OPTIMIZATION OF TROUBLESHOOTING ROUTE IN LARGE ACCELERATORS

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One of the main functions of the large accelerator control system is automation of a troubleshooting process. Following from the assumption that the functional structure of the linear electron accelerator can be presented as a sequence of blocks linked among themselves into a prime oriented chain the comparison of two troubleshooting techniques has been performed. The first technique is a bisection method, which is simple in implementation but not optimum in general case. The second one is a more complex optimum iterative procedure. As a criterion of the method evaluation mean troubleshooting expenditures have been used. Sample results of the efficiency of the two methods for troubleshooting in 50-section linear electron accelerator (LEA) are presented.

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1. TROUBLESHOOTING PROCEDURE

If the LEA output parameters differ from their standard values dissecting diagnostics is needed in order to determine a defective section. On each step of the procedure a presence of a section failure is detected by using one or a few diagnostic techniques (see [1] for an example). The number of steps depends on the search strategy chosen.

LEA functional structure can be presented as a sequence of n blocks α_1, α_2, $\alpha_к$, …, α_m, …, α_n linked among themselves into a prime oriented chain. For ease of following analysis LEA sections are numbered in reverse order. The last output section corresponds to block α_1. In the case of block α_m malfunction a failure signal is detected while controlling any of blocks from α_m to α_1.

The probability of a section malfunction (Pi) and the cost of its checking (a_i) can be obtained as follows: a priori probability of the section malfunction is determined from the annual average frequency of the section malfunction and the value of a_i is determined from the average time of the failure removal (τ_ι):

$$a_i = Co \cdot \tau_\iota ,$$

where Co is the cost of one hour of LEA functioning.

The current value of $P_i(t)$ can be estimated by using automatic procedures of malfunctioning prognostication [4]. Thus, we have to solve the well-known problem of technical diagnostics, i.e., choosing the control route for a continuous object, having in this case a linear structure if $P_i \neq const$ and $a_i \neq const$. A number of methods to solve such problems are developed [2].

Let us compare two troubleshooting techniques: a bisection method, which is simple in implementation but not optimum in general case and a more complex optimum iterative procedure [3]. As a criterion of the method evaluation we use mean troubleshooting expenditures.

2. ITERATIVE PROCEDURE

On the preliminary stage elements of a triangular matrix of minimum mean expenditures A are calculated for a given linear-directed graph $\Gamma(1,N)$, which vertexes are characterized by elements of sets $\{ai\}_n$ and $\{pi\}_n$, respectively. The consequence of arcs (route) in the graph is simple and elementary [5]. The end of each arc coincides with the beginning of the following one. None of the arcs or vertexes is met twice. The calculations are performed for all possible sub-graphs of the main graph starting from the two-vertex sub-graphs by using the following iterative formula:

$$A^{opt.}_{k,k+m} = \min_j \left(a_j + \frac{P_k + P_{k+1} + \ldots + P_{j-1}}{\sum\limits_{i=k}^{k+m} Pi} \cdot A_{k,j-1} + \frac{P_j + P_{j+1} + \ldots + P_{k+m}}{\sum\limits_{i=k}^{k+m} Pi} \cdot A_{j,k+m} \right)$$

$$1 \le k + m \le n;\ 1 \le k \le n;\ k+1 \le j \le k+m.$$

Then the matrix of optimum (by the mean losses minimum) numbers of the first checked blocks for all possible sub-graphs is composed:

$$I^{opt}_{k,k+m} = I_{(\min A_k, k+m)} \cdot$$

On each step of the troubleshooting for a given sub-graph (for a whole graph on the first stage) the corresponding number $j_{k,k+m}$ is chosen from matrix I. After checking the j-th block the sub-graph is divided into two ones, then a sub-graph with a malfunction is determined and a corresponding number is chosen from matrix I. The procedure is repeated until the defect block is found.

3. BISECTION METHOD

On each step the number of checked block is found by using the following formula:

$$j = \text{int}\left[\frac{k + (k + m)}{2}\right].$$

An average cost of the malfunction search in this case is equal to:

$$A^{bis}_{k,k+m} = \sum_{i=k}^{k+m} P_i b_i ,$$

where b_I is the cost of the malfunction search in the *I-th* block by using this algorithm.
b_i is calculated as a sum of a_j. For example, for the linear-directed graph Γ(1,3) b_i will have the following values:

$b_1=a_2+a_1$; $b_2=a_2$; $b_3=a_2+a_3$.

For graph Γ(1,4) .

$b_1=a_2+a_1$; $b_2=a_2$;
$b_3=a_2+a_3$; $b_4=a_2+a_3+a_4$.

and so on.

4. COMPARISON OF EFFICIENCIES OF THE METHODS

To compare the efficiencies of the methods for the troubleshooting in a given system with the structure *Γ(1,N)* we propose to use the ratio of mean troubleshooting expenditures:

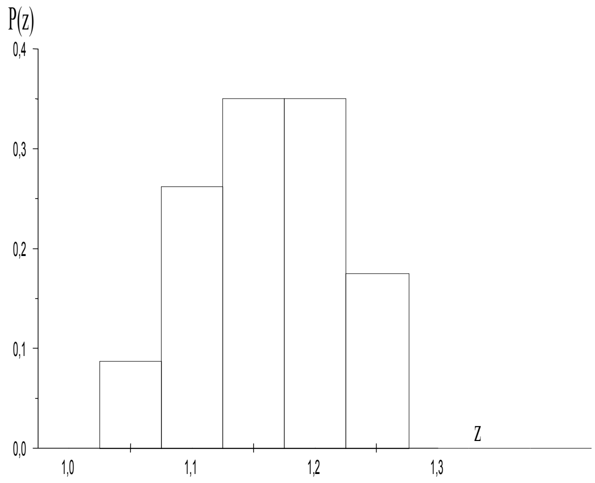
$$Z = \frac{A^{bis}}{A^{opt}}.$$

Varying randomly the values of parameters $\{a\}_n$ and $\{P\}_n$ we obtain the estimation of probability distribution *P(Z)* for a given system. Let us estimate the efficiency of the use of the bisection method and iterative procedure for troubleshooting in 50-section linear electron accelerator. The system is described by the following parameters:

$$\Gamma(1,50),\ 0 < P_I < 1,\ 1 < a_I < 2.$$

The estimation of *P(Z)* obtained by computing of 200 randomly generated variants of values of the elements of sets $\{a\}$, $\{P\}$ is depicted in Fig. This figure shows that for given system parameters on the average the iterative method is 1.2 times more efficient.

The procedure proposed can be used to compare two troubleshooting techniques.



For usage of the described procedure the accelerator control system must have technological possibility for simultaneous measuring of signal parameters at input and output of the checked block. That is why all linear electron accelerators recently developed at the Scientific Research Complex (SRC) "Accelerator" of the National Science Center, Kharkov Institute of Physics and Technology (KIPT) are equipped with multichannel control systems [6]. The measuring devices of these control systems provide receiving the signal from analog to digital converters (ADC) probes with the 50 or 100 nsec discreteness by two or four commutating channels simultaneously.

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