1. Blokh M.D., Magarill L.I. "Theory of photogalvanic effect on free carriers" // PTG, vol. 22, №8, 1980, pp. 2279-2284, (in Russian).
2. Chernyshov N.N. "Theory of transfer phenomena in an electric field for crystals without an inversion centre"// Physical surface engineering, vol. 10, №1, NPTC, Kharkov, 2012, pp. 96-101, (in Russian).
3. Chernyshov N.N. "Photogalvanic effect in crystals without a centre of inversion in view of electron-hole interaction"/All- Ukrainian collected volume // Radiotechnika, № 177, KhNURE, 2014, pp. 94-97, (in Russian).
4. Dember H., "Über einer photoelectromotorische kraft in Kupferoxydul – kristallen" // Phys. Zeit, vol.32, № 14, 1931, pp.554 - 556.
5. Dresselhaus G. "Spin-Orbit Coupling Effects in Zinc Blende Structures" // Phys. Rev., vol. 100, 1955, pp.580-586.
6. Chernyshov N.N., Slipchenko N.I., Tsymbal A.M., Umyarov K.T, Lukianenko V.L. "The photogalvanic effect within spin resonance in quantizing magnetic field" // Physical surface engineering, vol. 11, №4, NPTC, Kharkov, 2013, pp. 427-430.
7. Y.F. Chern, M. Dobrovolska, et al. "Interference of electric-dipole and magnetic-dipole interactions in conduction-electron-spin resonance in InSb" // Phys. Rev. B., vol. 32, 1985, pp. 890-902.

PARALLEL ALGORITHM OF INSCRIBING FIGURES INTO ACCEPTABILITY REGION

Nazarov D.A.
Institute of Automation and Control Processes, Far Eastern Branch of Russian Academy of Scienses, Vladivostok
nazardim@iacp.dvo.ru

Abstract— The problem of analogous system acceptability region analysis for improving system parametric reliability is discussed. Under the term of acceptability region a bounded part of system parameter space containing points which yield proper system performance. A discrete model of acceptability region is considered. The algorithms of inscribing convex symmetrical shapes into acceptability region based on the discrete model are considered. The methods of their parallel implementation are proposed in order to reduce total computation time and optimize CPU usage.

Keywords—reliability; acceptability region; parallel algorithm.

INTRODUCTION

The problem of acceptability region (AR) determination usually arises during engineering system design. In general, AR is a set of points inside system parameters space, where system performances meet their specifications. Exploration of this region allows considering parametric deviation and gradual drift during parameter sizing. This task becomes especially important when designing systems of responsible design, unique technical systems, to which the statistical methods are not applicable [1].

AR configuration is usually unknown, and its determination is associated with computational complexity and high dimension of parameter space. Obtaining AR characteristics allows avoiding multiple system simulations during solving various tasks of AR analysis. A discrete model of AR representation, based on approximation of multidimensional region with a set of elementary hyper-parallelepipeds, defined with regular grid, and multidimensional probing method. This AR representation allows exploring the region interior, and constructing inscribed figures which implement maximum distance from the boundary criteria [2, 3].

The algorithms of AR analysis described in works [2, 3] are sequential. Although AR exploration does not require model simulations, the algorithms are based on enumeration and have an exponential complexity, depending on dimension of parameter space. Application of parallel computations to this task may reduce its solution time even on modern personal workstations splitting the process and distributing it between available processor cores.

In this work, the algorithms of AR analysis are considered and their parallel implementations are proposed. Since the algorithms are based on AR discrete representation, it is reasonable to consider the main idea of this representation first.

ACCEPTABILITY REGION DISCRETE REPRESENTATION

An engineering system model which maps component parameters, given by n-vector (1):

$$\mathbf{x} = (x_1, x_2, ..., x_n), \tag{1}$$

to system performances, described by m-vector (2):

$$\mathbf{y} = (y_1, y_2, ..., y_m), \tag{2}$$

in a form of (3):

$$y_j = y_j(\mathbf{x}), \forall j = 1,2,...,m. \tag{3}$$

Both system parameters (1) and system performances (2) are constrained. System parameters are usually constrained with manufacturer tolerances:

$$x_{i\min} \le x_i \le x_{i\max}, \forall i = 1,2,...,n. \tag{4}$$

System performances are constrained with their specifications:

$$y_{j\min} \le y_j \le y_{j\max}, \forall j = 1,2,...,m. \tag{5}$$

The specifications (5) constitute the criterion of proper system performance. Violation of one of the inequalities (5) is qualified as a failure. Such failures usually occur as a result of system parameter deviation under the influence of both ambient factors (temperature, humidity, radiation) and internal processes of wearing and aging.

Parametric synthesis problem [4] consists in determination of such nominal parameters that provide maximal probability of fail-safe operation during operation time T:

$$\mathbf{x}_{nom} = \arg\max P(y_{j\min} \le y_j(X(\mathbf{x}_{nom}, t)) \le y_{j\max}, \forall j = 1,2,...,m, t \in [0,T]), \tag{6}$$

where $X(\mathbf{x}_{nom}, t)$ is a stochastic process of system parameter variations during operation time T.

The problem of parametric synthesis (6) can be also formulated the following way:

$$\mathbf{x}_{nom} = \arg\max P(X(\mathbf{x}_{nom}, t) \in D_x,\ t \in [0,T]), \tag{7}$$

where D_x is a region inside system parameter space containing points which yield system performances that meet their specifications (5). This region is called Acceptability Region (AR) and defined as follows:

$$D_x = \{\mathbf{x} \in R^n : y_{j\min} \le y_j(\mathbf{x}) \le y_{j\max}, \forall j = 1,2,...,m\}. \tag{8}$$

The replacement of system performances check in (6) with a random parameters vector membership to D_x in (7) allows avoiding multiple system simulations (3) during obtaining various stochastic estimations. Moreover, obtaining AR characteristics offers additional opportunities for geometric exploration of a region of admissible parameter variations and application of deterministic criteria for optimal parameter sizing.

Main challenge in AR characteristics determining consists in parameter space dimension and lack of explicit analytical expressions for the model (3) as far as most of real and enough complicated models are given implicitly in algorithmic form or as a simulation model which calculates outputs for given system parameters.

In this work, the method of AR construction based on approximation of a multidimensional shape with a discrete set of elementary boxes (EB), defined with nodes of a regular grid, and multidimensional probing method inside these EB.

AR is constructed within bounding box *B*, defined with intervals:

$$B = \{ [x_{i\min}, x_{i\max}], \forall i = 1,2,...,n \}. \tag{9}$$

The bounding box can be defined both with tolerances (4) and boundaries of a circumscribed box determined with Monte-Carlo method [4].

Every interval $[x_{i\min}, x_{i\max}], i = 1,2,...,n$ is split into q_i equivalent sub-intervals called quanta. Their intersections define nodes of a multidimensional grid which define EB vertices. Every single EB is identified with a set of *n* indices $(k_1, k_2,..., k_n), k_i = 1,2,..., q_i$. Using these indices, bounding box ranges (9), and quanta amount $q_i, i = 1,2,..., n$, geometric characteristics of corresponding EB can be determined:

$$\begin{aligned} x_{i\min}^{k_i} &= x_{i\min} + h_i \cdot (k_i - 1), \\ x_{i\max}^{k_i} &= x_{i\min}^{k_i} + h_i = x_{i\min} + h_i \cdot k_i \end{aligned}, \tag{10}$$

where $h_i = (x_{i\max} - x_{i\min})/q_i$ is a grid step on *i*-th parameter within bounding box *B*.

In the center of every single EB a representative point is selected:

$$x_r(k_1, k_2,..., k_n) = (\frac{x_{1\min}^{k_1} + x_{1\min}^{k_1}}{2},..., \frac{x_{n\min}^{k_n} + x_{n\min}^{k_n}}{2}), \tag{11}$$

which is used for calculation system performances (2). If system performances $y(x_r(k_1, k_2,..., k_n))$ meet their specifications (5), the EB defined with $(k_1, k_2,..., k_n)$ is assigned weight "1", otherwise weight "0" is assigned. Thus, in order to store all membership indicators, an indicator set is defined:

$$S = (s_1, s_2, ..., s_R), \tag{12}$$

where $R = q_1 \cdot q_2 \cdot ... \cdot q_n$ is total amount of EB used for AR approximation, and $s_p \in \{0,1\}$ is the result of membership function:

$$\chi(k_1, k_2,..., k_n) = \begin{cases} 1, y_{j\min} \le y_j(x_r(k_1, k_2,..., k_n)) \le y_{j\max}, j = 1,2,..., m \\ 0, y_{j\min} > y_j(x_r(k_1, k_2,..., k_n)) \vee y_{j\max} < y_j(x_r(k_1, k_2,..., k_n)) \end{cases}. \tag{13}$$

The index *p* of the element of membership indicator set (12) is mutually relates to indices $(k_1, k_2,..., k_n)$:

$$p(k_1, k_2,..., k_n) = k_1 + q_1 \cdot (k_2 - 1) + q_1 q_2 (k_3 - 1) + ... + q_1 q_2 ... q_{n-1}(k_n - 1). \tag{14}$$

Thus, the model of discrete AR representation can be expressed as:

$$G_R = (n, B, Q, S),, \tag{15}$$

where *n* is parameter space dimension, *B* is bounding box (9), $Q = (q_1, q_2,..., q_n)$ is a vector with quanta amount, *S* is membership indicator set (12). The algorithm of AR construction on the basis of model (15) consists in calculation of every element of indicators set.

Let us denote EB as $g_{k_1,k_2,...k_n}$, and their set as $G = \{g_{k_1,k_2,...k_n}, k = 1,2,...,q_i, i = 1,2,...,n\}$. Then the membership function (13) defines the separation of set G:

$$G = G^+ \cup G^-, G^+ \cap G^- = \varnothing,, \quad (16)$$

where $G^+ = \{g_{k_1,k_2,...k_n} : s_{p(k_1,k_2,...k_n)} = 1\}$, $G^- = \{g_{k_1,k_2,...k_n} : s_{p(k_1,k_2,...k_n)} = 0\}$. Set G^+ represents AR discrete approximation inside system parameter space.

Utilization of AR data reduces to obtaining required EB indices $(k_1, k_2,..., k_n)$, calculation of corresponding membership set index (14) and checking membership indicator value. Such AR representation allows to perform EB enumeration, explore geometrical characteristics of the region, for example, finding the most distant from AR boundary point [2, 3]. The illustration of discrete AR approximation on the basis of the model (15) in 2-dimensional space is given in Figure 1.

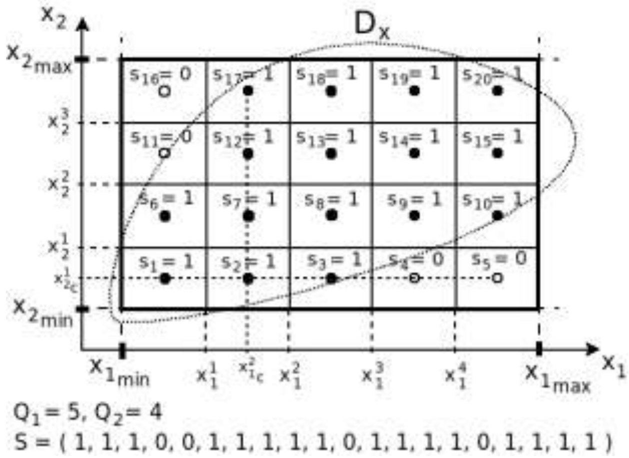

Fig.1 Acceptability Region discrete approximation

PARALLEL ALGORITHM OF INSCRIBING FIGURES INTO ACCEPTABILITY REGION

In works [2, 3] the algorithm of inscribing a cube of maximal volume as a criterion of optimal parameters sizing in the case of lack of information on parameter variations was described. The algorithm consists in enumeration of EB from G^+ with attempts to construct a convex shape laying inside AR which has a center in this EB. This shape consists of EB. According to the method of shape construction and element indexing, the most suitable shapes offered are *r*-cube and *r*-neighborhood which can be considered as multidimensional Moore neighborhood and von Neumann neighborhood respectively [5].

Let us denote shape with central element $g_{k_1,k_2,...k_n}$ and half-width $r \in N$ as $G_r(k_1, k_2,..., k_n) \in G$. Then *r*-cube consists of EB whose indices satisfy (17):

$$G_r^c(k_1, k_2,..., k_n) = \{g_{l_1,l_2,...l_n} \in G : k_i - r \le l_i \le k_i + r, r < k_i \le q_i, i = 1,2,...,n\}, \quad (17)$$

and *r*-neighborhood consists of EB which satisfy (18):

$$G_r^d(k_1, k_2,..., k_n) = \{g_{l_1,l_2,...l_n} \in G : \sum_{i=1}^{n} |l_i - k_i| \le r\}. \quad (18)$$

The examples of these shapes in 2-dimensional parameter space are illustrated in Figure 2.

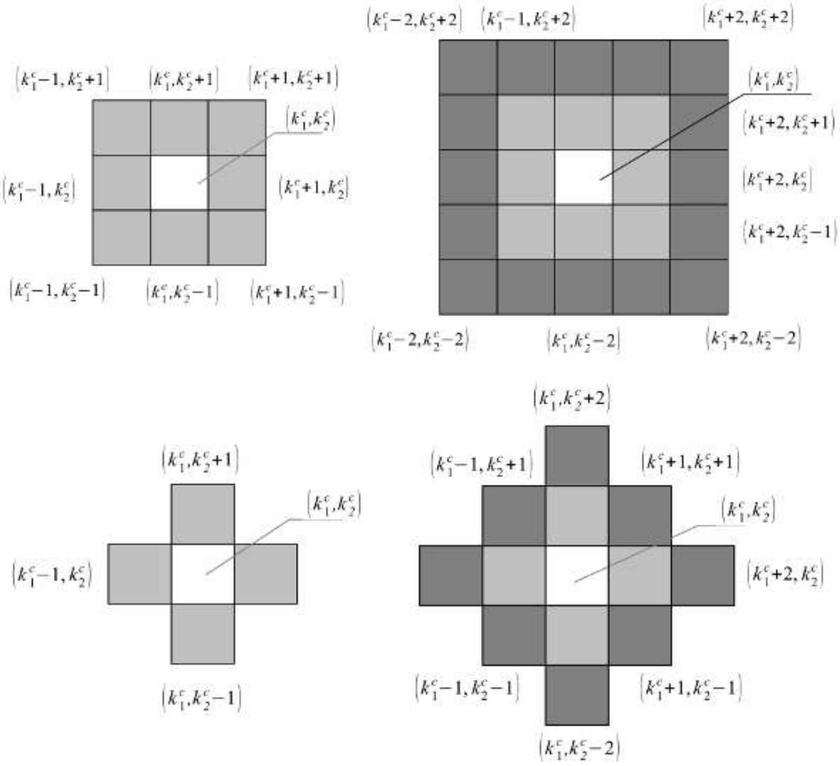

Fig.2 2-dimensional *r*-cube (above), and *r*-neighborhood (below).

A shape G_r (G_r^c or G_r^d) is inscribed into AR, when it consists from EB from G^+ only, or, according to (16), it does not contain any EB from G^-:

$$G_r \cap G^- = \varnothing. \tag{19}$$

The algorithm of inscribing convex shape consists in enumeration of EB $g_{k_1,k_2,\dots k_n} \in G^+$. Every single element is considered as a center of the shape. The following procedure is performed for this EB:

ALGORITHM I. INSCRIBING MAXIMAL SHAPE

1. Initial parameter if shape half-width is set $r=1$;
2. Enumeration of EB from G_r (according to (17) or (18)) is performed;
3. Check membership of the EB to G^+ (or enumeration until first EB from G^- is found);
4. If all EB of G_r belong to G^+, increase $r=r+1$ and go to step 2;
5. If $r>2$, assign current EB $g_{k_1,k_2,\dots k_n}$ a weight $r-1$;

As the result of the Algorithm 1, all the EB from G^+ are assigned weights which reflect the size of a shape that can be inscribed into AR with the center in this EB as a measure of minimal distance to AR boundary [2, 3].

As was shown before, the Algorithm 2 is performed sequentially on whole membership indicator set (12). Every element $s_p \in S$ is used in attempt to construction of inscribed into AR maximal shape, which consists of multiple checks of another EB membership. The decomposition of this algorithm is offered to perform on a set of membership indicators.

Decomposition of the algorithm consists in splitting of the set *S* into *K* non-overlapping intervals:

$$P_s = \{(p_1^1, p_2^1), (p_1^2, p_2^2), ..., (p_1^K, p_2^K)\}, \quad (20)$$

so:

$$S = \bigcup_{i=1}^{K} \{s_{p_1^i}, ..., s_{p_2^i}\}. \quad (21)$$

Every *i*-th parallel process performs Algorithm 1 on the interval (p_1^i, p_2^i). It is reasonable to note that in Algorithm 1, the outer loop enumerates EB from G^+ but actually the enumeration is performed on whole set of EB G with their membership check. A block diagram of a single parallel process of constructing an inscribed convex shape is illustrated in Figure 3.

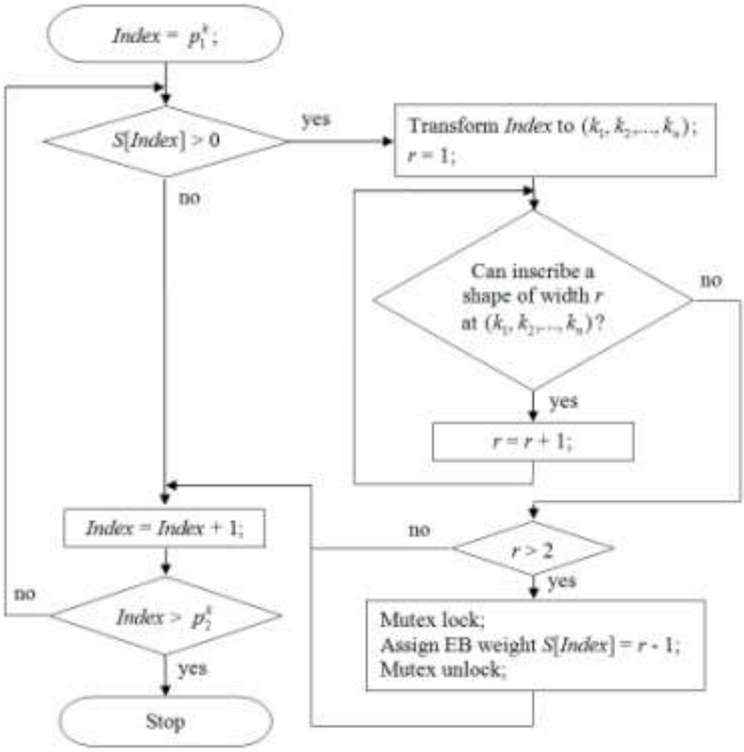

Fig.3 Parallel process of inscribing convex shape into Acceptability Region

The results of the experiment on inscribing *r*-cube into AR of voltage divider (4 parameters) on workstation with 2-core and 4-core CPU are shown respectively in Table 1 and Table 2.

TABLE I. PARALLEL ALGORITHM PERFORMANCE ON 2 CORES

Quanta	1 Process, sec	2 Processes, sec	Speedup
40	5.5	3.5	1.57
60	58	44	1.31
80	495	412	1.2
100	3233	2852	1.13

TABLE II. PARALLEL ALGORITHM PERFORMANCE ON 4 CORES

Quanta	1 Process, sec	2 Processes,	Speedup

		sec	
40	2	1	2
60	23	11	2.09
80	199	120	1.65
100	1356	835	1.62

CONCLUSION

Using AR for analysis of admissible system parameter variations allows avoiding multiple system simulations. It significantly reduces computational efforts during solving various tasks of AR exploration. Nevertheless, several task which require AR information have enumeration type, and, according to high dimension of parameter space, they may consume significant CPU resources. In order to improve the algorithm and effectively use modern multi-core CPU resources, the method of the algorithm of inscribing convex symmetrical shapes into AR decomposition is proposed. Parallel processes of the algorithm do not perform autonomously because interact with shared object – a membership indicator set. The results of experiments displayed reducing of total time for solving the problem.

REFERENCES

1. O. Abramov, B. Dimitrov, Reliability design in gradual failures: a functional-parametric approach // Reliability: Theory&Applications. 2017. Vol. 12. No. 4(47). Pp. 39 – 48.
2. O.V. Abramov, D.A. Nazarov, Regions of Acceptability in Reliability Design // Reliability: Theory & Applications. 2012. Vol. 7. No 3(26). Pp. 43 – 49.
3. Y. Katueva, D. Nazarov, The methods of parametric synthesis on the basis of acceptability region discrete approximation // Applied Mathematics in Engineering and Reliability: Proceedings of the 1st International Conference on Applied Mathematics in Engineering and Reliability (Ho Chi Minh City, Vietnam, 4-6 May 2016). Pp. 187 – 192. DOI:10.1201/b21348-31.
4. Abramov O.V., Katueva Y.V. and Nazarov D.A. Reliability-Directed Distributed Computer-Aided Design System // Proc. of the IEEE International Conference on Industrial Engineering and Engineering Management, Singapore, 2007. Pp. 1171 – 1175. DOI: 10.1109/IEEM.2007.4419376
5. Schiff J.L. "Cellular automata: a discrete view of the world". A John Wiley & Sons Inc. Publication. University of Auckland. 2008.

HARDWARE-SOFTWARE APPROACH FOR CONTROL OF COMPUTER NETWORKS

Nekrasov H.A., Romanova I.I.
National Research University Higher School of Economics
+7 (968) 937-35-05, alax27@mail.ru

Abstract— The article is devoted to the research of the approaches to solving the problems of computer networks diagnostics and control. The main problem faced by the administrators is the congestion in the computer network, arising from the impossibility of the network devices to work out the volume of incoming requests to it. Errors in the operation of protocols lead to problems of interaction between devices with each other. To do this, it is necessary to organize the collection and analysis of a variety of statistics in existing networks on various parameters with the help of software.