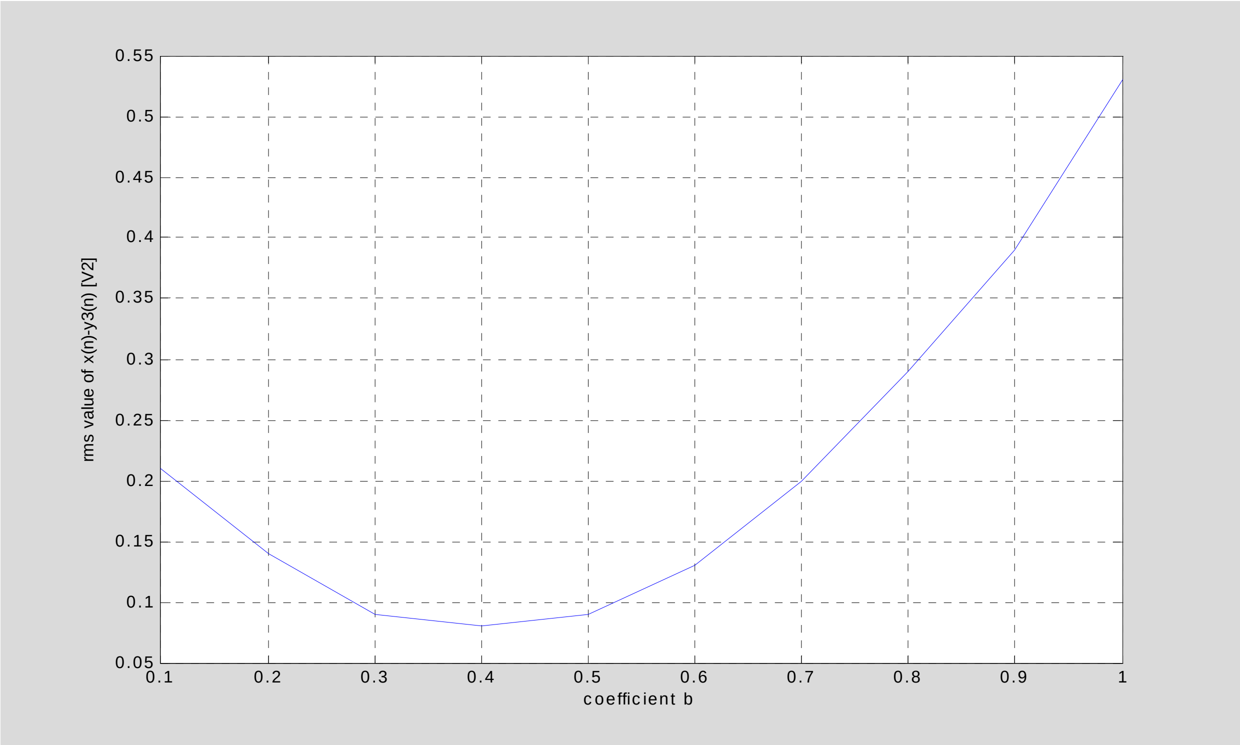

Fig. 4. rms error of filtering vs. coefficient *b* graph

All coefficients were adjusted experimentally in order to minimize the rms value of *x(n)-y3(n)*.

The effect of possible coefficient variations can be illustrated, for example, by the rms error value vs. coeff. *b* value curve given in Fig.4.

4. MATLAB FACILITIES

It must be noted that some important features of the MATLAB command median(.) were applied above, e.g. median(.), if applied to a 2D-matrix, returns medians of separate columns, as elements of a single row matrix. Furthermore the transfer of whole matrix rows enables us to create a new matrix including multiple rows of the same form.

5. CONCLUSION

A certain combined method of filtering of impulsive disturbances was investigated and the initial results were presented in the contribution. It has been shown that some properties of weighted medians and their linear functions can be used in nonlinear filtering algorithms. The MATLAB programming language seems to be an effective mean in such analysis and in design of filtering procedures.

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