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# Efficiency of Majoritarian Systems in Biotronics Networks

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## Introduction

Biological objects (BO) operate under influence of many external factors. Therefore their features are mostly the result of integral impact of these factors. It is difficult to measure directly values of most of these features, and measurement results are often not sufficiently reliable. Thus when forming decisions, it falls to use direct and indirect indexes (their values) at the same time, integrate estimates and to obtain one the most compelling. For this reason majoritarian redundancy measures are needed in many areas of networks of biotronics systems (BTS). Although the fundamentals of these measures are researched quite well, many unsolved problems emerge when creating stochastic systems and when implementing heuristic control in them. Let's examine them.

## Majoritarian evaluation of electronic systems (ES) efficiency

Despite all efforts, typical ES efficiency assurance measures (in order to increase reliability of devices and processes inside them, to improve control functions, etc.) are not sufficient in most cases. It falls to apply methods of structural, logical reliability improvement, to create heuristic control methods of stochastic systems, to use majoritarian decision formation principles (Fig. 1). Each of transmission systems could be characterized [1] by probability P(t).

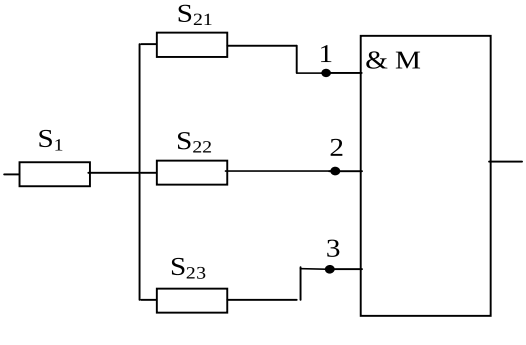


**Fig. 1.** Diagram of majoritarian redundancy

When properly controlling majoritarian structures, number of their components, reliability and operation algorithms of majoritarian device, the rational efficiency of their operation may be obtained. One of the main advantages of these systems is that when informativeness of separate sources is insufficient and when gathering data (often indirect one) from several different locations, processing and linking it, it is possible to obtain efficient decisions and control their level of efficiency.
Majoritarian device (&M) [2] is a logical device, which has uneven number of inputs *m=2k+1 (here k= 1, 2 ,3...)* and one output. Further we will refer to the redundancy using &M simply as majoritarian redundancy.

Digital signals «0» and «1» from the output $S_1$ of the digital system in the form of symbol sequence is transmitted into three simultaneously operating inputs ($S_{21}$, $S_{22}$ and $S_{23}$) which also form a redundant node in ES. Digital signals from outputs $S_{21}$, $S_{22}$ and $S_{23}$ are fed to respective inputs of &M (in this case it has three inputs, i.e. m=3**).** If each $S_{21}$, $S_{22}$ and $S_{23}$ is operative and uncorrupted, then at that time one and only binary symbol (0, or 1) will be found at their outputs, and that means, that the same symbol will be present at the inputs of &M. Also the digital signal of the same value will be present at the output of &M. If at least one of ES ($S_{21}$, $S_{22}$ and $S_{23}$) fails, then only binary symbol values of two &M inputs will be equal at the same moment of time. Binary symbol will be present at the output of &M and its value will match the values of outputs of two operative systems. &M will perform logical operation on the basis of so called "majority of values". Structural diagram of majoritarian element with 3 inputs is presented in Fig. 2; from this diagram its operation principle becomes obvious and is based on logical function:

$$Y = (x_1 \cap x_2) \cup (x_2 \cap x_3) \cup (x_1 \cap x_3) . \quad (1)$$

Let's find dependence of task accomplishment probability $P_M(t)$ of ES with majoritarian redundancy on no-failure probabilities P(t) of redundant systems and of system under redundancy. At first let's analyze example of earlier presented (in time *t*) device (with three inputs) (Fig. 2). Assume that the &M itself is absolutely reliable.

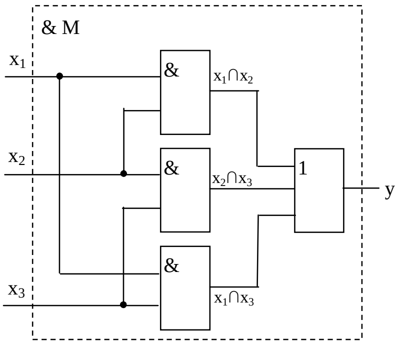


**Fig. 2.** Diagram of &M

The device will operate if its state is one of two described below:

First state. $S_{21}$, $S_{22}$ and $S_{23}$ are operating. Probability of such state:

$$P_1(t) = P^3(t)\,. \quad (2)$$

Second state. Any two ES are operating. Probability of such state:

$$P_2(t) = 3P^2(t)[1 - P(t)]\,. \quad (3)$$

In all other states ES will not be capable of carrying out its tasks.

Overall probability of ES task accomplishment

$$P_M(t) = P_1(t) + P_2(t) = 3P^2(t) - 2P^3(t)\,. \quad (4)$$

$P_M(t)$ values when m=5, m=7 etc., are found analogously. In general case $P_M(t)$ dependence on P(t) is expressed as:

$$P_M(t) = \sum_{i=l}^{m} C_m^i P^i(t)[1 - P(t)]^{m-i}\ ; \quad (5)$$

here

$$l = \frac{m+1}{2}\,; \quad (6)$$

$$C_m^i = \frac{m!}{i!(m-i)!}\,; \quad (7)$$

$C_m^i$ – number of combinations of size m taken from set of size i.

In Fig. 3 there is shown how $P_M(t)$ depends on no-failure probabilities P(t) of $S_{21}$, $S_{22}$ and $S_{23}$ when t=const and m are different. Most effect is assured by majoritarian redundancy until no-failure probabilities of systems $S_{21}$, $S_{22}$ and $S_{23}$ are P>0,5.

In practice &M is not absolutely reliable [3]. Often its no-failure probability $P_{\&}(t)$ is known. Then overall task accomplishment probability of ES with &M is

$$P_M(t) = P_{\&}(t)\sum_{i=l}^{m} C_m^i P^i(t)[1 - P(t)]^{m-i} \quad (8)$$

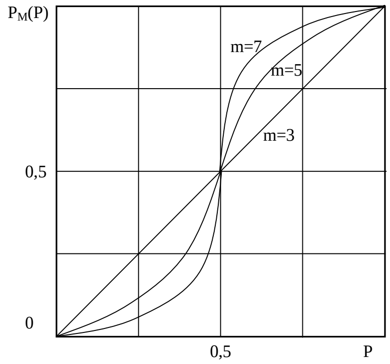


**Fig. 3.** Graph of $P_M(P)$ dependencies

In order to compare efficiencies of majoritarian and constant redundancy the expressions presented below can be used. When

$$m = 3\text{, and } P(t) = e^{-\lambda t} \quad (9)$$

here λ – intensity of failures of one ($S_{21}$, $S_{22}$ or $S_{23}$) system, then

$$P_M(t) = e^{-2\lambda t}(3 - 2e^{-\lambda t}), \quad (10)$$

and

$$P_R(t) = 1 - [1 - e^{-\lambda t}]^3\,; \quad (11)$$

here $P_R$ – no-failure probability of system under redundancy m=3. Assume, that $\lambda t << 1$, then

$$e^{-\lambda t} \approx 1 - \lambda t. \quad (12)$$

Therefore

$$P_M(t) \approx (1 - 2\lambda t)(1 + 2\lambda t) = 1 - 4\lambda^2 t^2, \quad (13)$$

and

$$P_R(t) \approx 1 - \lambda^3 t^3. \quad (14)$$

It follows from here, that in these two cases no-failure probabilities are respectively expressed as

$$Q_M(t) \approx 4\lambda^2 t^2; \quad (15)$$

$$Q_R(t) \approx \lambda^3 t^3. \quad (16)$$

Then

$$\frac{Q_R(t)}{Q_M(t)} \approx \frac{1}{4}\lambda t << 1, \quad (17)$$

and it means that

$$Q_M(t) >> Q_R(t). \quad (18)$$

This ascertains that the area of application of majoritarian redundancy is the assurance, improvement and control of efficiency of multi-source information analysis systems.

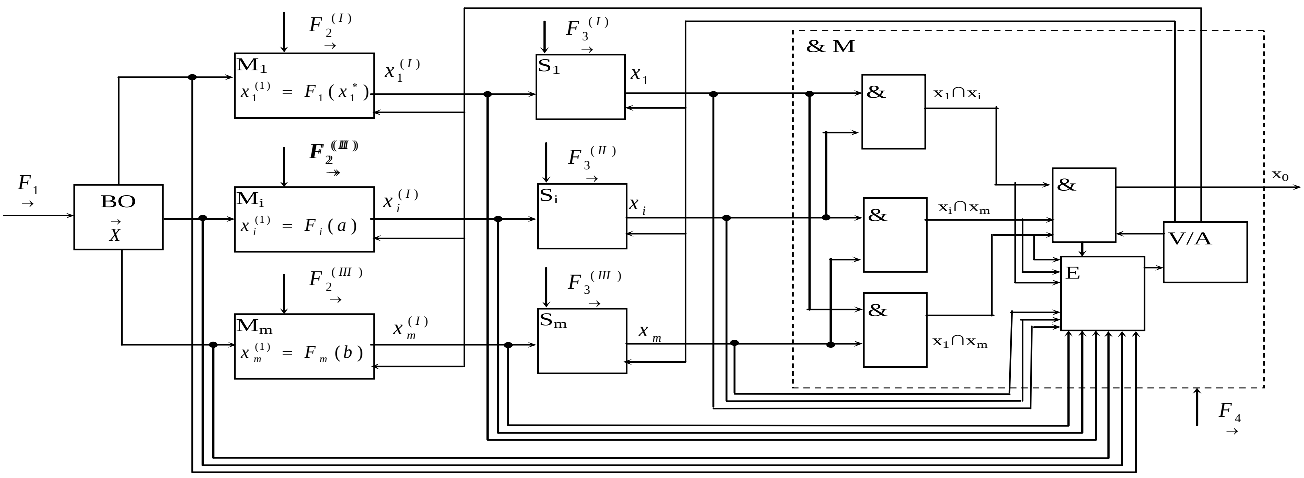


**Fig. 4.** ML structure

### Efficiency control of ES with majoritarian logic

When increasing efficiency of multi-source information processing systems, it inevitably falls to use majoritarian logic (ML). Majoritarian logic is a part of automat theory, dealing with features of majoritarian operator (MO) and with ways to visualize logical functions in it. ML ES are used when integrating multi-source direct and indirect information evaluations – when increasing reliability of decisions and at the same time increasing efficiency of control. Such decisions are necessary in network of integrated BTS, when forecasting defectivity of products and in many other areas, where direct and indirect information is employed for analysis and control of systematic influence of separate factors on integral property of the product. As an example we could also consider the systematic influence of sun rays, water, chemical materials and other factors on the properties of BO and processes inside of it, analysis and control ML ES.

In general case majoritarian operation (MO) of such ES

$$maj(x_1,x_2,...,x_j,...,x_m)=\begin{cases} a_2, jei \quad \sum_{j=1}^{m} x_j \ge a_2; \\ \sum_{j=1}^{m} x_j, jei \quad a_1 < \sum_{j=1}^{m} x_j < a_2; \\ -a_1, jei \quad \sum_{j=1}^{m} x_j \le -a_1; \end{cases} \tag{19}$$

here { $x_j$ } – whole numbers;

$$x_j \in [-a_1, a_2],\ j=\overline{1,m}; \tag{20}$$

m – uneven number; $a_1 > 0;\ a_2 > 0;$ $a_1$ and $a_2$ – symbols (operations) of opposite negations $\overline{x} = a_2 - a_1 - x$.

Typical example – three-dimensional ML in binary logic (-1, 1), when $a_1 = a_2 = 1;\ x_j = -1 \bigcup 1;\ m = 3.$

Most of problems emerge from ML for evaluation of information received from many sources of different reliability and received over channels of different efficiency.

### Research of ML structure

Let's analyze the structure of stochastic heuristic control ML (Fig. 4). Stochastic are those ES, for which it is not possible to determine the variation of their parameters (parameter values are random). ES control with self-learning functionality (using test results, a priori information, forecasts, etc.) is considered as heuristic.

Under the influence of the set $\underset{\rightarrow}{F_1}$ of factors, BO gains many new properties and definable indexes, the vector of which is $\vec{X}$. Some certain property is characterized by index X. m different sources are used to determine its value. Some of these sources present direct (e.g.: X), and other – indirect (e.g.: A and B) indexes. Random values of these indexes ( $x_1^*$, a and b) are received, and their distribution densities are $f_1(x_1^*)$, $f_i(a)$ and $f_m(b)$. These values enter the blocks of analysis (ES) of index interface models: $M_1, M_i, ..., M_m$ with recalculation functions:

$$x_1^{(I)} = F_1(x_1^{(*)}); \tag{21}$$

$$x_i^{(I)} = F_i(a); \tag{22}$$

$$x_m^{(I)} = F_m(b). \tag{23}$$

From these blocks (ES) values of index X $(x_1^{(I)},..., x_i^{(I)},..., x_m^{(I)})$ are transferred into interface ES $(S_1,..., S_i,..., S_m)$. Altered values $(x_1,..., x_i,..., x_m)$ are transferred from interfaces into *&M*. All systems beginning with BO and ending with &M are influenced by the set of factors $\underset{\rightarrow}{F_2^{(I)}}, \underset{\rightarrow}{F_2^{(II)}}, \underset{\rightarrow}{F_2^{(III)}}, \underset{\rightarrow}{F_3^{(I)}}, \underset{\rightarrow}{F_3^{(II)}}, \underset{\rightarrow}{F_3^{(III)}}$ and $\underset{\rightarrow}{F_4}$. &M form ML by using m-dimensional MO, heuristic part (ES)(E) and control /restoration ES (V/A).

Min advantages of such ML are the following: it is specialized for formation of multi-source information; provides possibilities to use indirect indexes, values of which are recalculated into $\overrightarrow{X}$ values; assesses limited reliability of interfaces between BO and &; implements heuristic control and restoration (correction, improvement) of {$M_i$} and {$S_i$}. Value $x_0$ of index X is received at the output of ML ES.

### Main directions of research of ML control efficiency

In order to form a method for ML ES efficiency evaluation, it would be best to start at first from analysis of properties, which describe BO states, and analysis of values of their indexes $\overrightarrow{X}$, from evaluation of links between values and investigations of impacts of factors $\underrightarrow{F_1}$. This would create basis for selection of indexes $X,...,A,...,B$, evaluation of randomness of their values and their links.

Second research direction – formation of blocks (ES) $M_1,...,M_i,...,M_m$, modeling of links between $x_1^*$ and $x_1^{(I)}$, a and $x_i^{(I)}$ and b and $x_m^{(I)}$ by assessing influence of factors $\underrightarrow{F_2^{(I)}},...,\underrightarrow{F_2^{(II)}},...,\underrightarrow{F_2^{(III)}}$, and planning of possibilities and assurance of centralized systematic control of these blocks with respect to MD operation results.

Third research direction – modeling and creation of interface ES $(S_1,...,S_i,...,S_m)$ and providing of control functionality from V/A block.

Seemingly the most complex and least-researched is the fourth part of works of MD operation efficiency assurance. When modeling MD procedures, main problems are caused by: not equal reliability of all {$x_i$}, not equal level of their randomness and thus not equal impact on decision making; creation of heuristic control (correction, improvement) methods with respect to the amount of information, its age, etc.; selection of algorithm and technical measures for renewal of failed (aged) ML ES components, etc.

These are the tasks for future research.

### Conclusions

It can be seen from accomplished research, that typical ML from the efficiency point of view is not suitable to replace a system with constantly redundancy of the analogical complexity, but it significantly increases reliability of information and efficiency of decision making.

When increasing number of inputs of m-dimensional ML efficiency of decisions rapidly grows at first. Particularly this effect is observed when efficiencies of different inputs are sufficiently large.

In order to control efficiently the operation of BTS, the use of stochastic heuristic control methods of these systems is required.

It can be seen from the presented ML ES structure diagram, that prior to creating control methods it is necessary to accomplish lots of research regarding BO properties, possibilities of modeling of their links, control algorithms.

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It is indicated that properties of biological objects are mostly the result of integral impact of various factors, and during decision making it falls to use direct and indirect indexes at the same time, to integrate their estimates and to receive one the most persuasive. For this purpose it is necessary to use various measures of majoritarian redundancy. Principles of majoritarian evaluation of ES efficiency are presented. Investigation of structure of majoritarian logic is performed. Main research directions of control efficiency of majoritarian logic are presented, which are fostered when creating systems of biotronics. Ill. 4, bibl. 3 (in English; summaries in English, Russian and Lithuanian).

**Е. Кярас, П. Балайщис, Д. Эйдукас, А. Валиневичюс. Эффективность мажоритарных систем, применяемых в сетях биотроники // Электроника и электротехника. – Каунас: Технология, 2008. – № 2(82). – С. 79–82.**

Указывается, что свойства биологических объектов часто бывают интегрированными результатами совместного воздействия розничных факторов, а при принятии решения приходится одновременно пользоватся прямыми и косвенными показателями, их значениями, интегрировать оценки и получать одну наиболее вероятную. Для этого приходится применять разумные средства мажоритарного резервирования. Анализируются структуры мажоритарной логики. Приводятся основные направления исследований эффективности управления мажоритарной логикой при создании систем биотроники. Ил. 4, библ. 3 (на английском языке; рефераты на английском, русском и литовском яз.).

**E. Keras, P. Balaišis, D. Eidukas, A. Valinevičius. Biotronikos tinklų mažoritarinių sistemų efektyvumas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 2(82). – P. 79–82.**

Nurodoma, kad biologinių objektų savybės dažniausiai būna integrinio įvairių veiksnių poveikio rezultatas, o sudarant sprendimą tenka tuo pačiu metu naudoti tiesioginius ir netiesioginius rodiklius, jų vertes, integruoti įverčius ir gauti vieną labiausiai tikėtiną. Tam reikia naudoti įvairias mažoritarinio rezervavimo priemones. Pateikiami ES efektyvumo mažoritarinio vertinimo principai. Atliekamas mažoritarinės logikos struktūros tyrimas. Pateikiamos pagrindinės mažoritarinės logikos valdymo efektyvumo tyrimų kryptys, kurios puoselėjamos kuriant biotronikos sistemas. Il. 4, bibl. 3 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).