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Quality Level Linear Models Electronic Systems

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Introduction

Reliability and efficiency of electronics systems (ES) are described in [1–6].

The continuous operational control main probabilities characteristics modeling techniques for multilevel electronics systems is analyzed in [1–3]. These are useful when separate independent parameters defect level probabilities distributions are set (known) for chosen (selected) control schematics place. Denied electronics systems streams goes back to production process for regeneration and electronics systems classification rules in different control levels are similar, when electronics system classification first and second type errors are not denied by different parameters (good is denied or bad is accepted as good). Offered to use approximated models instead of exact whole electronics system defect level probabilities density transformed models because of complicated process of integration.

Models of control quality are described in [4, 5]. Here a method is offered for synthesis of stochastic distributions of defectivity levels of multiparametric ES with interindependent parameters. This synthesis can be performed in groups of parameters or for entire product according to known distributions of defectivity levels of separate parameters. For practical applications it is advisable to differentiate average defectivity levels of separate parameters according to selected defectivity level of entire product, when ratio between defectivity levels in separate groups is selected or according to needed dispersion of parameters (selected variation coefficient).

Initial models

Multiparameter ES product defect level nonlinear transformation models in continuous quality control, evaluating separate parameter and the whole product probability characteristics also first and second type errors, when products are classified, described in [1,6]. Electronic systems [ES] quality level probabilistic models, expressed by separate parameters probabilistic characteristics, when defect levels by separate parameters are characterized using beta densities.

Electronic tool quality level directly transformed probabilistic characteristics models from separate parameters probabilistic characteristics transformations and controlled parameters nomenclature variation are described in [1]. When ES are repaired immediately after control operation and returned for repeated control with localized repair operation [2] for fixed second type classification errors by different parameters. For analysis needs we will use defect ES probabilities by i-th parameter θi and good product probabilities $\eta i=1-\theta i$ characteristic models [2] repeatedly, when θi~Be(bi, ai), ηi~Be(bi, ai) – beta laws with parameters ai, bi:

- averages

$$\mathrm{E}\theta_i = \mu_i = \frac{a_i}{a_i + b_i}, \ \mathrm{E}\eta_i = 1 - \mu_i = \overline{\mu}_i, \quad (1)$$

- dispersions

$$\mathrm{V}\theta_i = \sigma_i^2 = \frac{\mu_i \overline{\mu}_i}{a_i + b_i + 1} = \mathrm{V}\eta_i, \quad (2)$$

- densities:

$$g_i(\theta_i) = B^{-1}(a_i, b_i)\theta_i^{a_i - 1}(1-\theta_i)^{b_i - 1}, \quad (3)$$

$$\varphi_i(\eta_i) = g_i(1-\eta_i), \quad (4)$$

when $B(a_i, b_i) = \frac{\Gamma(a_i)\Gamma(b_i)}{\Gamma(a_i + b_i)}$ – beta function, $\Gamma(z)$ – gama function.

For all l – electronic tool parameter

$$\eta = \prod_{i=1}^{\ell} \eta_i, \ \theta = 1 - \eta, E_n = \overline{\mu} = \prod_{i=1}^{\ell} \overline{\mu}_i, \mathrm{E}\theta = \mu = 1 - \overline{\mu}. \quad (5)$$

Dispersion by two parameters (i=1, 2)

$$\mathrm{V}\theta_{12} = \sigma_{12}^2 = \sigma_1^2 \overline{\mu}_2^2 + \sigma_2^2 \overline{\mu}_1^2 + \sigma_1^2 \sigma_2^2. \quad (6)$$

Common linear transformation models

Analyzing defect level θ_i linear transformation to defect level τ_i (Fig. 1). Single-stage control K with localized repair operation R is characterized by second type error probability β_{Ri} – in operation R [1–3].

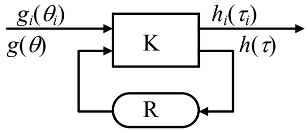

Fig. 1. Single-stage continuous control schematic

If β_{Ri}=const. exists and ES repeats ("spins") through these operations, until all are recognized as good (first type errors probability α_i=0), then both operations K and R are characterized in generalized probability β_{0i} [1, 2]

$$\beta_{0i} = \frac{\beta_i}{1-\beta_{R_i}(1-\beta_i)}, \quad i = 1-\ell . \tag{7}$$

If control system is made of k serial stages, then for all system by i-th parameter we get (when every stage is characterized $\beta_{0i}(j)$)

$$\beta_{0i} = \prod_{j=1}^{k} \beta_{0i}(j), \quad j = 1-k . \tag{8}$$

After control K defected ES probability τ_i and good ES probability ζ_i=1−τ_i by i-th parameter are equal [16]

$$\tau_i \beta_{0i}\theta_i , \zeta_i = \bar{\beta}_i + \beta_{0i}\eta_i , \bar{\beta}_i = 1-\beta_{0i} . \tag{9}$$

Averages and dispersions are:

$$\begin{cases} \mathrm{E}\tau_i = \mu_{\tau_i} = \beta_{0i}\mu_i , \ \mathrm{E}\zeta_i = \bar{\mu}_{\tau_i} = 1-\mu_{\tau_i} , \\ \mathrm{V}\tau_i = \mathrm{V}\zeta_i = \sigma^2_{\tau_i} = \beta^2_{\tau_i}\sigma^2_i . \end{cases} \tag{10}$$

Beta densities $g_i(\theta_i), \varphi_i(\eta_i)$ after control by [1] transforming to generalized beta densities $h_i(\tau_i)$ and $\dot{\varphi}_i(\zeta_i)$ with τ_i, ζ_i variation interval $\tau_i \in (0, \beta_{0i})$ and $\zeta_i \in (\bar{\beta}_i ,1)$:

$$\begin{cases} h_i(\tau_i) = \dfrac{B^{-1}(a_i, b_i)}{\beta_{0i}^{a_i+b_i-1}} \tau_i^{a_i-1}(\beta_{0i}-\tau_i)^{b_i-1}, \ \tau_i \in (0, \beta_{0i}), \\ \dot{\varphi}_i(\zeta_i) = \dfrac{B^{-1}(a_i, b_i)}{\beta_{0i}^{a_i+b_i-1}} (1-\zeta_i)^{a_i-1}(\zeta_i - \bar{\beta}_i)^{b_i-1} \zeta_i \in (\bar{\beta}_i, 1). \end{cases} \tag{11}$$

For all ES probabilities τ and ζ general digital characteristics after control process are

$$\mathrm{E}\zeta = \prod_{i=1}^{\ell} \bar{\mu}_{\tau_i} = \bar{\mu}_\tau , \mathrm{E}\tau = \mu_\tau = 1-\bar{\mu}_\tau . \tag{12}$$

By two parameters (i=1, 2)

$$\mathrm{V}\tau_{12} = \mathrm{V}\zeta_{12} = \sigma^2_{\tau_{12}} = \sigma^2_{\tau_1}\bar{\mu}^2_{\tau_2} + \sigma^2_{\tau_2}\bar{\mu}^2_{\tau_1} + \sigma^2_{\tau_1}\sigma^2_{\tau_2} . \tag{13}$$

Later σ^2_τ is found analogically (connecting) like σ^2. If j-th parameter during control process, $j \in (1-\ell)$, is not checked, then β_{0j}=1 and $\tau_j \equiv \theta_j$, $h_j(\tau_j) \equiv g_j(\theta_j)$. Stochastic value τ, ζ distribution functions $H(\tau)$, $\dot{\Phi}(\zeta)$ and densities $h(\tau)$, $\dot{\varphi}(\zeta)$ are analyzed farther.

Functions $\dot{\Phi}(\zeta)$ are expressed using two-dimensional defined integrals

$$I = I(y_{0i}, y_{1i}) = \int_{y_{01}}^{y_{11}} \int_{y_{02}}^{y_{12}} \dot{\varphi}_1(\zeta_1)\dot{\varphi}_2(\zeta_2) d\zeta_2 d\zeta_1 , i = 1, 2 \tag{14}$$

Densities $\dot{\varphi}(\zeta)$ are expressed using single-dimensional integral

$$I^* = I^*(y_{01}, y_{11}) = \int_{y_{01}}^{y_{11}} \frac{1}{\zeta_1} \dot{\varphi}_1(\zeta_1)\dot{\varphi}_2\left(\frac{\zeta}{\zeta_1}\right) d\zeta_1 . \tag{15}$$

Transformed densities approximations

In the same nonlinear transformation case [1], densities $h(\tau)$ are more useful to approximate more simple models for engineering analysis. Using single-parameter model [2], we use generalized beta density $h_\sigma(\tau)$

$$h_\sigma(\tau) = \frac{B^{-1}(a^*, b^*)}{\beta_0^{a^*+b^*-1}} \tau^{a^*-1}(\beta_0-\tau)^{b^*-1} , \tau \in (0, \beta_0) , \tag{16}$$

here

$$a^* = \frac{\mu_\tau}{\beta_0}\left[\frac{\mu_\tau(\beta_0-\mu_\tau)}{\beta^2_\tau} - 1\right], b^* = \left(\frac{\beta_0}{\mu_\tau} - 1\right) a^* \tag{17}$$

and mode

$$\tau_M = \beta_0 \frac{a^*-1}{a^*+b^*-2} . \tag{18}$$

With maximum $h_{M\sigma}$=$h_\sigma(\tau_M)$ valid formulas

$$\tau_\tau = \beta_0 \frac{a^*}{a^*+b^*} , \sigma^2_\tau = \beta_0 = \frac{\mu_\tau \cdot b^*}{(a^*+b^*)(a^*+b^*+1)} . \tag{19}$$

Distribution function $H_\sigma(\tau)$ found using programmed methods.

In partial case, when one of the parameters is not checked, $h_\sigma(\tau)$ becomes beta density, because $\tau \in (0,1)$.

Mathematical realizations, ℓ=2. 1=b_i=2.

β_{01}=1/4, β_{02}=1/2, β_0=5/8=0,625:

$\mu_{\tau_1} = 1/8$, $\mu_{\tau_2} = 1/4$, $\sigma^2_{\tau_1} = 1/192$, $\sigma^2_{\tau_2} = 1/48$,

$\mu_\tau = 11/32 = 0{,}3438$, $\sigma^2_\tau = 0{,}019$,

$a^* = 2{,}250$, $b^* = 1{,}841$.

$$h(\tau) = 8\begin{cases} \ln(1-\tau)^{-1}, \tau \in (0, 1/4), \\ \ln 4/3 = 2{,}302 , \ \tau \in (1/4, \ 1/2), \\ \ln\left[\frac{8}{3}(1-\tau)\right], \ \tau \in (1/2, \ 5/8), \end{cases} \tag{20}$$

$$h_\sigma(\tau) = 26{,}95\,\tau^{1{,}25}\left(\frac{5}{8}-\tau\right)^{0{,}841}, \tau \in (0, 5/8),$$

$\tau_{M\sigma} = 0{,}374$, $h_{M\sigma} = 2{,}465$,

$\beta_{02}=1$, $\beta_{01}=1/4$, $\tau \in (0,1)$,

$\mu_{\tau_2} = \mu_2 = 1/2$, $\sigma^2_{\tau_2} = \sigma^2_2 = 1/12$, $\mu_\tau = 0{,}5625$,

$\sigma^2_\tau = 0{,}06554$, $a^* = 1{,}55$, $b^* = 1{,}205$.

$$h(\tau/\beta_{02}=1) = 4\begin{cases} \ln(1-\tau)^{-1}, \tau \in (0,1/4), \\ \ln 4/3 = 1{,}151,\ \tau \in (1/4,1), \end{cases} \quad (21)$$

$h_\sigma(\tau/\beta_{02}=1) = \tau^{0{,}55}(1-\tau)^{0{,}205}, \tau \in (0,1)$,

$\tau_{M\sigma} = 0{,}733$, $h_{M\sigma} = 1{,}276$.

Density values for both cases are shown in Table 1 and densities are graphically shown in Fig. 2 and Fig. 3.

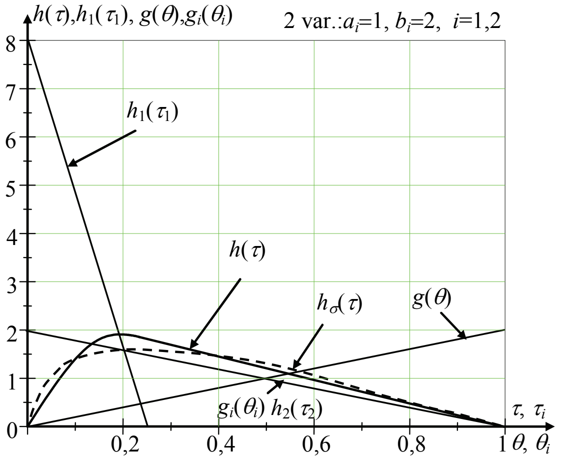

Fig. 2. Two parameters, $\beta_{02}=1$. Densities, when $\beta_{01}=1/4$

Multiparameter electronic systems

Multiparameter ES is characterized when $l \geq 3$ and accidental values ζ and τ are described analogically [16], when β_{0i} varies in interval.

Multiparameter ES is characterized when $l \geq 3$, and

$$\zeta \in (\overline{\beta}_0, 1), \tau \in (0, \beta_0), \quad (22)$$

here $\overline{\beta}_0 = \overline{\beta}_1\overline{\beta}_2, \beta_0 = 1-\overline{\beta}_0, \overline{\beta}_i = 1-\beta_{0i}, i=1,2,3.$

In this case

$$\overline{\beta}_0 = \prod_{i=1}^{3}\overline{\beta}_i, \beta_0 = 1-\overline{\beta}_0, \overline{\beta}_i = 1-\beta_{01}, i=1,2,3. \quad (23)$$

Mathematical realizations (l+3), when

$\beta_{03} = 1$, $\beta_{01} = \beta_{02} = 3/8$; $\tau \in (0,1)$,

$\mu_{\tau_i} = 3/16, i=1,2; \mu_{\tau_3} = 1/2, \mu_\tau = 0{,}67; \sigma^2_{\tau_i}\ 3/256, i=1,2,$

$\sigma^2_{\tau_3} = 1/12$, $\sigma^2_\tau = 0{,}04152$; $a^* \approx 2{,}9$, $b^* = 1{,}45$,

$$h(\tau/\overline{\beta}_3=0) = \frac{32}{9}\begin{cases} \ln^2(1-\tau), \tau \in (0,3/8), \\ \ln^2(1-\tau) - 2\ln^2 1{,}6(1-\tau),\ \tau \in (3/8, 39/64), \\ 2\ln^2 0{,}625 = 1{,}571,\ \tau \in (39/64, 1); 39/64 \approx 0{,}61, \end{cases} \quad (24)$$

$h_\sigma(\tau/\overline{\beta}_3=0) = 5{,}852\tau^{1{,}9}(1-\tau)^{0{,}45}$, $\tau \in (0{,}01)$,

$\tau_{M\sigma} = 0{,}808, h_{M\sigma} = 1{,}857$.

Density values are shown in Table 2 and densities are graphically shown in Fig. 3.

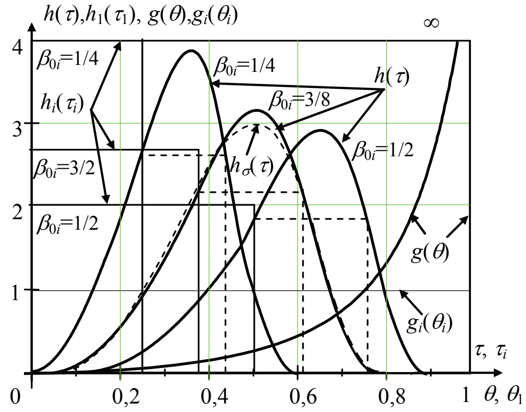

Fig. 3. Three parameters, i=1,2,3. Densities $a_i=b_i=1$, $\beta_{01}=\beta_{02}=\beta_{03}$

Density values are in table 3, densities – Fig. 1 /$h_i(\tau_i)$ models – by (5).

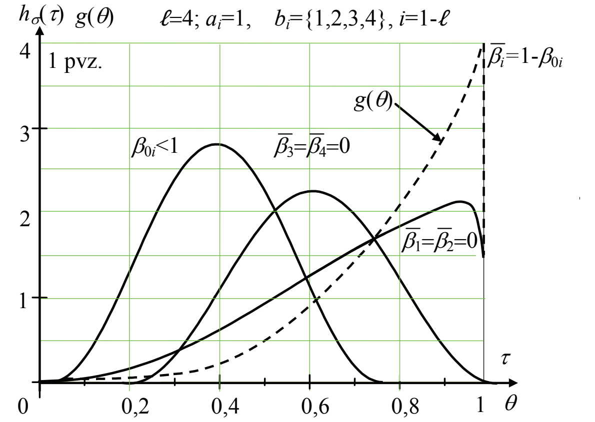

Fig. 4. Densities when, β_{0i}={1/2,1/3,1/4,1/5}<1; $\beta_{03}=\beta_{04}=1$; $\beta_{03}=\beta_{04}=1$

Table 1. Densities: ℓ=2

Var.	β_{0i}	Density values							
1	$\beta_{01}=1/4$	τ	0,05	0,15	0,25	0,375	0,45	0,5	0,55	0,6
	$\beta_{02}=1/2$	$h(\tau)$	1,398	2,966	2,853	1,647	0,923	1,441	0,106	0,004
		$h_\sigma(\tau)$	1,429	2,937	2,873	1,666	0,855	0,424	0,136	0,011
2	$\beta_{02}=1$	τ	0,05	0,1	0,2	0,25	0,5	0,7	0,9	1
	$\beta_{01}=1/4$	$h(\tau)$	0,719	1,269	1,825	1,809	1,206	0,724	0,241	0
		$h_\sigma(\tau)$	0,960	1,277	1,555	1,597	1,304	0,765	0,190	0

Table 2. ℓ=3, density values, when $a_i=b_i=1$

1 var.: β_{0i}=3/8, i=1,2,3										
τ	0,05	0,15	0,25	0,375	0,438	0,5	0,609	0,7	0,75	0,756
$h(\tau)$	0,025	0,250	0,785	2,095	2,823	3,139	2,095	0,403	0,005	0
$h_\sigma(\tau)$	0,004	0,185	0,866	2,230	2,776	2,962	2,056	0,515	0,008	0

Table 3. ℓ=4, density values

a_i=1, b_i={1,2,3,4}, i=1-ℓ; β_{0i}={1/2, 1/3, 1/4, 1/5}<1										
β_{0i}<1	τ	0,05	0,1	0,15	0,2	0,3	0,4	0,5	0,6	0,7
	$h_\sigma(\tau)$	0,034	0,224	0,611	1,147	2,258	2,747	2,258	1,147	0,224
$\beta_{03}=\beta_{04}$=1	τ	0,1	0,2	0,3	0,4	0,5	0,7	0,8	0,9	0,99
	$h_\sigma(\tau)$	0,011	0,137	0,507	1,121	1,791	2,099	1,396	0,447	0,003
$\beta_{01}=\beta_{02}$=1	$h_\sigma(\tau)$	0,085	0,243	0,447	0,685	0,948	1,520	1,803	2,036	1,942

Conclusions

Linear transformed defect levels densities by different parameters are more simple than in case of linear transformation, but for all ES especially when parameters are increasing, it becomes more complicated because of integral intervals disjunction to separate intervals where density models become different.

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Continuous control main probability characteristic modeling methods for ES has been made, when separate independent device parameters defect level probabilistic distributions are “a priori” known. Defected devices flow in control operation is targeted to localized repair operation in this stage, then ES with second type errors goes again into control and “rotates” until all devices are accepted as good. Second type classification errors probabilities in control and repair operations are described by one generalized error model, which is used in linear defect level transformation by different parameters. For all defect level transformation, defect levels densities by different parameters combination, is used referencing by transformation model. It is offered to use approximated models instead of exact whole ES defect level probabilistic density by different parameters, described by beta law density. This method simplifies modeling procedure, without decreasing engineering analysis accuracy. Ill. 4, bibl. 6, tabl. 3 (in English; abstracts in English and Lithuanian).

D. Eidukas. Elektroninių sistemų kokybės lygio tiesiniai modeliai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 3(119). – P. 57–60.

Sudaryta metodika daugiaparametrinių mechatroninių gaminių ištisinės kontrolės pagrindinių tikimybių charakteristikoms modeliuoti, kai atskirų nepriklausomų gaminio parametrų defektingumo lygių tikimybiniai skirstiniai yra aprioriškai žinomi. Kontrolės operacijoje išbrauktų gaminių srautas nukreipiamas į šio etapo lokalizuotą remonto operaciją, po kurios gaminiai su antros rūšies klaida vėl grąžinami kontrolei atlikti ir tai kartojasi tol, kol visi gaminiai pripažįstami gerais. Antros rūšies klasifikavimo klaidų tikimybės (defektų turintis gaminys pripažįstamas geru) kontrolės ir remonto operacijose aprašomas vienu apibendrintos klaidos modeliu, kuris taikomas tiesinei defektingumo lygių transformacijai pagal atskirus parametrus. Viso gaminio defektingumo lygio transformacijai taikomas defektingumo lygių tankių pagal atskirus parametrus sujungimas, remiantis transformacijos modeliu. Pasiūlyta vietoj tikslių viso gaminio defektingumo lygio tikimybių tankio transformuotų modelių taikyti aproksimuotus modelius, aprašomus apibendrinto beta dėsnio tankiu, nes tai vientisas modelis, o tikslus defektingumo lygio tankis išreiškiamas keliolika skirtingų modelių kiekviename integravimo rėžių daliniame intervale. Tai gerokai supaprastina modeliavimo procedūrą, bet nesumažina inžinerinės analizės rezultatų tikslumo. Il. 4, bibl. 6, lent. 3 (anglų kalba; santraukos anglų ir lietuvių k.).