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ALGORITHMS FOR COUNTING RATE - CONVENIENT FOR DIGITAL RADIATION MONITORS

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Quasi exponential algorithm and three versions of the linear algorithm are presented and analysed. The response time is the parameter which is used to compare different algorithms. From this comparison follow the conclusions which algorithms are convenient, or inconvenient for stationary and/or portable radiation monitors.

Introduction

The quality of the computer based monitors depends greatly on the applied algorithm for counting rate estimation since the main source of the information are pulses originating from radiation detector. The applied algorithm influences directly the quality of results given by the instrument.

The important qualities for radiation monitors in radiological protection are the response time when the measured quantity varies, instrumental fluctuation due to statistical nature of the monitored phenomena, and the accuracy. The most important is the response time since it directly effects the prompt intervention when the radiation field level is monitored, and the efficient determination of the limits of the contaminated surfaces, when the contamination is surveyed.

Consequently, the response time is the parameter which is used in this paper for analysis and comparison of different algorithms.

Algorithms

In the computer based measuring instruments the results of the measurement are not accomplished by the hardware but through appropriate algorithms built in the software. The algorithm defines the treatments of elementary data received from the hardware, such as the number of registered pulses from the radiation detector, N_i, and measuring time interval, T_i. Obviously the quality of the results depends on the treatment of the data i.e. on the features of the used algorithm. To simplify the analysis the pulse rate as the final numerical result will be discussed. It is interesting to start with an algorithm that performs data treatment in a way analogue to diode pump integrating circuit used in ratemeter RC circuits [1], [2].

Recursive relations (1) represent the data treatment in such algorithms. The k-th part

$$R_n = \frac{1}{T} \cdot \frac{S_{n-1} - \frac{S_{n-1}}{k} + N_n}{k} \quad ; \quad S_n = S_{n-1} - \frac{S_{n-1}}{k} + N_n \; ; \text{ where } S_0 = 0, \; T = c^t \tag{1}$$

$$R_t = \frac{N}{T} \cdot \left[1 - \left(\frac{k}{k-1} \right)^{-t} \right] \tag{2}$$

of the sum S_{n-1} of pulses from previous cycle is subtracted, the new registered pulse number N_i is added and the current result R_n is calculated.

There is an obvious analogy to the integrating RC circuit in a part of this algorithm.

Stair case curves of the actual reading of the measuring instrument with such algorithm, for different k, are shown in Fig.1. The envelope of the actual readings is given as Eq.(2) and this helps the analysis of the performance of the instrument. For a certain k the envelope is exactly exponential. This justifies the name of this algorithm as "quasi exponential".

The following three algorithms are based on the "floating mean value" i.e. the actual

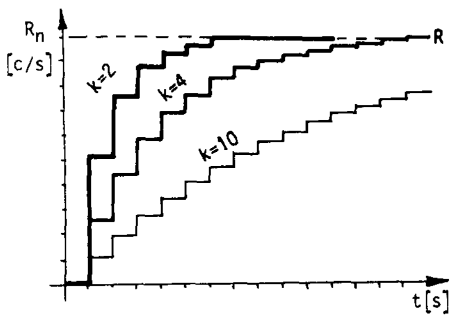

Fig.1 Quasi exponential algorithm

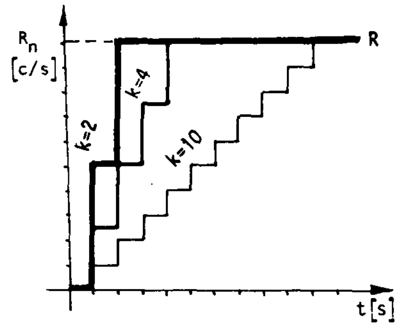

Fig.2 Linear algorithm

reading is formed from k successive measuring results. The floating mean value algorithm is given by Eq.(3). Since in this paper we assume T_i=Const., Equation (3) is simplified to Eq.(4). Both equations provide linear response of the actual reading curve on step change of a measured parameter, except for first k measuring cycles after switch on. Consequently, these algorithms are named "linear algorithms".

$$R_n = \frac{\sum_{n-k+1}^{n} N_i}{\sum_{n-k+1}^{n} T_i} \quad (3) \quad ; \quad R_n = \frac{\sum_{n-k+1}^{n} N_i}{k \cdot T} \quad (4)$$

Stair case curves of the actual reading of the measuring instrument with such algorithms are shown in Fig.2.

This algorithm becomes too slow for a big k, i.e. when the greater accuracy is wanted, what is inconvenient when large changes of measured parameter occur. The extent of change is graduated by standard deviation, σ, of measured parameter. We modify the above linear algorithm and define "step" algorithm where results are obtained in accordance with the following relations:

$$R_n = \frac{\sum_{1}^{n} N_i}{\sum_{1}^{n} T_i}, \text{ for } n \le k \quad (5) \quad ; \quad R_n = \frac{\sum_{n-k+1}^{n} N_i}{\sum_{n-k+1}^{n} T_i} \text{ for } n > k \quad (6)$$

$$\text{If } |R_{pn} - R_{n-1}| > \theta, \ \theta = f(\sigma), \text{ where } R_{pn} = N_n/T_n, \text{ then restart} \quad (7)$$

For small step changes the algorithm provides the linear changes of actual readings. For sufficiently great change of the measured parameter the condition (7) will be satisfied and the reading immediately takes high (or low) value, although less accurate. When the new level is stable enough, the averaging shall take place in the next measuring cycles and the accuracy of the result will be improved.

When the measured parameter is of a statistical nature, what is the case for radiation monitors, the actual readings immediately after a step change may fluctuate significantly and make the perception of result uncertain. To avoid such situations, further modification of a linear algorithm is introduced, and the "damped" step algorithm is obtained. In this algorithm the results are obtained by relations defined in (8), (9) and (10).

$$R_n = \frac{(k-n)N_1 + \sum_1^n N_i}{(k-n)T_1 + \sum_1^n T_i}, \text{ for } n \leq k \quad (8) \qquad R_n = \frac{\sum_{n-k+1}^{n} N_i}{\sum_{n-k+1}^{n} T_i}, \text{ for } n > k \quad (9)$$

$$\text{If } |R_{pn} - R_{n-1}| > \theta, \text{ then restart} \quad (10)$$

The performance of three linear algorithms for enough large step change is shown in Fig.3. The qualities of each algorithm are evident from the Figure. One should remember that for small step changes, i.e. slow changes, the algorithms perform equivalently: follow the step changes linearly.

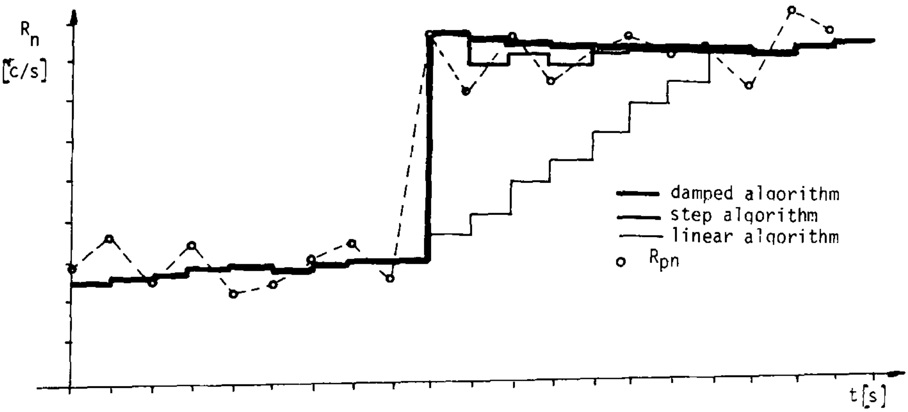

Fig.3. Actual readings with different algorithms when step occurs

For radiation monitors is important to provide fast evidence of rapid changes of measured value. The response times for described algorithms are shown in Table I.

The response times are given for different k and correspond to an arbitrary normalised measuring time T. Quasi exponential algorithm is extremely inconvenient in that respect while step and damped algorithms show significant advantages for any k, and particularly for large step changes.

One may conclude that for portable radiation monitors, where an immediate recognition of fast changes is important feature, and for stationary monitors, where the prompt intervention is desirable, the step and the damped algorithms are obviously preferable. For instruments with visual numerical display, the damped algorithm has an advantage. It should be

Table I

Response time for different algorithms

Algorithm:	"Quasi exponential"			"Linear"	"Step"		"Damped"	
Reached level:	0.99R*	0.999R	~R	R	R		R	
k					step< θ	step> θ	step< θ	step>θ
2	7T	10T	35T					
4	17T	25T	86T	kT	kT	T	kT	T
6	26T	38T	138T					
10	44T	66T	244T					

*R is the real constant rate

noticed that by increasing k the accuracy is increased, but also, response time is increased. The proper choice of k is a compromise between the desired response time and the acceptable accuracy.

Conclusion

For the algorithms discussed here the situation when measuring time is constant is assumed. Algorithms allow variable measuring times and then some new features may appear. The attractive possibility is to shorten the measuring time, when the level of measured parameter increases, with no serious loss in accuracy. This may be the subject of further analysis.

Quasi exponential algorithm, resembling the old technology is not at all justified to be used when computer aided methods are applied. The linear algorithms match better the desired qualities for monitors with computer oriented structures.

In that case, the damped algorithm is very convenient for portable monitors and the step algorithms might be acceptable for stationary monitors where the reading of numerical display is of a minor importance.

The realized instrument with damped algorithm [3] approves the conveniences of such algorithm.

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