REDUCING OF AN IMPULSE NOISE INFLUENCE
ON A/D CONVERSION RESULTS
USING NEURAL NETWORKS

V.Koval [(1)], V.Turchenko [(1)], V.Kochan [(1)], A.Sachenko [(1)],
T.Laopoulos [(2)]

[(1)] Ternopil Academy of National Economy, Institute of Computer Information Technologies,
3 Peremoga Square, 46004, Ternopil, Ukraine
[(2)] Aristotle University of Thessaloniki, Electronics Lab, Physics Dept.,
54006, Thessaloniki, Greece

Abstract - *The method of reducing of an impulse noise influence on A/D conversion results using neural networks is considered in this paper. The main feature of the proposed method is rejection of some training vectors with impulse noises from training sample of the neural network.*

Keywords - A/D conversion results, reducing of impulse noise, neural network

1. INTRODUCTION

It is known, the error of analog-to-digital (A/D) conversion is determined not only by instrumentation error, but also by influence of various kind of noises in the real exploitation conditions. The noise rejection is enough hard task [1]. For example, the special kinds of A/D converters such as integrating ADCs [2] are used for sinusoidal noise rejection, which reject noises at 80-90 dB. However, such converters provide rather low speed. Therefore recently the significant attention is given to methods of A/D conversion results processing with the purpose of reducing of various kinds of noise influence, in particularly, methods of digital filtering. These methods allow operatively changing parameters of noise rejection process depending on kind of noises. The most dangerous kind of noise is impulse noise because it significantly distort A/D conversion result. Impulse noises mean significant single deviations of A/D conversion result from rating value. These noises usually present as results of electromagnetic impulses influence to A/D conversion result at various switching processes. The amplitude, duration and time of impulse noises generation have a casual character in most cases, that hardly make difficulties with its rejection.

Impulse noises are especially dangerous at ADC zero setting and calibration, because (i) they make multiply influence on results of A/D conversion [3], and (ii) they have a long aftereffect (they influencing on the whole series of A/D conversion results up to the following cycle of zero setting and calibration). The aftereffect danger of impulse noises will increase at drift correction and prediction of zero setting and calibration using neural networks [3]. It is means that, (i) the impulse noises worsen parameters of neural networks training (increase an error of correction factor definition), and (ii) the prediction ADC error allows sharply to increase an intertesting interval and to increase aftereffect time of impulse noises. It is expedient previously to censor sample of A/D conversion results by statistical methods for reducing of impulse noise influence at direct current ADC zero setting and calibration [4]. Usually the "3-sigma" criterion is used for this purpose (results of A/D conversion are rejected from sample, which deviate from average of distribution on the triple significance of mean square deviation). However the "3-sigma" criterion is unacceptable because of difficulty of average of distribution definition under A/D conversion results at varying signals conversion. The input A/D signal can be changed not only at conversion physical quantity to code, but also at zero setting and calibration by variable reference signal. For example, it is expedient to make ADC zero setting and calibration by the same signal form as the power voltage for the sensor circuit at using ratiometer circuits and displacement method of signals to code conversion of inductive and capacity sensor. Thus, the task of impulse noises reducing is rather actual.

2. THE EXISTING METHODS OF IMPULSE NOISE REDUCING

The various filtering methods traditionally are used for reducing of impulse noise influences on A/D conversion results [4]. The good noise rejection and adaptability of parameters is provided by digital filters [5]. However the efficiency of classical digital filters at rejection of non-periodic impulse noise is considerably reduced, that caused necessity of filters modernizing and searching of the new methods [6, 7]. Using artificial intelligence methods, in particularly neural networks [8], is perspective for rejection of various kind of noises. The methods of reducing of impulse noise influence using neural networks also are known. The algorithm of impulse noise rejection based on dependence of neural network training error from regularity of values placement into training sample is proposed in [9]. The impulse noises infringe natural placement of A/D conversion results and worsen training of neural network.

Firstly N neural networks are trained on all sample of N A/D conversion results and there is calculated Total Generalization Error (TGE) as average value of the absolute errors of neural networks training for selection of impulse noises. After that N reduced training samples are formed by sequential rejection of the regularly scheduled A/D

conversion result from all training sample. At the following step N separate neural networks are trained on obtained N reduced training samples and calculated N values of Modified Generalization Error (MGE) as average value of the absolute errors of neural networks training (similarly to TGE). The N Error Reduction (ER) values as difference between appropriate TGE and MGE are calculated after this. At the following step (i) the N A/D conversion results are sorted in ER decreasing order and (ii) one A/D conversion result sequentially is rejected from training sample (start from first value) and (iii) new neural network is trained and (iv) new ER value is calculated. The result of A/D conversion finally are rejected from training sample as value, which received influence of the impulse noise if ER will be more than zero on some step of rejection. Otherwise the result of A/D conversion returns into training sample. As it is shown, the above algorithm is very complicated in application despite of its high efficiency. It is necessary to train very large number of neural networks, that requires significant time of A/D conversion results processing for algorithm fulfillment. Therefore, it is difficult use such algorithm into systems of sensors signal processing.

3. THE PROPOSED METHOD OF THE IMPULSE NOISE REDUCING

Neural networks properties to find the hidden regularities in training sample is used into proposed method of reducing of impulse noises influence on A/D conversion results [9, 10]. The error of neural network training is less, than the natural character of training sample is strong. Impulse noises distort natural character of training sample and sharply worsen training process of neural network. It tendency is visible from increasing of training error for certain amount of epoch or from increasing of amount of epoch necessary for certain training error reaching.

It is necessary to execute the following operations for realization of proposed method of sample censoring of A/D conversion results:

1. Neural network training on all N sample of A/D conversion results;
2. Calculation of the absolute error values $\Delta a1$ of sample approximation by neural network;
3. Calculation of maximum value of the absolute error max($\Delta a1$);
4. Rejection of training vector which appropriate max($\Delta a1$) from sample of A/D conversion results;
5. Neural network training on reduced N sample of A/D conversion results;
6. Calculation of the absolute error values $\Delta a2$ of sample approximation by neural network;
7. Calculation of maximum value of the absolute error max($\Delta a2$);
8. Comparison of maximum values of the absolute errors max($\Delta a1$) and max($\Delta a2$);
9. The rejected on step 4 A/D conversion result is replaced by prediction value if max($\Delta a1$) < max($\Delta a2$)

10. Otherwise, the rejected training vector returns into sample;

The "window" method is used for neural network training. However the classical "window" method [11] causes "increasing" of impulse noise influence. Impulse noise enters into training vectors so much time, how many elements are contained into the "window". For removing of such "increasing" the training sample is divided on training vectors where amount of A/D conversion results exceeds amount of neural network inputs n by one unit and one of A/D conversion result is neural network output. The computer modeling has shown that A/D conversion results with impulse noises on neural network output are well rejected. Therefore is necessary parallel using of n+1 neural networks, where their outputs are presented as all n+1 A/D conversion results in turn which are included in training vector. The feature of proposed method of reducing of impulse noise influence is that the best results are provided by perceptron with linear activation function of neurons. The second feature of proposed method is necessity of limitation of number of training epoch up to several tens or appropriate increasing of sum-squared training error for removing of retraining effect of neural network [8,12]. These features sharply reduce necessary time for proposed method executing that expand possibilities of its application.

4. COMPUTER MODELING

The MATLAB Neural Networks Toolbox [13] is used for execution of computer modeling. The sample of A/D conversion results was formed using hypothetical data [14]. The ideal sensor signal (see Figure 1a) was formed using function $y = \sqrt{x}$ (simulates a stationary nonlinear changing of input signal) and also using periodic function $y=\sin(x)$ (simulates a periodic nonlinear changing). The casual values distributed on the normal law with average of distribution = 0 and mean square deviation = 1 (see Figure 1b) are used for simulation of noise influence on A/D conversion results. The generator of random numbers distributed on uniform law (see Figure 1c) is used for forming of impulse noise influence on A/D conversion results. These noises differ on amplitude and placement in sample of A/D conversion results.

The structure of multi-layer perceptron with 5 input neurons, 5 hidden neurons with logistic activation function and one linear output neuron was used for simulation. For removing of neural network retraining effect the training process has limited by 50 epoch or sum-squared error 0.1. The average time of neural network training is 0.5 seconds on the computer Intel Celeron-400. The result of impulse noises rejection is presented on Figure 1d. The results of modeling have shown, that the proposed method rejects not only artificially made impulse noises at normal distribution law of noise influence, but also the values "signal + noise", which are commensurable with impulse noises on amplitude. As it is seen from Figure 1a and Figure 1d, the proposed method reduces impulse noise of A/D conversion results up to level, approximate to the ideal signal.
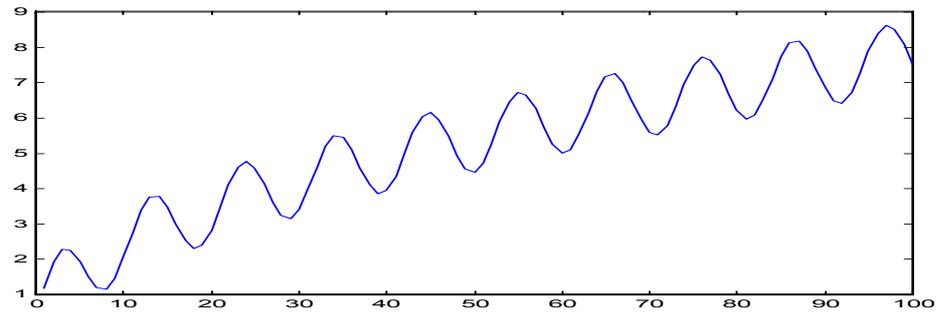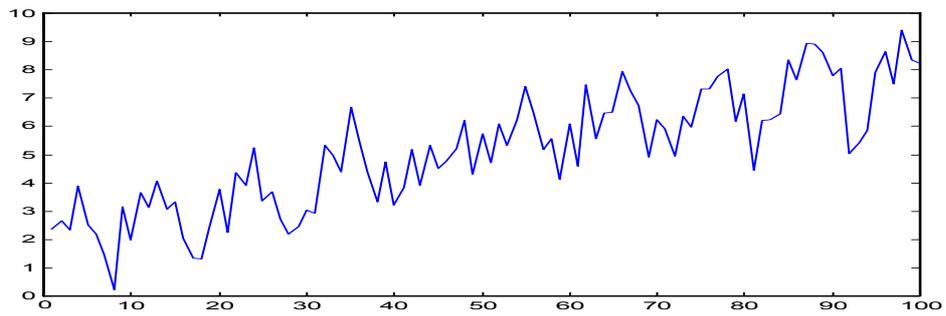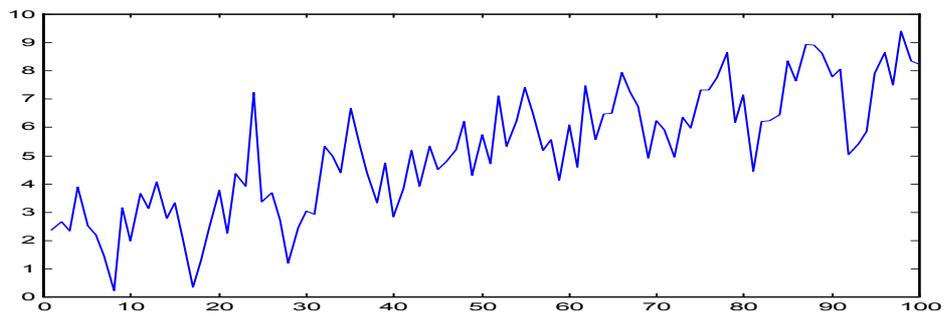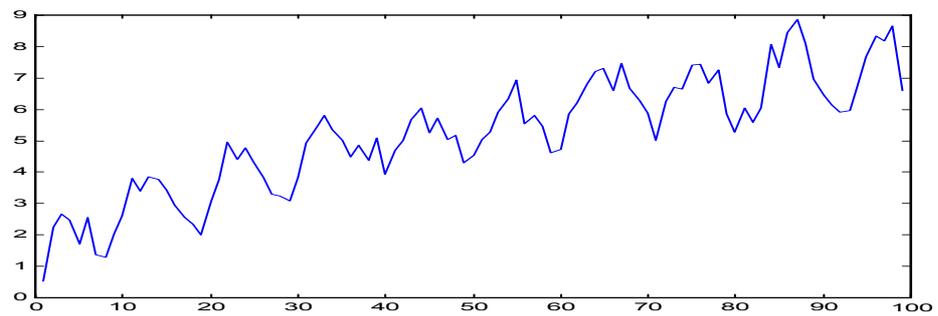
Figure 1. The graphic representation of proposed method: (a) ideal sensor signal, (b) noise influence on A/D conversion results, (c) impulse noise influence on A/D conversion results, (d) result of impulse noise rejection

5. CONCLUSION

The results of computer modeling have shown that the proposed method provides (i) large universality, than "3-sigma" criterion (allows to reject impulse noises at A/D converter input signal changing) and (ii) large efficiency, than known digital filters. However, the 3-sigma criterion requires smaller computing time, but the proposed method can be used at zero setting and calibration, providing universality at development of A/D converter processing software.

REFERENCES

[1]   F. Russo, Impulse Noise Detection and Filtering Using Fuzzy Models, *Proceedings of the 17th IEEE Instrumentation and Measurement Technology Conference* (Baltimore, May 1-4 2000), USA, 2000, p. 1041-1044.

[2]   P.P.Ornatsky, *Automatic measurements and devices*, Kiev, Vyscha shkola, 1986, 504 p.

[3]   A.Sachenko, V.Kochan, V.Turchenko, V.Golovko, T.Laopoulos, Using Neural Networks for Decreasing ADC Error, *Proceedings of 4th IMEKO International Workshop on ADC Modeling and Testing* (Bordeaux, Sep 9-10 1999), France, 1999, p.78-81.

[4]   P.P.Ornatsky, *Theoretical fundamentals of information-instrumental techniques*, Kiev, Vyscha shkola, 1983, 455 p.

[5]   I.Pitas and A.N.Venetsanopoulos, *Nonlinear digital filters: principles and applications*, Kluwer, 1990.

[6]   C.Spinola, A.Gago, Filtering of impulse noise from laser sensor signals in the process of non-contact thickness measurement in a stainless steel sheet production line, *Proceedings of the 17th IEEE Instrumentation and Measurement Technology Conference* (Baltimore, May 1-4 2000), USA, 2000, p. 1303-1307.

[7]   Shachtarin B.I., Optimal filtering and prediction of random processes, MGTU, Moscow, 1991.

[8]   Shachtarin B.I., Sviatnyi D.A., Butenko A.A., About one neural-based method of filtering, http://members/xoom.com/sdvmail/

[9]   Pat. USA 5559929, IPC G06F 007/00, *Method of enhancing the selection of a training set for use in training of a neural network*, Wasserman Philip (USA); Unisys Corp. - No282250; Issued 29.07.94; Filed 24.09.96; Class 395/23. - 18 p.

[10] V. Vitsentiy, V. Koval, V. Kochan, A. Sachenko, Neuronetwork Algorithm of Impulse Noise Filtering During Sensors Signal Processing, *Proceeding of 10-th National Scientific Symposium with International Participation Metrology and Metrology Assurance'2000*, Sep 14-17, 2000, Sozopol, Bulgaria, p.207-211

[11] Golovko V.A., *NeuroIntelligence: theory and application*, BPI, Brest, 1999, 264 p.

[12] Wasserman P. D., *Neural Computing: Theory & Practice*, Van Nostrand Reinhold, New York, 1989.

[13] *MATLAB Language Reference Manual*, the MathWorks Inc, 1998.

[14] V.Golovko, L.Grandinetti, V.Kochan, T.Laopoulos, A.Sachenko, V.Turchenko, Sensor Signal Processing Using Neural Networks, *Proceedings of the IEEE Region 8 International Conference Africon'99* (Cape Town, Sep 29-Oct 1 1999), South Africa, 1999, p. 345-350.