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Intellectualisation of Biotronics Systems and their Efficiency

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Biotronics control peculiarities

Plants – biological objects (BO) and electronic measures (EM) are commercially related [1] with the aim to control biological systems (BS). This is done by monitoring parameters of BS and controlling EM (from which electronic systems (ES) are formed) according to the values of these parameters. Interaction of BS and ES is considered as system of biotronics [1] (BTS). Most of BTS are integrated [2], multiparametric, multi-objective, complex, of integrated impact and often continuously operating systems. Processes taking place inside of these systems and which are used for control are conditionally classified into two groups [1]: fast and slow processes. Fast processes are present in security and persistence control systems, and slow processes are mostly present in purpose function and evolution control systems. That determines the requirements for the components of these systems (receptory, block interface, information control and processing devices, control algorithms, their decision making models, etc.).

During analysis or control of slow processes, the speeds of information retrieval, storing, transmission, analysis make small impact on the efficiency of the results. The efficiency of slow process control systems are more conditioned by the quality of control methods and algorithms, adequacy of the models to the modeled objects, data informativeness and other factors.

Since the amount of gathered information, which is necessary for the control, is dependant on the detection time, transmission rate, speed of analysis and expedition of decision making and implementation, the security and persistence control sensors should be as quick-acting as possible, information transmission channels should have maximum possible throughput at all hierarchical levels of integrated BTS (IBTS) [2], and control algorithms should maximally employ the *a priori* information, collected during earlier control cycles.

The multiparametric and multi-objective control of the fast processes determines intricate situation (BO state) optimization models and requires considerable performance of personal computers (PC), used in control, which permits quick creation, alteration or application structures of complex (often even heuristic) system. These PC should have higher memory and other resources.

Measures of communication with the central system [2], between central systems and other, which are used to form the IBTS environment, should also have high performance of information search and transmission.

Measures of various level of intelligence can be used to control the states of BO. Therefore it falls to decide if intelligent BO control measures are needed, where and when they are needed?

BTS intellectualisation expedience

Quality of BTS (IBTS) is understood as the level of suitability of these systems to analyze BO and control BS. Thus when analyzing the expedience of intellectualization (use of artificial intelligence (AI))) the following should be distinguished: analytical BT and utilitarian BT, e.g. biocybernetics (BC).

Aims of BT research: better understanding of BO, their BS, how they are influenced by various factors and to create possibilities to improve BTS (including the ES).

At this point the artificial intelligence measure (AIM) [2] imitates the human cognition (it thinks as human) or thinks reasonably, using the logic of itself. In analytical BT it is difficult to foresee, what new results could be acquired if the self-learning analysis measures are used. Often the availability of such measures is limited.

In biocybernetics, the intelligent devices influence ES and the control of BS at the same time (it controls similarly as human or controls in intelligent way). At this point they are widely available and the expenses needed to acquire and maintain them conditions the success of the business.

Scientists have found, that neural cells use considerably more energy in order to sustain its functions compare to muscular cells. Probably that was the reason why most of the animals (especially predatory ones) do not have great intellect and train their muscles instead. That should be considered when creating BTS (IBTS)

In case of intelligent IBTS, energy transmission measures are used in place of biologic nerves, and complex software, complex operation algorithms and object models and also big amount and varying information is used in them. This is the reason why the rational levels of BTS (IBTS) intelligence should be selected according to the self-cost of BO product growth or maintenance of its state. It means that the rational level of BTS (IBTS) intelligence should be selected according to how its use will decrease the self-cost of the products, increase their amount or/and their quality level. Product manufacture yield, self-cost and quality are few of the main indexes, characterizing the efficiency of BK [2].

In Lithuania the self-cost of industrially-grown vegetables is 15-20% higher than in the foreign countries of similar climate – leaders of this business. PCs are already used in business of these countries (Netherlands, Denmark, etc.) for a long time. Main component of the self-cost of BO products in Lithuania is the input of workforce, energy and materials.

There is no doubt, that the possibilities to decrease the expenditure of workforce, energy and materials still exist. This is demonstrated by the dispersions of values of different components of BO products of Lithuanian business objects. Furthermore, annually in Lithuania:

-the price of farmland increases;

-the self-cost of buildings increases;

-the prices of materials (fertilizers, water, pesticides, fungicides, etc.) increase;

-the price of workforce increases;

-the energy (electricity, heat) price increases;

-the prices of electronic devices (including intellectual) decrease.

This is the base of BTS intellectualization. With application of intelligent BTS it would be possible to decrease not only the expenditures of control equipment usage, but also the expenditures of materials, workforce, and energy, required to manufacture one unit of BO product amount. Additionally, the results of analytical BT would create the possibilities for maximal exploitation of potential physiological BO reserves. It can be thought about such prospects after comparing the typical sizes of sea-anemone and kiwi, their yield from one plant, etc.

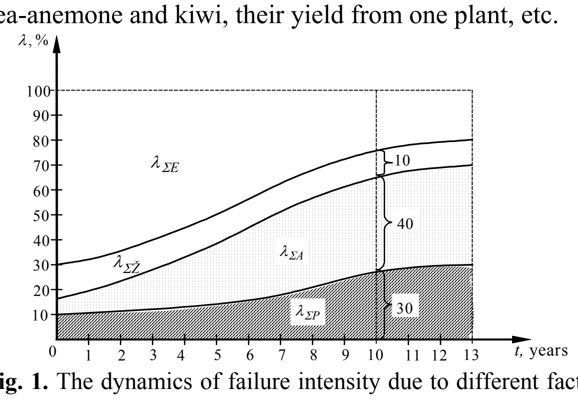

Fig. 1. The dynamics of failure intensity due to different factors; $\lambda_{\Sigma E}$, $\lambda_{\Sigma \check{Z}}$, $\lambda_{\Sigma A}$, $\lambda_{\Sigma P}$ – the ES failure intensities conditioned by electronic devices, human-operator, operation algorithms and software

Rationally used results of analytical BT and AI are the criteria of optimal performance. Still that can be achieved only by performing continuous complex and systematic research and by improving the BTS software, systematically collecting the experience of other specialists. That conditions the necessity of IBTS network and central systems inside of it [1].

With development of ES the relative levels of their failures (disturbances) due to different reasons vary continuously (Fig. 1) [3].

The more intensively AI is used in these systems, the more rapidly increases the amount of programs, used in them (Fig. 2) [4-6], and their exploitation cost increases at the same time (Fig. 3).

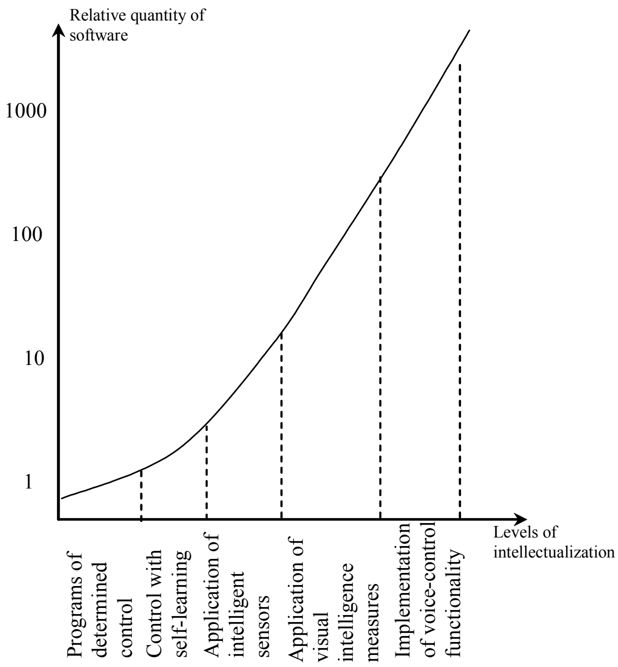

Fig. 2. The dependence of software amount on the level of intellectualization

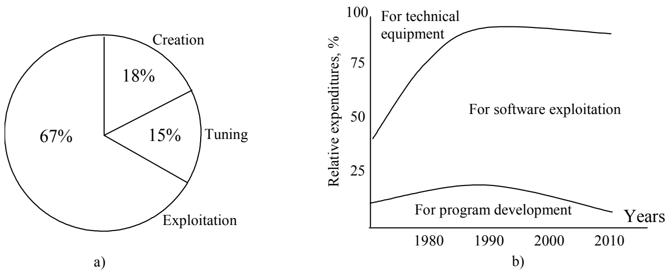

Fig. 3. Relative expenditures: a – in separate program development stages, b – in different time periods

Fig. 2 and Fig. 3,b proves one more time, that it is necessary to create the centers of IBTS with the expansion of biocybernetics, and Fig. 2 separately shows, that when introducing BTS it is necessary to pay attention to software reliability (efficiency), and also to the rebilitronics and persistence assurance measures, used in systems. It is necessary to introduce additional level of control quality (reliability) control (the level of security measures).

When looking for analogy to industrial manufacture it is easy to ascertain, that (Fig. 4) when increasing the span of BO product manufacture, non-automated BTS ensures the least cost of control equipment usage (C_s), and later this is ensured by automatic BTS of strictly determined behavior and non-varying regulation processes, and at the end the specific manufacture level is reached, under the presence of which the intelligent BTS becomes the most rational choice. Its intelligence level should be sufficient to guarantee maximal application efficiency.

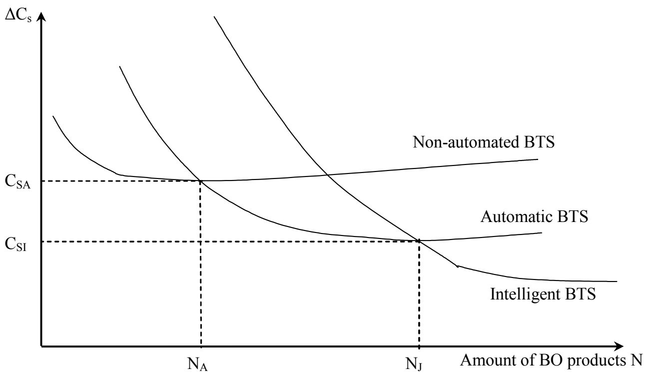

Fig. 4. Dynamics of C_S

Efficiency of intelligent BTS

One of the main lacks of intelligent BTS is that it uses multiparametric, multi-purpose control of objective functions in the multi-factorial environment. Therefore most of the circumstances (factors, relations of properties, their dynamics laws, etc.) are unknown or known insufficiently precisely. This fact determines that the results (values of the main self-cost components of the product) of control are not always acceptable. In intellectual BTS the influence of this drawback would gradually decrease with accumulation of experience.

Inadequate assessment of control conditions (poor control of rebilitronics and persistence assurance measures) also determines other negative BTS exploitation outcomes: various breakdowns, which emerge when unforeseen situation is formed; failures of this system; decrease of control efficiency when environment has changed and when system is not improving (with insufficient evolution level), etc.

It can be seen from the presented thoughts, that all control of IBTS can be divided into two parts: control of purpose functions, which is performed by the lowest level (expeditious control) BTS (ES) (Fig. 5), and function control quality regulation.

When IBTS efficiency (E_Σ (t)) is characterized by its degree, by which it satisfies needs, and is expressed using task accomplishment probability in time t, then

$$E_\Sigma(t) = f_E(E^{(I)}(t), E^{(II)}(t), E^{(R)}(t)); \qquad (1)$$

where f_E (·) – the function of influence of expeditious (I), tactical (II) and strategic (R) control level efficiencies ($E^{(I)}$ (t), $E^{(II)}$ (t), $E^{(R)}$ (t)) on overall efficiency.

Since momentary efficiency of IBTS is not very informative [2], and system events which determine efficiency are independent, then overall IBTS efficiency during the given time period $t_1 - t_2$:

$$E_\Sigma(t_1 \div t_2) = \frac{\int_{t_1}^{t_2} \sum_{j=1}^{N_F} \gamma_j [1-(1-E_{Fj}(t)\cdot E_j(t))(1-E_{Pj}(t)(1-E_{ATj}(t)(1-E_j^{(R)}(t))]}{t_2 - t_1} \times$$

$$\times \prod_{i=1}^{V} E_{ij}(t); \qquad (2)$$

where γ_j – the index of significance of j-th BTS purpose function; $E_{Fj}(t)$ and $E_j(t)$ – efficiencies of j-th ES and BTS (Fig. 6,b); $E_{pj}(t)$ and $E_{ATj}(t)$ – efficiencies of ES_p and ES_{AT}, when j-th purpose function is performed; $E_{ij}(t)$ – efficiency of ES_{Ai}, when j-th purpose function is performed; V – number of A systems (Fig. 5,a); $E^{(R)}(t)$ – efficiency of strategic control system, in respect of j-th purpose function; N_F – number of IBTS functions.

After analyzing the peculiarities of BTS network [1] and security measures, it can be ascertained, that one of the main tasks for developers of these systems is the increase of E_{Fj} (t), E_j (t), E_{pj} (t), E_{ATj} (t) and $E_j^{(R)}$ (t) and intellectualization of ES_{Fj}, BTS_j ES_p, Es_{AT} and IBTS (Fig. 5,b). Let's examine the efficiency of BTS with AIM (Fig. 6).

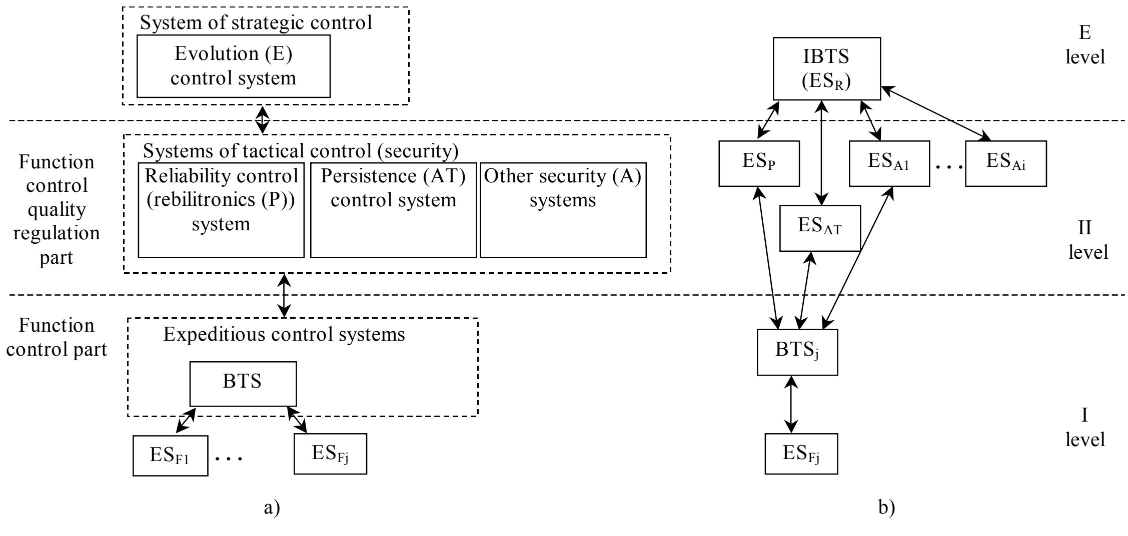

Fig. 5. IBTS control levels (F_j – j-th purpose function) (a – two-part IBTS; b – symbolic levels of IBTS)

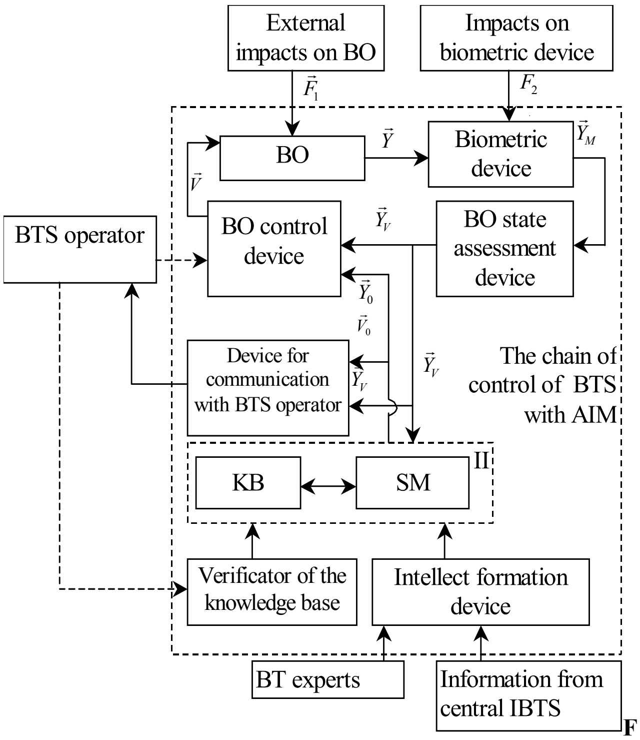

Fig. 6. The structure of BTS with DIM

In Fig. 6: $\vec{F}_1$ and $\vec{F}_2$ – external impacts on BO and biometric device; $\vec{Y}$, $\vec{Y}_M$ and $\vec{Y}_V$ – the sets of actual BO features, their measurement results and BO evaluation results; $\vec{Y}_O$ – the set of BO state optimization results; $\vec{V}$ – the set of BO control commands; $\vec{V}_0$ – the set of optimal control impacts on BO; KB – knowledge base; SM – decision-making mechanism.

Since the efficiency of AIM is the level by which it satisfies needs, and since these measures are mostly used in control, then the efficiencies of these measures and efficiency of BTS with these measures can be distinguished. The first is determined by: implemented intellect (II); its reliability and the reliability of devices, used to implement it. The second is determined by: efficiencies of control of BTS functions, its structures, devices, algorithms, programs, information, reliability, etc.

II level is determined by intellectual device (ID), i.e. KB, SM and measures of self-learning (KB and SM), adaptation (KA and SA), inter-coordination (ŽS and SS), evolution (KE and SE), experience accumulation (KK and SK) and other measures. Therefore the efficiency of II :

$$E_{II} = E_{\check{Z}M} \cdot E_{\check{Z}A} \cdot E_{\check{Z}S} \cdot E_{\check{Z}E} \cdot E_{\check{Z}K} \cdot E_{SM} \cdot E_{SA} \cdot E_{SS} \cdot E_{SE} \cdot E_{SK}; \quad (3)$$

where multiplicands are the efficiencies of measures used in KB and SM. Adaptation is the variations of BTS control decisions when the impacts on it vary. Inter-coordination measures alter BTS structures and its control. When evolving, the BTS changes fundamentally (changes its objectives, tasks, etc.). With accumulation of experience, BTS changes the level of its intellect (AIM).

The efficiency of any measures of KB or SM (e.g., E_{SM}) can be expressed as:

$$E_{SM} = E_{II} \cdot E_{IP} \cdot E_{PP}; \quad (4)$$

where E_{II} – the level by which the implemented intellect matches needs; E_{IP} – the level of intellect reliability (IR); E_{PP} – efficiency of measures used for self-learning:

$$E_{II} = \sum_{i=1}^{F} \eta_i \cdot E_i, \quad (5)$$

where F – the number of factors influencing the control efficiency; η_i – significance coefficient of the i-th factor; E_i – II efficiency, when controlling BTS, ED, which are influenced by the i-th factor:

$$E_i = \prod_{j=1}^{m} \int_{l_{ij\,\min}}^{l_{ij\,\max}} f(l_{ij}) dl_{ij} \;; \quad (6)$$

where $f(l_{ij})$ – distribution density of values of the i-th factor j-th parameter; $l_{ij\min}$ and $l_{ij\max}$ – II coverage limits; m – the number of parameters of i-th factor influencing BTS control efficiency:

$$E_{IP}(t') = \begin{cases} \dfrac{E_{II}(t=t')}{E_{II}(t=0)}, when E_{II}(t=t') \langle E_{II}(t=0); \\ 1, when E_{II}(t=t') \geq E_{II}(t=0); \end{cases} \quad (7)$$

where t' – time moment, at which IP is evaluated. E_{IP} is determined by excess of intellect and its dynamics. When the states of self-learning measures are inter-incompatible:

$$E_{PP} = \sum_{s=1}^{B} P_s \cdot E_s; \quad (8)$$

where P_s – s–th state probability of self-learning measures; E_s – self-learning efficiency of the s-th state measures; B – number of states of self-learning measures.

Efficiency of BTS with DIM:

$$E_{BTS}^{(0)} = \prod_{v=1}^{n} E_v^{(0)}; \quad (9)$$

where n – number of BTS attributes (functions, structures, etc.), which are controlled under assistance of AIM; $E_v^{(0)}$ – control efficiency of the v-th attribute of BTS. Influence of DIM on the BTS control efficiency

$$\Delta E = E_{BTS}^{(0)} - E_N; \quad (10)$$

where E_N – BTS control efficiency, when AIM are not used.

The efficiency of the system presented in Fig. 6 can be also expressed as

$$E = 1 - \frac{|y - y_0|}{y} K(y); \quad (11)$$

where y and y_0 – actual and optimal values of the parameter Y; $K(y)$ – index of efficiency variation speed.

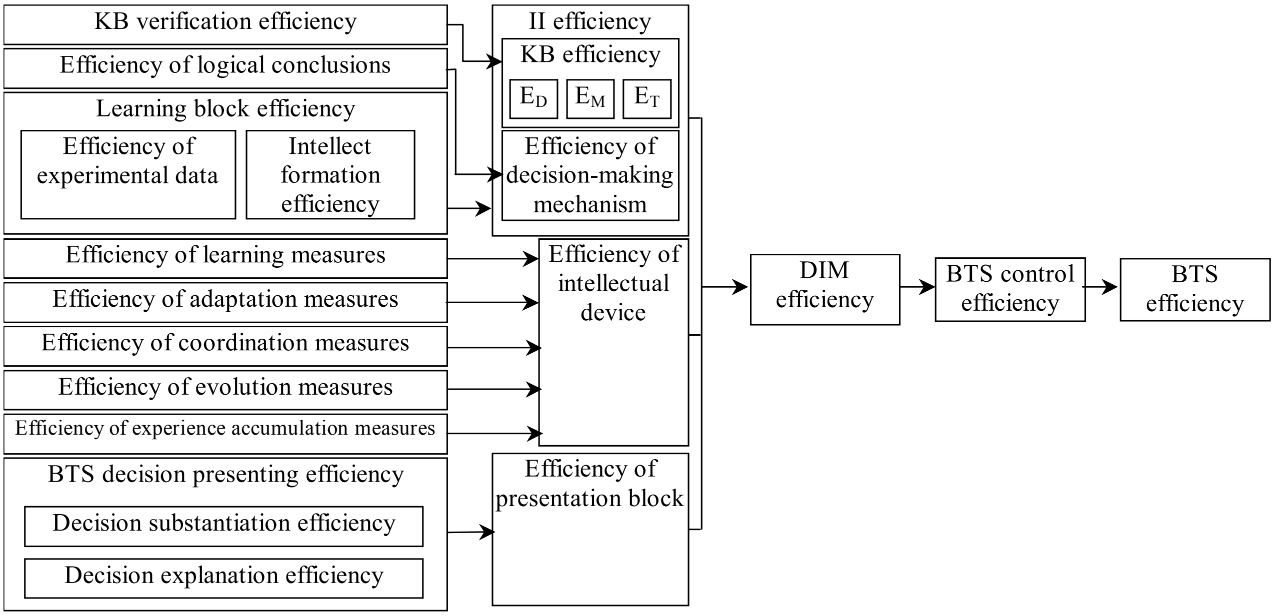

Fig. 7. Integration scheme of efficiency features (E_D, E_M, E_T – efficiencies of data, metaknowledge and rules)

Scheme of integration of BTS efficiency components is shown in Fig. 7.

All these features and their indexes mainly determine the values of $E^{(I)}(t)$ (see formula (1)). Values of $E^{(II)}(t)$ and $E^{(R)}(t)$ are more often determined by BTS function control quality regulation part (level), where ES_p, ES_{AT}, ES_A and ES_R are active. How could be the influence of these systems on the efficiency of BTS evaluated?

The index of readiness of any ES

$$K_P = \frac{1}{1 + \dfrac{\lambda_{ES}}{\mu_{ES}}}; \quad (12)$$

where λ_{ES} and μ_{ES} – intensities of ES failures (disturbances) and restoration (repair). When this BTS system is influenced by ES_p

$$K_P = \frac{1}{1 + \dfrac{\lambda_{ES} - \Delta\lambda_P}{\mu_{ES}} + \dfrac{\lambda_P}{\mu_P}}; \quad (13)$$

where λ_p and μ_p – intensities of reliability control ES_p failures (disturbances) and repair; $\Delta\lambda_p$ – intensity decrease of ES failures (disturbances), when ES_p ir operating reliably. Value of λ_p is conditioned by incorrect decisions of ES_p regarding ES disturbances. Value of μ_p depends on how quickly the incorrect decision of ES_p can be detected and how quickly the outcomes can be removed.

Analogous influence on the coefficient of BTS readiness is also done by ES_{AT}, which changes ES actions or structures, repeats the functions of this system and assures timely accomplishment of purpose functions, when some of ES failures (disturbances) emerge which could not be avoided by ES_p, and by these actions it even more decreases the final λ_{ES} value by amount $\Delta\lambda_{AT}$. Still, even ES_{AT} can fail or make a mistake. The intensity of such events is λ_{AT}, and their outcome removal intensity is μ_{AT}.

Therefore

$$K_P = \frac{1}{1 + \dfrac{\lambda_{ES} - \Delta\lambda_P - \Delta\lambda_{AT}}{\mu_{ES}} + \dfrac{\lambda_P}{\mu_P} + \dfrac{\lambda_{AT}}{\mu_{AT}}}. \quad (14)$$

IBTS intellectualization level determines the values of $\Delta\lambda_p$, $\Delta\lambda_{AT}$, λ_p, λ_{AT}, μ_{ES}, μ_p and also μ_{AT}, and at the same time the value of K_p.

When BTS control commands are relatively short-timed,

$$E_{Pj}(t) \approx K_{PPj};\ E_{ATj}(t) \approx K_{PATj} \text{ ir } E_j^{(R)}(t) \approx K_{PRj}; \quad (15)$$

where K_{PPj}, K_{PATj} and K_{Rj} – efficiencies of ES_p, ES_{At} and ES_R, when they execute the j-th purpose function.

The efficiency of $\{ES_{Ai}\}$ systems and DIM influence on their operation can be evaluated analogously. Only in this case the probabilities of disasters and system possibilities to avoid fully or partially the results, caused by these disasters, by using intellect, should be considered also.

Conclusions

It can be seen from the presented reasoning, that:

1. One of the main BTS efficiency increase directions is the implementation of AIM in them.
2. When improving BTS, the number of processes taking place inside them rapidly increases, and at the same time the influence of reliability of these processes on its efficiency also increases.
3. When different manufacture extents are present, non-automated, automatic or intellectual BTS can be most efficient.
4. Continuously increasing amount of BTS software, increasing expenditures for it exploitation forces to design the networks of these systems with information

centers. This proves the correctness of the variant selected in [1].

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Conception of system of biotronics (BTS), their integration and efficiency are presented. All processes in BTS can be divided in two parts: slow and fast, control of both of them needs different requirements. Conceptions of analytical and applied biotronics are formulated. The need of BTS intellectualization is motivated. When BTS is getting more perfect, percentage of troubles because of process algorithm and programs imperfection rises in the total fault flow. Software volume in such systems is rising, and expenses for maintenance of it makes about 60% of all expenses of creation and using. These costs are extremely growing. Expression of efficiency of intellectual BTS and structure of this system with measures of artificial intelligence (AIM) are given. The scheme of integration of BTS with AIM efficiency features is made. Main rates of BTS with DIM efficiency are given. Ill. 7, bibl. 6 (in English; summaries in English, Russian and Lithuanian).

А. Валиневичюс, Е. Кярас, П. Балайщис. Интеллектулизация систем биотроники и ее эффективность // Электроника и электротехника. – Каунас: Технология, 2007. – № 4(76). – С. 41–46.

Приведены понятия систем биотроники (СБТ), их интегрирования и эффективности. Все, протекающие в СБТ процессы разделены на две группы: медленные и скоротечные, управлению которых предъявляются разные требования. Сформулированы понятия аналитической и практической биотроники. Приведены мотивы целесообазности интелектуализации СБТ. Показано, что при усовершенствовании СБТ постоянно увеличивается удельный вес их сбоев из-за несовершенства алгорифмов и программ в общем потоке отказов и сбоев. Указано, что объемы программного обеспечения таких систем постоянно увеличиваются, а затраты на их эксплуатацию составляют более чем 60% от всех расходов на их создание и применение. Показано, что указанные затраты с годами постоянно увеличиваются. Приведены выражения эффективности СБТ с искусственным интелектом и структура этой системы со средствами искусственного интелекта. Составлена схема интегрирования свойств эффективности СБТ со средствами искусственного интеллекта. Предложены основные выражения показателей эффективности СБТ со средствами искусственного интелекта. Ил. **7**, библ. 6 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Valinevičius, E. Keras, P. Balaišis. Biotronikos sistemų intelektualizavimas ir jo efektyvumas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 4(76). – P. 41–46.

Pateiktos biotronikos sistemos (BTS), jų integravimo bei efektyvumo sampratos. Visi BTS vykstantys procesai suskirstyti į dvi dalis: lėtuosius ir greituosius, kurių valdymui keliami skirtingi reikalavimai. Suformuluotos analitinės ir taikomosios biotronikos sampratos. Motyvuojamas BTS intelektualizavimo būtinumas. Parodyta, kad, tobulėjant BTS, nuolatos didėja jų sutrikimų dėl veikimo algoritmų bei programų netobulumo dalis bendrame gedimų ir sutrikimų sraute. Nurodoma, kad tokių sistemų programinės įrangos apimtys nuolatos didėja, o sąnaudos joms eksploatuoti sudaro daugiau, nei 60 % visų su jų kūrimu ir naudojimu susijusių išlaidų. Parodyta, kad šios sąnaudos sparčiai didėja. Pateikta intelektualių BTS efektyvumo išraiška bei šios sistemos su dirbtinio intelekto priemonėmis (DIP) struktūra. Sudaryta BTS su DIP efektyvumo savybių integravimo schema. Pateiktos pagrindinės BTS su DIP efektyvumo rodiklių išraiškos. Il. 7, bibl. 6 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).