Directions of Efficiency Research for Biotronics Technologies

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Introduction

Peculiarities of biological objects (BO) often become a major issue when trying to interconnect them with various technical measures and when attempting to research and control them. These objects are usually attributed to the class of complex objects, for which the potential of growing, reproduction, reaction to the environmental impacts and change in order to initiate or improve the adaptation, flexibility and evolution is characteristic. In major part these objects are autonomous, multi-process, insufficiently researched, multiparametric (when parameters are interconnected) and therefore difficult to model.

When BO and an electronic object (EO) are adequately interconnected [1], the biotronic object (BT) is received. By linking biological and electronic systems (BS and ES), systems of biotronics (BTS) are created. These systems differ from biotronics measures in the fact, that they are being integrated in a specific manner [2].

Integration of BS and ES

BS and ES can be integrated in different ways, depending on the needs of the consumer and the specifics of selected problem. BTS efficiency also depends on the selected method of integration [3].

Assume that BTS interconnects only one BS and one ES. Three variants of their interfacing structure can be distinguished (Fig. 1).
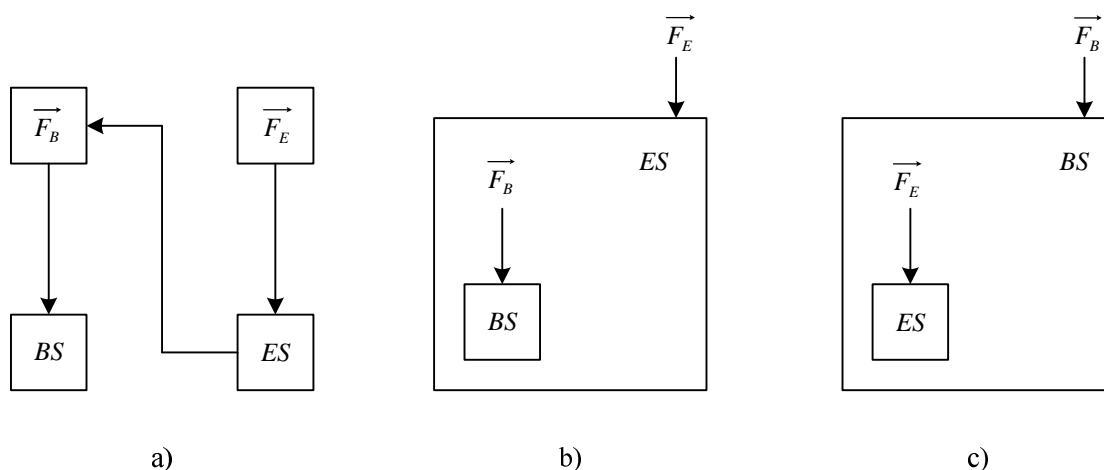

Fig. 1. Three variants of BS and ES composition: a) systems, which directly do not depend on each other; b) ES priority systems; c) BS priority systems

In all cases BS and ES are being influenced by the sets of their environment factors ($\overrightarrow{F_B}$ and $\overrightarrow{F_E}$). In the firs case (Fig. 1, a) BS and ES are not directly dependent on each other (there is no direct link between them). ES controls one (F_{Bi}) or several ({F_{Bi}}) factors which influence BS ($F_{Bi} \in \overrightarrow{F_B}$). When $\overrightarrow{F_B}$ varies, BS operation conditions and at the same time its operation efficiency partly uncontrollably varies. This is a typical and presently widely employed variant of interface between biotronics measures and BS. In this case momentary (in time t_1) and

average (during time period $t_1 \div t_2$) BS operation efficiencies ($E(t_1)$ and $E_v(t_1 \div t_2)$) [3] will be also uncontrollable and can be lower than required ($E_p(t_1)$ and $E_p(t_1 \div t_2)$).

$$E_v\left(t_1 \div t_2\right) = \frac{\int\limits_{t_1}^{t_2} E(t)\,dt}{t_2 - t_1}\,; \qquad (1)$$

here $E(t)$ – dependence of BS operation efficiency on time (t). Main advantage of BTS is the fact that it provides the direct interaction of BS and ES. The system is called integrated [3] system, when its subsystems are pursuing the same collective objectives and also have a centralized control.

ES priority integrated systems (Fig. 1, b) are pursuing the objectives of this system and usually make some reservations when implementing objectives of BS, for example, forecasts possible losses due to inadequate operation of BS, etc. In the system with such priority the information about states of BS, when specific objectives of ES are given, can not always ensure the needed reaction in the biological system from the higher level system.

When selecting BS objectives according to BTS priority (Fig. 1, c), it is realistic to expect more efficient implementation of these objectives, spanning many various states, which could be determined by $\overrightarrow{F_B}$ factors.

That provides the opportunities to ensure the systemic control of ES, considering conditions and BS states determined by $\overrightarrow{F_B}$ factors. However in this case a considerably more extensive research of BO peculiarities is required.

BT directions and goals

The entirety of BT research and synthesis methods can be broadly divided into two directions: analytical and utilitarian. Commercial ventures are usually more interested in the second direction of BT, which spans the security and monitorics of BO. This part determines the technologies of research, modeling and control (BTS technologies). Monitorics consists of the fundamentals of creation of detection, surveillance, stimulation and control technologies. It is based on biophysics, biochemistry, biomechanics and other sciences.

One of main tasks of utilitarian BTS technologies is to control BO and its environment. This task can be separated into: control of receptorics; biometry; control of information streams; analysis of the states; decision making; decision implementation (control) and evaluation of efficiency of control impact.

Biotronic cybernetics (BTC) should be created to solve all these problems.

BTC development peculiarities

BTC is an area of cybernetics, dealing with analysis and creation of control methods and measures of interactions of biological and electronic objects. It differs from biological cybernetics (biocybernetics (BC)) in the fact that it provides an integrated control of BS and ES. BC is an area of cybernetics, investigating and creating control methods and measures of biological objects (measures of biological control). Therefore it is possible to distinguish the following areas out of BTC: technical cybernetics (TC) and BC, which are systematized in respect of each other and create the common decisions. By synchronizing commercial aims with the objectives of BTC (economical gain), economical cybernetics could be formed. Regardless what variant of the cybernetics (from the mentioned ones) would be created, it will be based on: information theory; theory of control methods and theory of control systems. Creation of BTC technologies would be based on: automaton theory; algorithm theory; general system theory; stability theory; invariant theory; optimal control theory; operation research theory; probability theory; etc. By considering the purpose of BTC, the following are distinguished: medical BTC; physiological BTC; psychological BTC; neuro-BTC; phytotronic cybernetics and others.

Further we will narrow our discussion only down to analysis of phytotronic cybernetics. For convenience let's sign it as FC. Plant priority remains in the integrated FC and control takes place by considering the state of the plant, by monitoring its parameters and by using electronics technologies and other measures.

FC technologies (FCT) are based on theories of BC and TC. However, several features are characteristic to them, which determine their research and development trends. According to the objectives of FCT, we can distinguish: features of BO state indicators; features of detection of BO states; features of phytometry (phytotelemetry); features of BO environment and its factors; peculiarities of modeling of BO, BTS and FCT; peculiarities of FC information; FC information transmission peculiarities; peculiarities of FC information analysis; peculiarities of FC decision making, implementation and processing; peculiarities of FC algorithms; peculiarities of FC device development, etc.

In order to research these features and peculiarities, to determine their influence on monitoring and to use them in practice, the following fundamental directions are being developed: experimental FC; theoretical FC, and technical FC.

Although in practice these directions often complement each other, BTC developer is more interested in technical side or the research.

In the further part of the paper we will use abbreviation BO as a symbol of the vegetative structure.

Directions of the research of BO indicators

After selecting BO state (evolution) as an objective of integrated BTS, it is very important to accomplish the research of indicators of this object properly. There is still a lack of potentially all states of BO adequately indicating indicators, particularly: biophysical; biochemical; biomechanical and other. Despite the numerous attempts to relate BO states with its geometrical parameters (e.g. in phytotronics – plant leaf size, shape, nervation, edge smoothness, etc.), neither exact dependencies nor automated measurement devices have been created.

Computerized analysis methods for plant color gamut and its dislocation still are not created also. For this reason this group of BO indicators is also used very cautiously in FCT.

There are many discussions in the field of radiostezic BO indicators, but neither serious confirmation nor disproof of their existence has been stated, not mentioning availability of automated measurement methods of such parameters.

Interrelations of indicators of integral impact of several factors on BO, their integrity formation mechanisms are still not explored, and there are no selective ways and measures to determine this.

There is a lack of indicators for statistic evaluations of dynamics of BO states and calculations of its efficiency.

Systematization methods of selected indicators of BO states should be researched more deeply.

Much of the research should be devoted to the search of indicators, characterizing the early signs of anticipatory BO states.

Methods should be created for evaluation of adequacy of the results of practical application of the model, created using the selected or rational set of BO indicators, to the real state of the object.

These are several and perhaps not the most important directions of research of BO indicators. They will be complemented or will change with the ongoing expansion of the research of BO indicators and their detection possibilities (methods).

Research of methods for detection of BO states

The classification of this research is based on four main problems: what to detect, how to do that, how to control the processes of detection and what technical electronic measures should be used for this purpose.

In general case, when detecting BO states efforts are put to receive the values of biophysical, biochemical, biomechanical, geometric, radiostezic, genetic and other indicators and to determine the randomness (consistency) and dynamics of these values.

Detection should be performed in a way which would allow to relate values of the indicators of all groups, to determine their interdependences, scattering characteristics, influence of environmental factors (including non-stationary and non-forecasted [3]) on them and dynamics in time. Thus at the same time it becomes necessary to detect BO individuals, their features, impacts of environment factors and time. Randomness of indicator values and their dynamics forces to do this several times (rational number of times) and to repeat detection procedures on each specific (rational or specified) period of time.

In general case the type of detection technologies can be directory (specified strictly and in advance) and freely synthesized (by operator or computer) by considering the current situation.

How to select groups of BO and environment factors, moments for their value readings, repeatability, periodicity and also what detection technologies to use – all these aspects are the problems of the future research. This could also become a specific research area of phytometry.

Control (monitoring) of detection procedures (technologies creates opportunities to strive for performance, perfectness, technical and economical rationality, adaptivity, flexibility of these procedures and to increase the level of their intellectuality. In essence the monitoring of the detection is not a new idea. This is already being implemented in most of technical areas. But in FCT it is still not used, therefore it is required and it should be analyzed and implemented. It becomes critically actual when computerizing (intellectualizing) the FCT, when detection measures become partly autonomous (local), they gather information and experience by themselves, and receive only directives (norms) from the central BTS.

The fourth direction of research of detection methods consists of the research of creation techniques of detection measures (DM). When performing these investigations, it is firstly required to foresee the entirety of DM in structural manner, requirements for their modularity, adaptivity, flexibility, performance, mobility, controllability and implementation of distance control. During the further research the additional requirements may arise for operation synchronization, energetic independence, activity level, intellectuality, rationality, versatility, etc. In order to achieve that all DM would form the continuous (compatible FCT measures) entirety, all they should be created using the "from top to down" principle – beginning from requirements for entire FCT, down to requirements for each of its components.

Informatics of FCT

Informatics of FCT is a separate branch of informatics, dealing with FCT information structure, organization, interaction with other control components, data acquisition, storage, processing and transmission regularities and methods.

Research of FCT information is an area of a very broad research, spanning the analysis of the single-basis and multi-basis information. The following is attributed to the multi-basis information: genetic, biochemical, biophysical, biomechanical, radiostesic, etc. types of information. These types can be single-source (obtained from a single source) and multi-source. In the first and the second cases it is necessary to assess the objectivity (reliability) of these sources. For this reason the multi-source information could be more reliable. The reliability of information and its sources is determined by performing the analysis of the mechanism of providing the FCT with data. The evaluations provided below are used for this purpose.
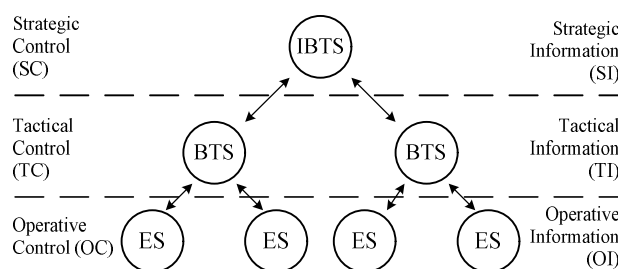

Fig. 2. Control levels

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Since the hierarchy of tasks solved by FCT determines the hierarchy of control levels (systems) [1,2] (ES, BTS, IBTS...) (Fig. 2) – operative tactical and strategic control (OC, TC and SC), hereof some certain information is being acquired and stored in these levels (OI, TI ir SI).

Information of different levels differs in its formation rapidity, level of generalization, transmission rate, etc. Thus it is unequally effcient (reliable) when using it in different control levels (Fig. 3).
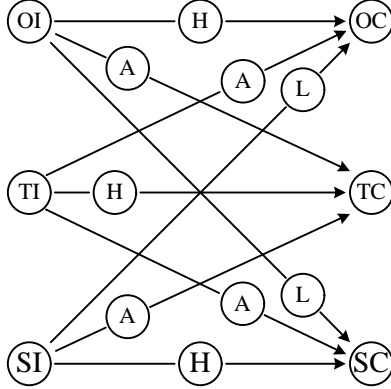

Fig. 3. Information efficiencies (H – high; A – average; L – low)

So, for example, the efficiency of operative delivery of information to the systems in time t is

$$E_{OI}(t) = f_{OI}\begin{pmatrix} I_{OI \to OC}(t), I_{TI \to OC}(t), I_{SI \to OC}(t), \\ E_{OI \to OC}(t), E_{TI \to OC}(t), E_{SI \to OC}(t), t \end{pmatrix}; \quad (2)$$

here $E_{OI \to OC}(t)$, $E_{TI \to OC}(t)$ and $E_{SI \to OC}(t)$ – efficiencies of information of respective levels used for operative control during time t; $I_{OI \to OC}(t)$, , $I_{TI \to OC}(t)$ and $I_{SI \to OC}(t)$ – the amounts of information of respective levels used for this control during time t. Exact expressions of these indicators is an object for the further research. However it is obvious, that e.g.,

$$E_{OI \to OC}(t) = f_O\begin{pmatrix} E_{OIG}(I_{OG}, t), E_{OICH}(I_{OCH}, t), E_{OIP}(I_{OP}, t), \\ E_{OIM}(I_{OM}, t), E_{OIR}(I_{OR}, t), ..., t \end{pmatrix}; (3)$$

here $I_{OIG}(I_{OG}, t)$ – efficiency of genetic information (from the level OI) of amount I_{OG} used for operative control during time t; other symbols denote chemical, physical, mechanical, radiostezic and other information respectively.

Information of any level can be single-value (I_v) (determinated) and partly random (I_A). When performing the operative control, in the first case

$$E_{OI \to OC}^{(V)}(t) = f_V\left(P_{OS}^{(V)}(t), t\right) \quad (4)$$

and in the second case –

$$E_{OI \to OC}^{(A)}(t) = f_A\left(n_{OA}, P_{OS}^{(A)}(t), t\right), \quad (5)$$

here $P_{OS}^{(V)}(t)$ and $P_{OS}^{(A)}(t)$ – reliability of the sources of operative, single-value and partly random (respectively)

information during time t; n_{OA} – number of random values of operative random information.

When the information of the same content is registered during different stages of the analyzed process ($n_E(t)$ is the number of stages), then

$$E_{OI \to OC}^{(A)}(t) = f_{AE}\left(n_{OAi}(t), n_E(t), \left\{P_{OSi}^{(A)}(t)\right\}, \left\{P_{Ai}^{(A)}(t)\right\}, t\right); \quad (6)$$

here $n_{OAi}(t)$ – number of values in the i–th stage during time t; $P_{OSi}^{(A)}(t)$ – reliability of the source of random information from the i–th stage during time t; $P_{Ai}^{(A)}(t)$ – reliability of apriori known analytical relations between random values of the i–th and i+1–th stages during time t.

When a part of random (OI) information is used for OC (e.g., part $I_{OI \to OC}^{(T)}(t)$) is direct, and other part $\left(I_{OI \to OC}^{(N)}(t)\right)$ is indirect), then

$$\begin{aligned} E_{OI \to OC}\left(I_{OI \to OC}^{(T)}(t), t\right) &= \\ &= f_{A1}\left(n_{OA}^{(T)}, P_{OS}^{(A)}(t), I_{OI \to OC}^{(T)}(t), t\right) \end{aligned} \quad (7)$$

and

$$\begin{aligned} E_{OI \to OC}\left(I_{OI \to OC}^{(N)}(t), t\right) &= \\ &= f_{A2}\left(\left\{n_{OAj}^{(N)}(t)\right\}, P_{OS}^{(A)}(t), \left\{I_{OI \to OCj}^{(N)}(t)\right\}, \left\{P_{Mj}(t)\right\}, t\right); \end{aligned} \quad (8)$$

here $n_{OAj}^{(N)}(t)$ – number of values of the j–th indirect information during time t; $I_{OI \to OCj}^{(N)}(t)$ – amount of j–th indirect information; $P_{Mj}(t)$ – reliability of models of formation of j–th direct information from the indirect one during time t.

Information of FCT is dynamic very often – its amount depends on the acquisition time (t_0) (e.g., $I_{OF}(t_0)$) and peculiarities of the acquisition processes. When its amount linearly depends on the acquisition time, then

$$I_{OF}(t_o) = I_{OF1} \cdot t_o; \quad (9)$$

here I_{OF1} – the amount of information acquired during unit of time. When the "satiation" with the information arises, then one of the possible expressions of $I_{OF}(t_o)$ could be

$$I_{OF}(t_o) = I_{OFS}\left(1 - e^{-\lambda_I \cdot t_o}\right); \quad (10)$$

here I_{OFS} – level of information "satiation"; λ_I – intensity of information acquisition. The rational level of $I_{OF}(t_o)$ and the rational duration t_o at the same time could be determined by using the objective operator, e.g.,

$$\min_{t_o} \cdot \left[C_I(t_o) + C_N(t_o)\right]; \quad (11)$$

here $C_I(t_o)$ – expenditure on information acquisition during time t_o; $C_N(t_o)$ – losses due to inadequately

rational decisions of FCT (e.g., when performing the operative control), related to the lack of information (e.g., $I_{OF}(t_o)$). Time t_o determines the rational operativity of control (e.g., OV). However these models do not assess the obsolescence level of the FCT information.

When analyzing the efficiencies of application of stationary and non-stationary information, we could narrow the analysis using the conception, that the first one is one-time and its acquisition in FCT does not pose any bigger problems, and the second one is evaluated by using models (2) – (10).

Separate objects of the research could be: evaluation of efficiencies of differential and integral information; relations between data evaluation methods and their influence on the efficiency of FCT; dynamics of apriori information and its influence of the efficiency of FCT; intellectual acquisition of information and its efficiency; etc.

When solving FCT information acquisition problems, the main objectives are: the assurance and retention of its systematic structure; reliable data storage during the given period, etc.

When FCT information circulates among hierarchical control levels, the need arises to evaluate the efficiencies of its technologies of single-channel and multi-channel transmission from various sources, and also to evaluate other types of efficiencies. Part of these problems have been already attempted to solve [4,5].

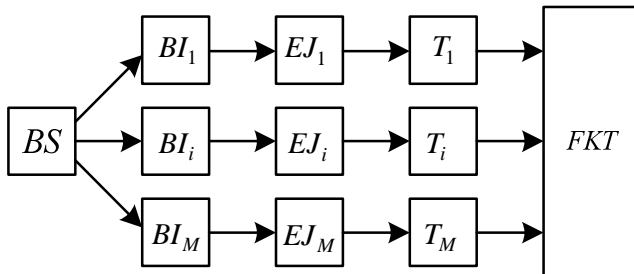Let's consider the scheme of transmission of multi-source information (Fig. 4)

Fig. 4. Scheme of information transmission from the multiple sources

By the use of different biologic indicators ($BI_1 \div BI_M$) the information from BS is relayed to electronic sensors ($EJ_1 \div SJ_M$), transmission measures ($T_1 \div T_M$) and after that to FCT. If the same information is being detected (e.g value of parameter l of BS state L), then the reliability of the i–th source

$$P_i = P_{BI_1} \cdot P_{EJ_i} \cdot P_{T_i} ; \qquad (12)$$

here P_{BI_1}, P_{EJ_i} and P_{T_i} – task accomplishment probabilities of the i–th biologic indicator, electrical sensor and information processing and transmission device. Information of various reliability (efficiency) will enter the FCT (Fig. 5)
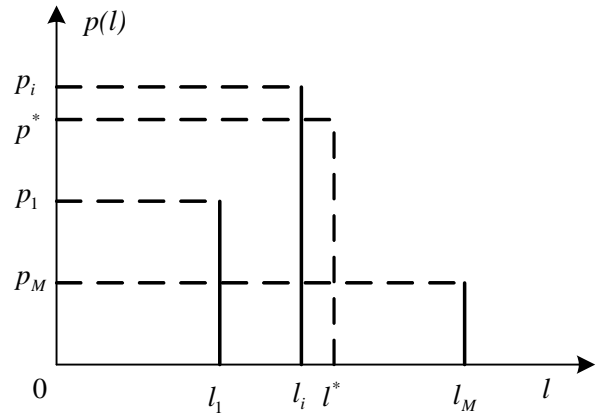

Fig. 5. The reliability of different information evaluations

For this reason the generalized value of the L parameter of the multi-source information

$$l^* = \sum_{i=1}^{M} l_i \frac{P_i}{\sum_{j=1}^{M} P_j} ; \qquad (13)$$

here P_j – task accomplishment probability of the j–th source. In this case the probability that l^* value will fall into the interval from the minimal registered $l_{min.}$ to the maximal $l_{max.}$ is calculated in the following way:

$$P^*_{min.-max.} = 1 - \prod_{i=1}^{M} \left(1 - P_i\right) . \qquad (14)$$

General principles of evaluation of dynamic ES, including the efficiency evaluation of phytotronic systems, have been already formulated [6].

In the future it would be purposeful to investigate the formation variants and efficiency of purpose algorithms, models, partial processes and other attributes of FC. It is still unknown how and what the BS and ES control efficiencies (separately from each other) depend on.

Conclusions

It can be seen from the presented material, that systems of BTS and systems of phytotronics at the same time form only a part of all variously integrated ES and BS. It could be expected, that systems of phytotronics formed on the basis of BTS formation principles would provide higher efficiency of their operation.

When creating these integrated systems, it is purposeful to follow the principles of synthesis of the measures of biotronics and cybernetics. Creation of these systems (their operation technologies) spans the selection of BO indicators and their detection methods, optimization of information acquisition, transmission and application, and other procedures.

In can be seen from the presented reasoning, that the distinctive research direction of FCT informatics is formed when solving problems of FC.

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P. Balaišis, R. Gužauskas, D. Eidukas, A. Valinevičius. Directions of Efficiency Research for Biotronics Technologies // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 1(89). – P. 49–54.

The direction of efficiency research was formulated for biotronics technologies. Distinctiveness of integrated biotronics systems was emphasized in comparison to the other integrated biological and electronic systems. Directions of efficiency research of biotronics systems were formulated and research tasks were formed. The conception of phytotronic cybernetics was offered. Composition of technologies of phytotronic cybernetics was illustrated, directions of efficiency research of these technologies were provided. A conception of informatics of phytotronic cybernetics technologies was offered, peculiarities of information detection, storage and efficiency evaluation of these technologies were demonstrated. It is offered to consider the features of dynamic information, reliability of its sources, data transmission methods, etc. Several directions for the future research were offered. Ill. 5, bibl. 6 (in English; abstracts in English, Russian and Lithuanian).

П. Балайшис, Р. Гужаускас, Д. Ейдукас, А. Валиневичус. Направление исследований эффективности технологий биотроники // Электроника и электротехника. – Каунас: Технология, 2009. – № 1(89). – С. 49–54.

Сформулировано направление исследований эффективности технологий биотроники. Показаны отличительные особенности интегрированных систем биотроники среди остальных интегрированных биотронических и электронных систем. Сформулированы направления исследований эффективности систем биотроники и приведены задачи указанных исследований. Предложено понятие фитотронной кибернетики. Приведен состав технологий фитотронной кибернетики и предусмотрены основные направления исследований эффективности этих технологий. Введено понятие информатики технологий фитотронной кибернетики. Показаны особенности детекции, накопления, обобщения и применения информации фитотронной кибернетики с точки зрения обеспечения её эффективности. Предлагается учитывать особенности динамической информации, её условную случайность, степень интегрированности, надежность источников, способы передачи и области применения. Предложено несколько направлений дальнейших исследований. Ил. 5, библ. 6 (на английском языке; рефераты на английском, русском и литовском яз.).

P. Balaišis, R. Gužauskas, D. Eidukas, A. Valinevičius. Biotronikos technologijų efektyvumo tyrimų kryptys // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 1(89). – P. 49–54.

Suformuluotos biotronikos technologijų efektyvumo tyrimų kryptys. Parodyta, kuo integruotos biotronikos sistemos išsiskiria iš kitų integruotų biologinių ir elektroninių sistemų. Suformuluotos biotronikos sistemų efektyvumo tyrimų kryptys, sudaryti tyrimų uždaviniai. Pasiūlyta fitotroninės kibernetikos samprata. Pateikta fitotroninės kibernetikos technologijų sudėtis, numatytos šių technologijų efektyvumo tyrimų kryptys. Pasiūlyta fitotroninės kibernetikos technologijų informatikos samprata, parodyti informacijos detekcijos, kaupimo ir efektyvumo vertinimo ypatumai. Siūloma atsižvelgti į dinaminės informacijos ypatumus, jos šaltinių patikimumą, duomenų perdavimo būdus ir kt. Pasiūlytos kelios tolesnių tyrimų kryptys. Il. 5, bibl. 6 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).