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Efficiency of the Multisource Information of the Biotronics Systems

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Introduction

Biotronics systems (BTS) [1] are the integrated entirety of the biologic and electronic systems [2] which operate by utilizing the attributes of biocybernetics [3] and technical cybernetics [4]. In each stage of control the decision and its efficiency [5] is influenced by many various factors [6], and the information is one of these. From the main features of biotronic cybernetics [4] the following can be distinguished: creation of the information model of the objects; modeling of information and control processes; systemic view to the information and control and also the statistical point of view to the information acquisition and control processes.

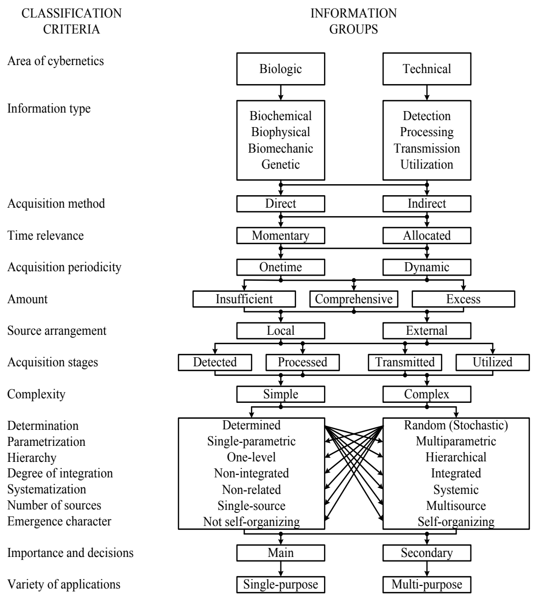

Fig. 1. Classification of the BTS information

Main information parameters are: its amount; reliability; timeliness and application efficiency [6]. In order to increase the amount of information and its reliability various models of multisource information [7] processing are applied. Therefore it falls to solve its efficiency evaluation problems. In the case of biotronic cybernetics the solution of these problems is being complicated by the fact that many sources of biologic and technical information of various degrees of reliability are used.

BTS multisource information groups

By considering the classification features the BTS information can be classified into several groups which determine different peculiarities of it (Fig. 1).

Names of many information classes are easily understood, but still some of them need wider explanation. Indirect information is obtained by analyzing the other kind of information – direct one. Fundamental feature of dynamic information is that its amount depends on the acquisition time, and the essence depends on the time when its analysis started. Determined, single-parametric, one-level non-integrated, non-related, single-source and non-self-organizing (by itself) information is called simple information. If at least one of these features is satisfied, then the information is attributed to the class of complex information. Therefore, for example, the determined information may be multiparametric, hierarchical, integrated, systemic, multisource and (or) self-organizing. Analogously, for example, random information may be single-parametric, one-level, etc. Even though it is not indicated in Fig. 1, but in the similar way we can classify, for example, single-source or self-organizing information also. In all these cases it will be attributed to the class of complex information. The information is attributed to the classes of main or secondary information by considering its influence to the decision (or the decision model). Multi-purpose information is usually used to make two or more different decisions (in two or more different models).

By considering the offered classification it is possible to state that the conception of the multisource information spans all classes indicated in Fig. 2 except for the classes of simple and single-source information.

Evaluation of the multisource information

When creating the scheme of the acquisition and application of the BTS multisource information, the relevant indicators are used in all cases: to obtain the biologic information – biologic indicator [3]; technical – technical indicator (signal, movement or other).

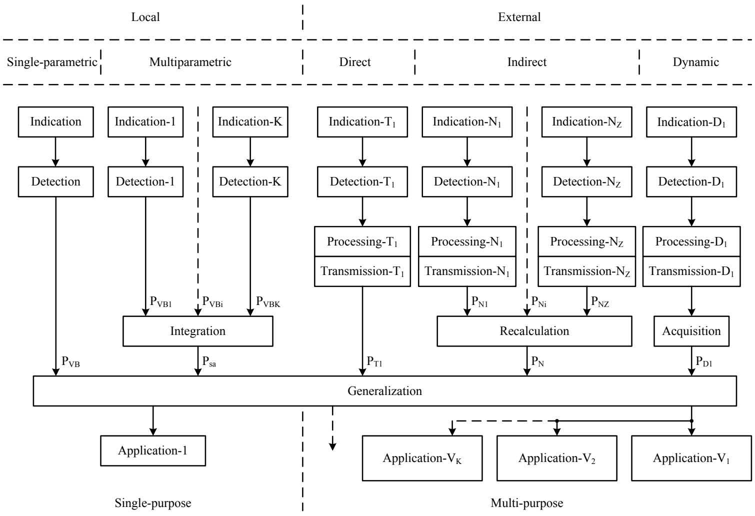

Fig. 2. The example of utilization of multisource information of various classes

Various detection measures (sensors) are used to register the biologic indications. Since BTS uses large amounts of various information which determines the efficiency of the operation, it is necessary to evaluate the reliability, rationality and other properties of each information type. For this purpose the information utilization scheme is created. The generalized example of such scheme is given in Fig. 2.

In order to obtain single-parametric and multiparametric, local, biologic information (in case of Fig. 2) the following is required [2]: biologic indicator (BI), electronic sensor (EJ). Even if the information was determined momentary and one-time, the probability to obtain it (in case of inter-independent events) would be

$$P_{VB} = (t,\underrightarrow{F_B},\underrightarrow{F_T}) = P_{BI}(t,\underrightarrow{F_B}) \cdot P_{BD}(t,\underrightarrow{F_B},\underrightarrow{F_T}), \qquad (1)$$

here $P_{VB}(t,\underrightarrow{F_B},\underrightarrow{F_T})$ – the probability of correct detecting of single-parametric biologic information during time *t*, under the influence of sets of biological and technical factors $\underrightarrow{F_B}$ and $\underrightarrow{F_T}$, $P_{BI}(t,\underrightarrow{F_B})$ – probability of biologic indication (BI) conformance to the state of biologic object during time *t* in the $\underrightarrow{F_B}$ environment; $P_{BD}(t,\underrightarrow{F_B},\underrightarrow{F_T})$ – probability of correct detection of (indicated) biologic feature during time *t* in the environments $\underrightarrow{F_B}$ and $\underrightarrow{F_T}$ (by using EJ). In case of single-parametric technical information

$$P_{VT} = (t,\underrightarrow{F_T}) = P_{TI}(t,\underrightarrow{F_T}) \cdot P_{TD}(t,\underrightarrow{F_T}), \qquad (2)$$

denotations used above are analogous to the earlier presented ones. Often when collecting determined local technical information $P_{TI}(t,\underrightarrow{F_T}) \approx 1{,}0$.

In case of multiparametric local biologic information the set of estimates $\{P_{VBi}(t,\{\underrightarrow{F_B}\},\{\underrightarrow{F_{Ti}}\})\}$ $(i = 1,K)$ emerges (see Fig. 2), which are determined by the parameter values of factors $\{\underrightarrow{F_{Bij}}\}$ and $\{\underrightarrow{F_{Tij}}\}$ which are characteristic to each of them $(\{f_{Bijs}(t)\}\text{bei}\{f_{Tijs}(t)\})$. In this case $f_{Bijs}(t)$, or $f_{Tijs}(t)$ – values of *j*-th factor *s*-th parameters influencing the *i*-th biologic or technical information during time *t* ($j = 1\ldots,R_i$; R_i - number of factors influencing the *i*-th biologic or technical information; $s = 1,\ldots R_{ij}$; R_{ij} – number of parameters of the *j*-th factor influencing the *i*-th information). Therefore by applying the formula (1) we can assume that

$$P_{VBi} = P_{BIi}[t,\{f_{Bijs}(t)\} \cdot P_{BDi}[t,\{f_{Bijs}(t)\},\{f_{Tijs}(t)\}], \qquad (3)$$

here $P_{BIi}[\cdot]$ and $P_{BDi}[\cdot\cdot]$ - the probabilities of correct indication and detecting of the *i*-th local biologic information. In the general case the repeated (excess) detection of the biologic indication can be used in the system. In case of the excess detection each detector of the *i*-th information may have L_i different and incompatible states. Parameter α_{li} could denote the probability of correct detection when detector is in the *l*-th state. In case when all (identical) m_i detectors of the *i*-th information perform the task at the same time, its accomplishment probability

$$P_{BDi} = \sum_{l_i=1}^{L_i} P_{li} \cdot \left[1-\left(1-\alpha_{li}\right)^{m_i}\right], \qquad (4)$$

here P_l – probability that detector will be in the *l*-th state. When several identical detectors perform the task during different time intervals and the second detector may attempt to accomplish the task when the previous one fails to accomplish it, then the task accomplishment probability

$$P_{BDi}^{(1)} = 1-\left(1-\sum_{l_i=1}^{L_i} P_{li}\alpha_{li}\right)^{m_i}. \qquad (5)$$

In most cases $\{f_{Bijs}(t)\}$ are partly random, thus it falls to use average P_{BIi} values – P_{BIiv} – to obtain the P_{VB} estimate. Then

$$P_{VBi} = P_{BIiv} \sum_{l_i}^{L_i} P_{l_i} \left[1 - \left(1 - \alpha_{l_i}\right)^{m_i}\right], \tag{6}$$

$$P_{VBi} = P_{BIiv} \cdot \left[1 - \left(1 - \sum_{l_i=1}^{L_i} P_{l_i} \alpha_{l_i}\right)^{m_i}\right]. \tag{7}$$

By integrating the multiparametric biologic information its efficiency can be evaluated by applying the model (M_J) which is given in Fig. 3.

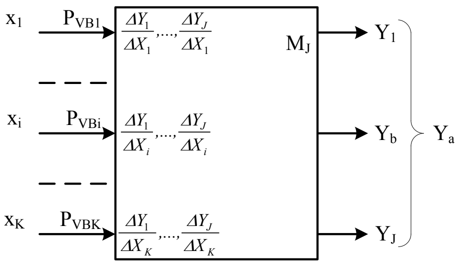

Fig. 3. Multiparametric biologic information integration model

The value of each *i*-th biologic parameter (indicator) (X_i) influences the value of *b*-th integral parameter $(Y_b(X_i))$. This impact can be characterized using the influence factor

$$S_{ib} = \frac{\Delta Y_b(\Delta x_i)}{\Delta x_i}, \tag{8}$$

here $\Delta Y_b(\Delta x_i)$ – the change of the *b*-th integral parameter value by magnitude Δx_i (e.g. from the possible minimum to the possible maximum) after the change of the parameter x_i value. Then the weightiness coefficient of the *i*-th parameter in respect of Y_b

$$k_{ib} = \frac{S_{ib}}{\sum_{v=1}^{K} S_{vb}}, \tag{9}$$

here *v* – the variable index obtained by summing the influence factors.

Weighted probability that the value of parameter Y_b will be correctly detected is expressed in the following way

$$P_{Sb} = \sum_{i=1}^{K} k_{ib} \cdot P_{VBi}. \tag{10}$$

In this manner the set $\{P_{sb}\}$ can be formed in which $b = 1,...,J$; *J* – number of integral parameters in the model M_J.

If in the previous level of integration $\{Y_b\}$ the parameters were integrated into one generalized parameter (Y_a), then the weighted task accomplishment probability could be found as

$$P_{Sa} = \sum_{b=1}^{J} k_{ba} \cdot P_{sb}, \tag{11}$$

$$k_{ba} = \frac{S_{ba}}{\sum_{v=1}^{J} S_{vo}}, \tag{12}$$

$$S_{ba} = \frac{\Delta Y_a(\Delta Y_b)}{\Delta Y_b}, \tag{13}$$

here $\Delta Y_a(\Delta Y_b)$ – the change of the generalized parameter value after the value of the *b*-th integral parameter is changed by the magnitude ΔY_b.

Efficiency of external direct biologic information (e.g. T_1) can be characterized using probability

$$P_{T_1} = P_{BIT_1} \cdot P_{BDT_1} \cdot P_{BAT_1} \cdot P_{BPT_1}, \tag{14}$$

here $P_{BIT_1}, P_{BDT_1}, P_{BAT_1}, P_{BPT_1}$ – the probabilities of correct indication, detection, processing and transmission of the T_1 biologic information.

By using the indirect external BTS information $(N_1, N_2,..., N_i,..., N_z)$ the formula (14) is suitable for evaluation of the efficiency of the initial acquisition stages. When indirect information is converted into the data which is used in the BTS decision-making models (preferred), the re-calculation models $(\{MN_i\})$ are created which additionally reduce the task accomplishment probability and control promptitude. Therefore the probability to obtain extensive required information

$$P_N(t) = \gamma[\{M_{N_i}\}, \{P_{N_i}(t)\}, t], \tag{15}$$

here $\gamma[\{M_{N_i}\}, \{P_{N_i}(t)\}, t]$ - the dependency of the probability to obtain the extensive required information on the set $\{M_{N_i}\}$ models and indirect information sources reliability (efficiency) index value arrays $\{P_{N_i}(t)\}$ used in these models. $P_N(t)$ evaluation procedure is analogous to the one illustrated in Fig. 3.

Amount of dynamic information (J_D) (e.g. D_1, Fig. 2) depends on its acquisition duration $\int t_0(J_D = f(t_0))$, or (if it varies over time) - on its detection and usage duration. In the first case such dependence is often suitable to describe its efficiency

$$P_{D1}(t_0) = 1 + a - be^{-ct_0}, \tag{16}$$

here *a* – efficiency of the *a priori* information, *b* and *c* – function parameters.

In this case (Fig. 2) the "generalization" is considered as the merging of the multisource information of different reliability in the BTS models. The model analogous to one which is shown in the Fig. 3 can be used to generalize the information. When the same values (e.g. x_{jo}) of the same parameter (e.g. X_j) or the sets of the random values characterized by distribution densities $f_1(x_j),..., f_5(x_j)$ and guaranteed with different probabilities are used at the input of such model (Fig. 4), the method described further can be used to evaluate the efficiency of the multisource information.

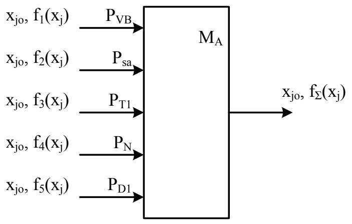

Fig. 4. Example of the multisource information generalization

In case of inter-independent events when evaluating the efficiency of the information x_{jo} we obtain

$$P_{xjo} = 1 - \left[(1-P_{VB})(1-P_{sa})(1-P_{T1})(1-P_N)(1-P_{D1})\right]. \quad (17)$$

When X_j parameter values $\{x_{js}\}$ are random and their probabilities in the information of various sources are $\{p_{jsi}\}$, then (in case of Fig. 4) the generalized probability of the value x_{js}

$$P_{xjs} = p_{js1}\cdot\frac{P_{VB}}{P_\Sigma} + p_{js2}\cdot\frac{P_{sa}}{P_\Sigma} + p_{js3}\cdot\frac{P_{T1}}{P_\Sigma} + p_{js4}\cdot\frac{P_N}{P_\Sigma} + p_{js5}\cdot\frac{P_{D1}}{P_\Sigma}, \quad (18)$$

here

$$P_\Sigma = P_{VB} + P_{sa} + P_{T1} + P_N + P_{D1}. \quad (19)$$

In this manner the probabilities of all values of the set $\{x_{js}\}$ are calculated and the expression of their density $f_\Sigma(x_j)$ is obtained. Efficiency of such multisource information is evaluated analogously to the formula (17), since each value x_{js}, as also the value x_{jo}, was evaluated in more reliable way.

Information usage efficiency is an object of the separate research. The evaluation of the multi-purpose information usage efficiency is particularly complicated.

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The conception of the information of biotronics systems (BTS) was formulated. The main BTS multi-source information groups were distinguished and their classification was presented. The BTS multi-source information usage scheme example was presented. Efficiency evaluation principles of local and external, single-parametric and multi-parametric, direct and indirect information were analyzed. The efficiency evaluation possibilities of the random multi-source BTS information were illustrated. Ill. 4, bibl. 7 (in English; abstracts in English, Russian and Lithuanian).

Р. Гужаускас, Д. Эйдукас, П. Балайшис. Эффективность моделирования динамических электронных систем // Электроника и электротехника. – Каунас: Технология, 2010. – № 8(104). – C. 19–22.

Сформулировано понятие информации систем биотроники (СБТ). Выделены основные группы информации СБТ, получаемой из многих источников. Приведена классификация группы указанной информации. Приведен образец схемы использования различной информации СБТ. Проанализированы принципы оценки эффективности местной и внешней, однопараметрической и многопараметрической, а также прямой и косвенной информации СБТ. Показаны возможности оценки эффективности случайной многоисточниковой информации СБТ. Ил. 4, библ. 7 (на английском языке; рефераты на английском, русском и литовском яз.).

R. Gužauskas, D. Eidukas, P. Balaišis. Biotronikos sistemų daugiašaltinės informacijos efektyvumas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 8(104). – P. 19–22.

Suformuluota biotronikos sistemų (BTS) informacijos samprata. Išskirtos pagrindinės BTS daugiašaltinės informacijos grupės, pateikta jų klasifikacija. Pateiktas BTS daugiašaltinės informacijos panaudojimo schemos pavyzdys. Išanalizuoti vietinės ir išorinės, vienaparametrės ir daugiaparametrės, tiesioginės ir netiesioginės informacijos efektyvumo vertinimo principai. Parodytos atsitiktinės daugiašaltinės BTS informacijos efektyvumo vertinimo galimybės. Il. 4, bibl. 7 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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