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COMPRESSION OF DIGITAL MEASUREMENT SIGNALS BY IMPROVED REVERSE SCALING RECONSTRUCTION METHOD

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Abstract – It is noticed in the paper that scaling of digital measurement signals and their registration in format which is comfortable to investigations during computer processing increase their volume. Possibility of realization a reverse scaling operation as an initial processing method preceding compression is mentioned**.**

The authors proposed to complete initial processing by generally well-known operation - calculation of differences between succeeding samples and they tested the additional compression ratio, resulting from the proposed transformations, using experiments.

Keywords: signal compression, measurement signal, data acquisition

1. INTRODUCTION

Digital technique is often used in measuring systems recording time variable signals. A typical recording system consists of a sensor of the measured quantity, being usually a measured quantity-voltage converter (to make the problem simple, we omit other possible carriers of the measurement signal), and an A/D converter where the signal is then sampled and converted into digital values $\{x_n\}$. In popular measurement data recording systems, especially those with data acquisition cards, signal scaling, consisting in changing sample values so that they express values of the measured quantity $\{y_n\}$, is made (in the case of data acquisition cards) on the digital side. Data transformed this way are usually saved in disk files in ASCII or IEEE Double Precision (DP) formats and transferred among various applications of data analysis and presentation (especially in the case of research work).

After some time we finish the work on a certain group of data and it is right time to archive the data. A natural approach to this problem is employing to data files one of the popular compression applications as RAR or ZIP [1]. And usually here comes a surprise.

Although the compressed file containing the $\{y_n\}$ series is clearly smaller, but significantly greater than the compressed file containing the $\{x_n\}$. This suggests an obvious conclusion that instead of the $\{y_n\}$ series it is the $\{x_n\}$ series that should be compressed because the transformation is known.

Not all data acquisition software products allow to direct access to the $\{x_n\}$ series, and even if they do we often do not remember this or we do not want to waste some space on the disk, as we carrying out analysis using $\{y_n\}$. It is therefore necessary to recover the $\{x_n\}$ series from the $\{y_n\}$ series using reverse scaling operation. The problem and advantages of compression $\{x_n\}$ series instead of $\{y_n\}$ series are described in [2].

Since the signal before it is subjected of compression is transformed to the entire form $\{x_n\}$, what mainly makes difficulties in files management, then additional transformations of signal that improve its compressibility can be done.

Handbooks dealing with compression principles [1] give an example of substitution of original values series by series of differences, what in general diminishes the number of values performing in signal and decreases its entropy.

2. THE METHOD

The $\{x_n\}$ series as the output from an A/D converter can be treated as 12 ÷16-bit numbers (depending on the resolution on the converter). Signal scaling consisting in changing the values of samples so that these values express the values of the measured quantity is performed through employing (usually) linear transformation:

$$y_n = a \cdot x_n + b \qquad n = 1,...N . \tag{1}$$

reverse to (1) can be expressed mathematically as:

$$x_n = (y_n - b)/a \qquad n = 1,...N . \tag{2}$$

Using the relation (2) to $\{y_n\}$ series we obtain integer number series $\{x_n\}$. The method of eliminating the numerical errors appearing in (1) and (2), consists in suitable usage of rounding, is described in [2]. If coefficients a and b are not known they can be calculated by analysis of $\{y_n\}$ series [2]. Then the differences can be calculated.

$$\begin{aligned} d_1 &= x_1 \\ d_n &= x_n - x_{n-1} \qquad n = 2,...N \end{aligned} . \tag{3}$$

The $\{d_n\}$ series is subjected to compression by RAR or ZIP program.

3. EXPERIMENT

For experiment the measurement data registered on the different mechanical objects and climatical data are applied in general 33 series of measurement data.

Investigation procedure of compression ratio of IRSR method is presented in Fig. 1. improved reverse scaling reconstruction method IRSR case A, reverse scaling reconstruction method RSR case B, and only RAR case C are depicted in Fig. 1.

Additional compression ratio ie. quotient of file size $\{y_n\}$ series in double precision format compressed by RAR (case C) and file size of compressed $\{d_n\}$ series as 16 bit integer numbers is reckoned (case A).

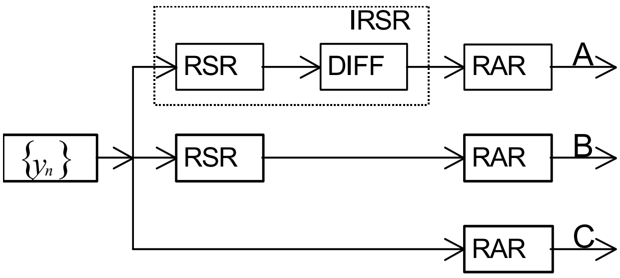

Fig. 1. Investigation procedure of compression ratio of IRSR method

It was found, that for longer data series advantage of usage of the RSR method is growing smaller. That is way comparisons are made separately for different data lengths (to obtain shorter data series the fragments of longer data series are used).

Exemplary results for data series length 1000 samples are showed in Table 1.

Table 1. Exemplary results for data series length 1000 samples

Signal nr	C file size	B file size	A file size	Compres sion gain B/A	Compres sion gain C/A
1	2	3	4	5	6
1	4535	1948	1523	1,28	2,98
2	1470	993	816	1,22	1,80
3	1723	1162	881	1,32	1,96
4	3672	1676	1159	1,45	3,17
5	6775	2035	1673	1,22	4,05
6	4581	1974	1433	1,38	3,20
7	1416	973	813	1,20	1,74
8	1499	1048	818	1,28	1,83
9	3352	1624	1160	1,40	2,89
10	6350	1989	1687	1,18	3,76
11	4577	2014	1514	1,33	3,02
12	1430	983	816	1,20	1,75
13	1596	1106	843	1,31	1,89
14	3399	1622	1032	1,57	3,29
15	1414	985	839	1,17	1,69
16	1463	1027	842	1,22	1,74
17	1407	974	823	1,18	1,71
18	2293	1411	870	1,62	2,64
19	356	263	263	1,00	1,35
20	389	264	267	0,99	1,46
21	1841	1165	796	1,46	2,31
22	1342	928	851	1,09	1,58
23	1694	1055	604	1,75	2,80
24	3015	1831	1417	1,29	2,13
25	1026	624	582	1,07	1,76
26	2261	1375	864	1,59	2,62
27	3696	2023	1626	1,24	2,27
28	2308	1458	1270	1,15	1,82
29	903	678	745	0,91	1,21
30	2492	1573	1322	1,19	1,89
31	1598	1155	1200	0,96	1,33
32	899	662	697	0,95	1,29
33	1254	900	895	1,01	1,40

In the table additional compression gain for method IRSR (case A) over simple case C and over RSR method (case B) are presented in columns 6 and 5 respectively. Cumulative distribution function of column 6 is presented in Fig. 2.

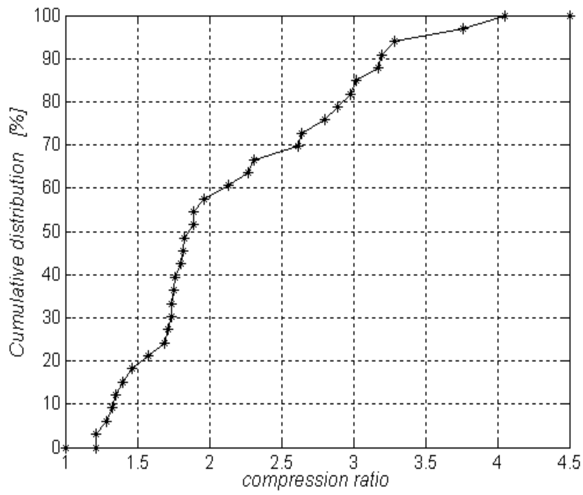

Fig.2. Cumulative distribution function of additional compression ratio (C/A)

The results are depicted as a function of series length, because relation between additional compression ratio and series length is observed.

Instead of results for each signal or cumulative distribution function the diagram presents values minimum, maximum and percentiles 10%, 50%, 90% what gives information about distribution of additional compression ratio.

Because the transformation (3) can be used also in case when $\{x_n\}$ series is accessible and should not be reconstructed from $\{y_n\}$ series, additional compression ratio

$\{d_n\}$ in relation to $\{x_n\}$ series (in 16 bit integers) compression is depicted in Fig.4. This illustrates improvement of RSR method by adding transformation (3) because this is additional compression gain case A over case B in Fig. 1 and column 5 in Table 1.

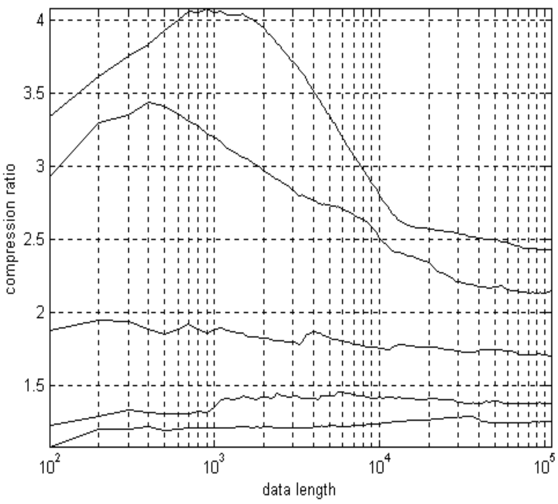

Fig.3. Additional compression ratio (over DP $\{y_n\}$) as a function of data length, (maximum and minimum, as well as percentiles 10%, 50%, 90%).

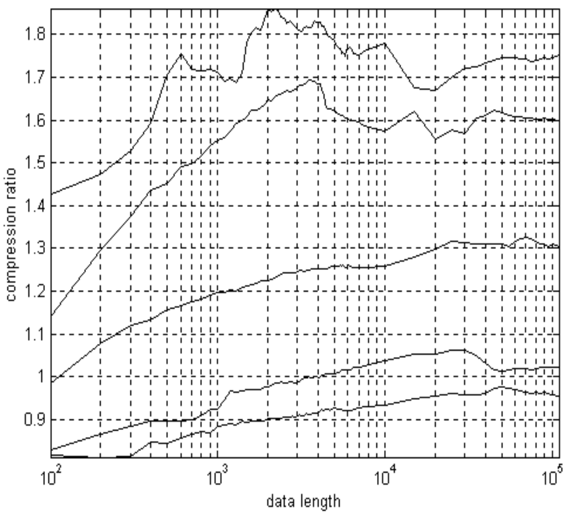

Fig.4. Additional compression ratio (over I16 $\{x_n\}$) as a function of data length, (maximum and minimum, as well as percentiles 10%, 50%, 90%).

Presented results (case C), in mediana case, are better up to 1,3 then in case of (2) (case B) transformation only, although there was signals (less than 10%) when for some short lengths additional compression ratio was 0,8 what means rather expansion.

4. CONCLUSIONS

Joining to the signal reconstruction method (by reverse scaling operation) a difference signal calculating as an initial transformation before RAR compression gives a betterment of compression ratio. The additional improvement of compression ratio is depicted by percentiles in Fig.4 and for mediana is up to 1,3.

The whole betterment of compression ratio presented in Fig.3. is significant for mediana 1,7÷2,0. Fig.4 has its additional interpretation usage of the differences to improve compression of the integer measurement signals. In both cases, RAR and ZIP programs became the subroutines of compression program, what makes the difficulties in files management.

5. ACKNOWLEDGMENT

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