

## Intelligent Analyzing System

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**Abstract:** Measurements of the observed parameters are carried out using a multiplex measuring system based on the adaptive commutation principle. The unit of numerical reflection of the state of the object performs the processing of non-redundant samples. The numerical procedure provides us with a specific number associated with its vector. The information uncertainty numerical representation algorithm and its practical realization were established, which makes it possible to carry out a current real time testing. *Copyright © 2013 IFSA.*

**Keywords:** Compression, Digital, Entropy, Intelligent, Measurement, Permutation, System.

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### 1. Introduction

Modern technologies, especially the creation of hydroelectric power station turbines, complicated electromechanical devices or aviation turbo gas engines, need numerous experimental investigations. Nowadays, dozens or even hundreds of transducers are employed as well as several hundreds or even thousands of different physical parameters need to be processed [1, 2]. For example, the testing of electromagnetic machines, generators and transformers turns out to be a very complicated operation. It necessitates several dozens of different parameters to be examined ( $i = \overline{1, n}$ ). Automatic testing systems for scientific research and for various industrial purposes greatly increase the effectiveness of the experiments conducted. These systems make it possible to realize the operative formation of the models of the phenomena and investigated processes, to rationalize the testing control as well as to facilitate the experimental tasks.

The measurement system is created for the purpose of decreasing the uncertainty of the observed

objects. In the information theory sense, this uncertainty is described by the object entropy [2]. Therefore, the entropy estimation mapping also permits to evaluate the information state of the object.

Anyway, the object entropy corresponds to the activities of the totality sources that may be estimated according to the observed behavior of the source signals. Thus, there are no signal changes if the object state is permanent, and, on the contrary, the stability of the signals is suddenly disrupted when some new unexpected situation emerges. The speed of signal change causes the appearance of its corresponding increment value. Obviously, the comparison of deviations of signals of different sources obtained at the same observation time enables one to make a conclusion about their activities. The larger deviation value testifies to the faster speed of the signal change, i.e., its greater current frequency. Having calculated the above mentioned activities it is possible to estimate the totality probability distribution of the sources, its corresponding entropy, i.e., to perform the express analysis of a state of the object.

The results of testing measurements may be presented as those belonging to some vector at  $n$  – dimensional space. Due to the technical norms for the objects investigated, it is possible to divide all the space into a certain number of subspaces. Each subspace corresponds to a certain observing object quality class, such as the best, good, bad, etc.

## 2. Fundamentals of State Estimation

Let us assume that the state of an object is investigated using a digital measurement system that mainly processes the sources having output analog signals.

On the one hand, according to the ADC procedure, the analog signal range is subdivided into a certain number of levels that correspond to the necessary quantification precision value. The quantification step is equal to the absolute quantification error value. Accordingly, if the analog signal value does not cross the tolerance zone borders, then its meaning is unessential for the estimation because the signal deviation is within the allowed error tolerance. On the contrary, the availability of any zone border crossing means that the signal value is essential indeed (the so-called non-redundant sample appearances).

On the other hand, the regular time-division system procedure is based on the Nyquist theorem [3] and it is oriented on the highest source frequency, which provides the information redundancy for a totality of sources. That is why there appeared a principle of designing a measurement system adaptive to the source data. Such compression techniques [4] are used to slacken the requirements to the communication channel capacity or to the data processing rate.

Most of the known data adaptive systems are based on the prediction or adaptive switcher principle [5]. As an example, two types of adaptive sampling systems were taken into consideration, one of them being a polynomial prediction and another one being based on the adaptive switching operational principle.

The first type of an adaptive sampling system (Fig. 1) is based on the predictions of sequential samples that are made using a horizontal projection, or zero-order polynomial from the present sample. When the current sample falls beyond the tolerance requirements, it is accepted as a non-redundant sample. It is necessary to place the non-redundant samples occurring at asynchronous intervals into a transmission storage buffer. Due to a limited number of storage cells, the loss of some non-redundant samples is possible. Time marks are sent with a constant time interval (Fig. 2) in order to indicate the time tags, and the source identification should be taken into consideration.

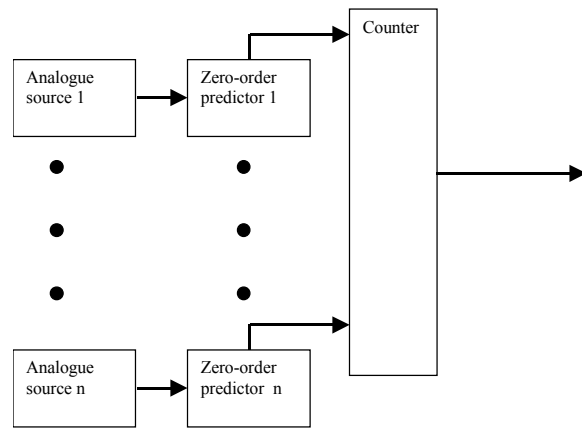


Fig. 1. Activity analyzing unit based on the zero-order predictors.

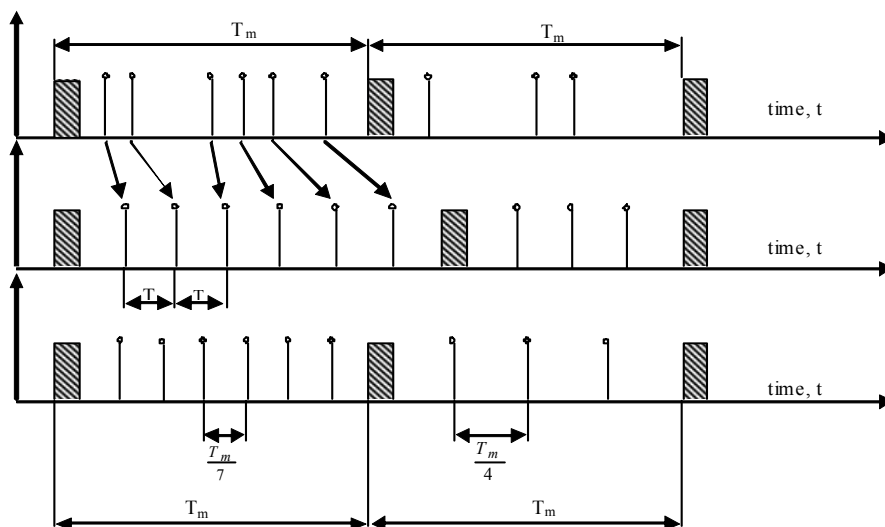


Fig. 2. Time diagram of the prediction type system.

The second type of an adaptive sampling system looks through all analog sources with a constant rate in time interval  $T$  (Fig. 3). Here, all analog sources are sampled at a constant rate with period  $T$ . In each sampling point, the adaptive switcher chooses from the total sources the most active source, i.e., the chosen source has the largest absolute value of the difference of two serial samples normalized with respect to the mean-square deviation of the analog measurement

signal of this source. The samples of the other sources are assumed to be redundant. The  $i$ -th most active source sampling value takes place in the  $i$ -th memory cell for the next sample time comparison (Fig.4). Practically, the  $i$ -th source difference is estimated by subtracting the current sampling momentary value from the previous activity manifestation value, which is extracted from the memory cell. Then, the unit operates according to its modulus.

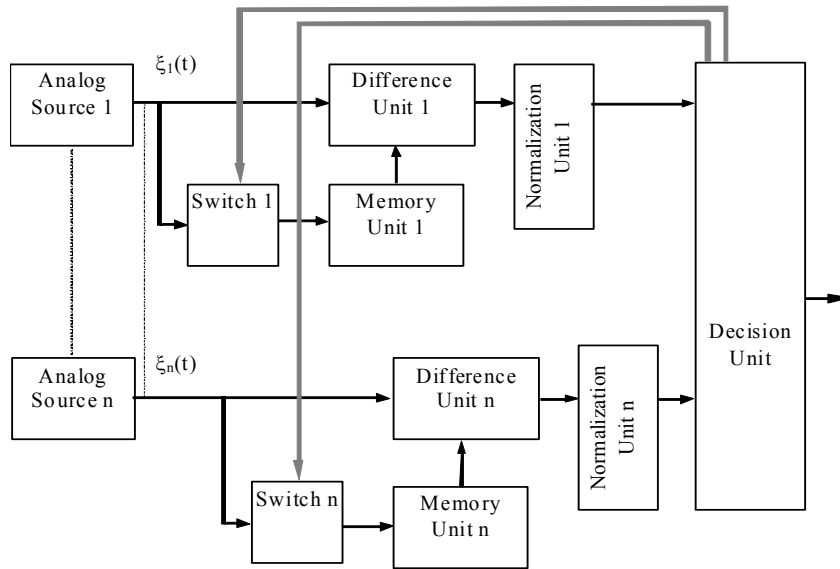


Fig. 3. Activity analyzing unit based on the adaptive switcher.

The total error includes prediction, time tag bias, and non-redundant sample loss components for the first type of an adaptive sampling system; sampling and quantification components for the second type of an adaptive sampling system; instrumentation and the link noise effect error components for both of them [6].

Any type of an adaptive system requires address information for each data source because the moment of the appearance of its non-redundant samples is unknown. This may be an individual or a group address. For our purpose, the group address is necessary that shows the order of the appearance of each source sample. During the analysis time, the current absolute activity distribution of the totality system sources is formed at the  $n$  counters. Thus, it is possible to gather the frame of non-redundant samples and to realize its real time group coding using the proposed algorithm [7]. At the same time, this code word is also the general image of the state of the investigated object. It is proved that the number of a certain sample of each source and its positions in the sequence correspond to the unique single-valued coding combination (i.e., code value) [7]. This group address word is both the distribution code of the activity of all sources and may be sent over the transmission link for the next data renovation on the receiver side.

### 3. Description of the Processing Algorithm

The appearance of the  $i$ -th source non-redundant sample is random, i.e., its position in the sequence is the random and the  $i$ -th samples total number is equal to  $N_i$  among all samples of the system sources  $N$ . The non-redundant samples introduce some permutation set sequence [8]:

$$p = \{x(1), x(2), \dots, x(N)\}, \quad (1)$$

where  $x(j)$  is the  $x$ - type symbol at the  $j$ -th position of permutation ( $x = \overline{1, n}; j = \overline{1, N}$ ).

The number of permutations is equal to

$$M = \frac{N!}{N_1! \dots N_n!}, \quad (2)$$

where  $N_i$  is the number of the  $i$ -th type symbol among the  $N$  sequence positions

$$(i = \overline{1, n}, \sum_i N_i).$$

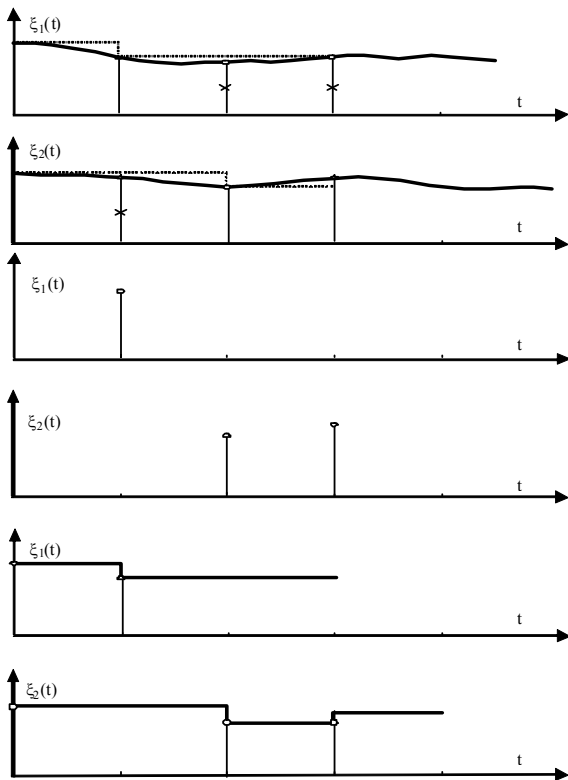


Fig. 4. Adaptive switching sampling time diagram.

In order to find the upper estimate of the equality (2), let us consider the polynomial formula [9]

$$\begin{aligned} (X_1 + X_2 + \dots + X_n)^N &= \\ &= \sum_{K_1+K_2+\dots+K_n=N} P(K_1, K_2, \dots, K_n) X_1^{K_1} X_2^{K_2} \dots X_n^{K_n} \end{aligned} \quad (3)$$

where

$$P(K_1, K_2, \dots, K_n) = \frac{(K_1 + K_2 + \dots + K_n)!}{K_1! K_2! \dots K_n!} \quad (4)$$

is the number of permutations with repetitions of  $K_i$  times of an element of  $i$ -type ( $i = \overline{1, n}$ ).

Having assumed  $K_i = N_i$  we get one of the possible summands in the right-hand part of the equality (3). That is why

$$(X_1 + X_2 + \dots + X_n)^N > P(N_1, N_2, \dots, N_n) X_1^{N_1} X_2^{N_2} \dots X_n^{N_n},$$

where  $\sum_i N_i = N$

thus

$$P(N_1, N_2, \dots, N_n) < (X_1 + X_2 + \dots + X_n)^N / \prod_{i=1}^n (X_i^{N_i}) \quad (5)$$

then we denote  $X_i = N_i$  and the permutation with repetitions is denoted by  $M$  similar to equation (2).

Let us consider the right-hand part of the inequality (5) by writing down  $X_i$  as  $N_i$ , and then we get:

$$\frac{N^N}{\prod_i N_i^{N_i}} = \frac{N^{\sum N_i}}{\prod_i N_i^{N_i}} = \frac{\prod_i N^{N_i}}{\prod_i N_i^{N_i}} = \prod_{i=1}^n \left( \frac{N}{N_i} \right)^{N_i}.$$

Returning back to the inequality (5) and equation (2) we get

$$\prod_i \left( \frac{N}{N_i} \right)^{N_i} > \frac{N!}{\prod_i N_i^{N_i}} \text{ thus, } -\prod_i \left( \frac{N_i}{N} \right)^{N_i} > \frac{N!}{\prod_i N_i^{N_i}}. \quad (6)$$

Taking into consideration logarithm operation of inequality (6) and dividing its both parts at number  $N$ , we get:

$$-N \sum_i \frac{N_i}{N} \log_2 \frac{N_i}{N} > \log_2 \frac{N!}{N_1! \dots N_n!} \quad (7)$$

But the right part of the inequality (7) is the number of binary symbols designating the permutation number of sequence of readings (2). Thus, the entropy of the activities of the totality of sources turns out to be the maximal estimate of the number of binary symbols for a group addressing which coincides with the permutation method.

It should be noted that the entropy of the totality sources attains its maximal value at uniform activities of all the system sources, that is at we get

$$H(\alpha) = \log_2 n. \quad (8)$$

#### 4. Description of the Coding Algorithm

The permutation numerical coding algorithm is based on the chain division after the permutation place symbol [10]. The permutation code reflects the state of the activity of the current totality sources [11], and, therefore, the system itself is capable of intelligently taking a decision [12] concerning the current state of the observed object. It was noticed that the power of each subset of permutations is proportional to the ratio of the number of a certain type of symbols to the total number of the sequence positions. At the second step, each subset is divided according to the type of the symbol which occupies the second position in the permutation. The power of a newly formed subset is proportional to the ratio of the number  $N_i = 0$  of a certain  $j$ -type of a symbol to the total number of positions in the sequence at this step (here, it means the ratio to  $(N-1)$  and  $N_i = 0$  it is number of  $j$ -type of a symbol, which occurs from the second to the last position of the permutation). However, if at the second position we have the same  $m$ -type symbol, then the ratio is

$N_m - 1 / (N - 1)$ , because at the second step we still have only  $N_m - 1 / (N - 1)$  symbols of  $m$ -type and  $N_m - 1 / (N - 1)$  total positions, and so on. At a certain  $j$ -th step, a symbol of some  $i$ -th type cannot appear, if its number is already exhausted. Such a procedure permits to provide a definite correspondence between a certain permutation set  $S$  and its number of the natural row  $0 \div (M - 1)$ . It was expected that there would be present a true enumeration coding if the sequence number is formed as follows:

$$K(p) = \sum_{j=1}^N \sum_{i=1}^{X(j-1)} M_j(i), \quad (9)$$

where  $M_j(i)$  is the  $S_j(i)$  subset power value; it should be noted that, both the subset  $S_j(i)$  permutations and the analyzed permutation  $p$  have both  $(j-1)$  identical positions and the  $i$ -type symbol at the  $j$ -th position of permutation.

Therefore, the first  $j$  permutation positions of a subset  $S_j(i)$  are fixed. The number of such permutations defines probable permutations of the rest symbols, wherein,  $[N_m - R_m(j)]$  - is the number of  $m$ -type symbols ( $m = \overline{1, n}; m \neq i$ ) and  $[N_m - R_m(j)] - 1$  - is the number of  $i$ -type symbols; here,  $R_m(j)$  - is the number of  $m$  - type symbols among the first  $(j-1)$  positions of the permutation  $p$ .

Thus, the power of subset  $S_j(i)$  for ( $m \neq i$ )

$$M_j(i) = \frac{(N-j)!}{\prod_{m=1}^n N_m!} \prod_{r=1}^{j-1} [N_{X(r)} - R_{X(r)}(r)] [N_i - R_i(j)] \quad (10)$$

The kernel of the last expression (10) is as follows:

$$D_j = \frac{(N-j)!}{\prod_{m=1}^n N_m!} \prod_{r=1}^{j-1} [N_{X(r)} - R_{X(r)}(r)] \quad (11)$$

We should note that

$$D_1 = \frac{(N-1)!}{\prod_{m=1}^n N_m!} \quad (12)$$

$$D_{j+1} = \frac{D_j}{(N-j)} [N_{X(j)} - R_{X(j)}(j)]$$

then, (9) may be shown as follows:

$$K(p) = \sum_{j=1}^N D_j \left[ \sum_{i=a}^b N_j - C_j \right] \text{ and} \quad (13)$$

$$C_j = \sum_{i=a}^b R_i(j),$$

where  $C_j$  is the quantity of symbols whose number-type is less than the symbol number-type located at the  $j$ -th position of the permutation.

This algorithm can be used if the absolute activities values  $N_i$  are known. Therefore, this is very convenient for the activities distribution reflection. This is the so-called Set Code.

The real appearance of the mapping of non-redundant samples of all sources during observation corresponds to the values  $N_i$  of *a priori* unknown activities during the coding word formation [7]. This is, the so-called Block Number Code.

For this case, it was noticed that each the  $i$ -th position counted from the beginning may be considered as the  $l$ -th position from the end. Thus,

$$l = N - j + 1. \quad (14)$$

The kernel (11) corresponding to the  $i$ -th position from the beginning is the same as for the  $l$ -th position from the end

$$D_j = D_l. \quad (15)$$

The number of  $i$ -type symbols among the last  $l$  positions of a permutation

$$N_i(l) = N_i - R_i(j), \quad (16)$$

Thus, using (14)-(16) in (12)-(13), we get a new algorithm [7]

$$K(p) = \sum_{l=1}^N D_l \sum_{i=a}^b N_i(l) = \sum_{l=1}^N K_l, \quad (17)$$

$$K_l = D_l \sum_{i=a}^b N_i(l),$$

$$D_l = \frac{D_{l-1}(l-1)}{N_{X(l)}(l)}, \quad (18)$$

$$D_1 = 1.$$

The permutation numbers obtained after (13) and (18) should be the same for the same input conditions, but with the opposite order of the appearance of the elements. Algorithm description is as follow:

**Input:**

$N$  – quantity of sequence positions  
 $Ni[]$  – array of type symbols number among the  $N$  sequence positions size of quantity of different values in sequence  
 $X[]$  – set of values to encode size of  $N$

**Output:**

$Kp$  – value of kernel  $K(p)$   
 $R[]$  – array of numbers of  $i$  – type symbols among the permutation  $p$

**Algorithm's initialization:**

$Kp \leftarrow 0$

$D \leftarrow 1$

$R[] \leftarrow \{0\}$

1:  $R[X[1]] \leftarrow R[X[1]] + 1$

Kernel  $p$  value calculation when  $l = 1$

2: **for**  $i=1$  **to**  $X[1]-1$

3: {

4:      $Kp \leftarrow Kp + Ni[i] - R[i]$

5: }

6: **if**  $N > 1$  **then**

7: {

    Comment: Kernel  $p$  value calculation when  $l > 1$

8:     **for**  $l=2$  **to**  $N$

9:     {

10:          $R[X[l]] \leftarrow R[X[l]] + 1$

    Comment:  $D$  assign value of

$$D_l = \frac{D_{l-1}(l-1)}{N_{X(l)}(l)}$$

11:          $D \leftarrow D * (l-1) / (Ni[X[l]] - R[X[l]])$

    Comment:  $Acc$  assign value of

$$\sum_{i=a}^b N_i(l)$$

12:          $Acc \leftarrow 0$

13:         **for**  $i=1$  **to**  $X[l]-1$

14:         {

15:              $Acc \leftarrow Acc + Ni[i] - R[i]$

16:         }

17:          $Kp \leftarrow Kp + D * Acc$

18:     }

19: }

Such service information perfectly corresponds to the information entropy of the object sources [11, 13, 14] and may be used for express analysis of the current state of object. At each step of analyzing of information state of the investigated object the most active sensor is chosen. An output analog signal of anyone sensor is conditioned and the certain address number is given to it. To illustrate analyzing process let us consider some simplified example of sensor network which consists of three sources and analyzing period is equal to six steps (i.e.,  $n=3$ ,  $N=6$ ). Let us suppose we received the activities sequence as follow: 2, 1, 1, 3, 1, 3. That means: the first active sensor has number 2 and the last one – number 3. After formula (18) in this case we obtain as follow:

$$D_1 = 1,$$

$$D_2 = D_1 \cdot 1 / N_{X(2)}(2) = 1 \cdot 1 / 1 = 1,$$

$$D_3 = D_2 \cdot 2 / N_{X(3)}(3) = 1 \cdot 2 / 2 = 1,$$

$$D_4 = D_3 \cdot 3 / N_{X(4)}(4) = 1 \cdot 3 / 1 = 3,$$

$$D_5 = D_4 \cdot 4 / N_{X(5)}(5) = 3 \cdot 4 / 3 = 4,$$

$$D_6 = D_5 \cdot 5 / N_{X(6)}(6) = 4 \cdot 5 / 2 = 10.$$

And the code (group number) corresponded with such situation (17) is following:

$$K(p) = \sum_{l=1}^N D_l \sum_{i=1}^{X(l)-1} N_i(l) = 1 \cdot 0 + 1 \cdot 0 + 1 \cdot 0 + 3(2+1) + 4 \cdot 0 + 10(3+1) = 40$$

It was formed in real time. Another order of addresses causes different group number therefore a set of group numbers describes an object information state density.

## 5. Conclusions

The Set Code reflects the current state of the investigated object, expressed by the activities of the whole totality of sources. It makes the real time automation testing possible. The found algorithm ensures the single-valued unique number reception. This is compressed information on the object state during the analyzing period. It should be noted that in this case, we needn't know the sources statistics before encoding. This permits to use the encoding algorithm in real time. The Set Code is formed simultaneously with the Block Number Code formation.

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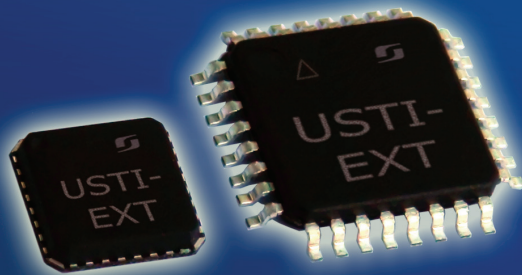
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