THE FORMATION OF UNIFIED METHOD OF TECHNOLOGICAL PROCESS EFFECTIVENESS EVOLUTION

УДК 519.71:658.51:629.58

TRUNOV Oleksandr Mykolajovych
First Vice-Rector, Ph.D., professor dept. of medical equipment and systems,
Black Sea State university named after Petro Mohyla.
Scientific interests: robotics, sensors, automated control systems, mathematical methods of modeling of nonlinear processes and objects.
e-mail: ant@kma.mk.ua, trunovalexandr@gmail.com

The commonality of creation and technology modernization processes allows to point three general stages: cognitive analyses; quantative evaluation; decision-making, which perfectness is directly determined by the quality of used effectiveness index [1-7]. In this context the task scientifically based of preparation and decision making depends on effectiveness index choice and is the actual problem [8, 9]. The research [2,9] is aimed to create methods allowing to present factors of different physic nature under limited metric space, to insert the rules of their structuring [2-5], to create the single metric for criterial and noncriterial structuring of alternatives [9].

Considered examples in which utility functions are deduced in according to the existing equipment and the examples of calculating of weight coefficients of convolution on the base of uniqueness metrics or on the base known of value effectiveness index and weight coefficients for prototype allow to compare the alternatives under comparable conditions [9]. Hence, vector's model of presenting data and multi-factor analyses for complicated systems can not be effective as it is based on the old principals of geometric modeling and computer graphic [6,7].

However, the search of a single standard criteria of effectiveness evaluation as the unified method of measure and which will be able to consider impact of multi factors is not possible. Such conclusion was made by a team of scientists in 1967 in the result of the attempts to create the standard criteria of effectiveness.

Moreover, the main unsolved problem is the task of creating qualitative effectiveness criteria based on these results and on the analyzed work [6-7, 9, 10, 12] can be reformulated as the task of creating of method standard deducing of formula the criteria of effectiveness for any technology operation or process.

The purpose of article is to create of standard method of deducing of the formula of vector effectiveness in contrary to other tries to create standard index of technological effectiveness.

POINTING THE TASK

Let's consider the system of technological operation process of any type or simple technological operation, that in during of its functioning, achieves the aim, value of quantities which as result is measured directly or indirectly and is introduced through known physical limited or unlimited quantities . The last ones as it is shown in the research [9] should be defined, by dividing all of them into two groups. The first group type of quantities is absolute goal achieving or executing as result, which means that it is describing quantities (characteristics) which have to be achieved or have to be executed in during solving the task as its result with required accuracy.

The first group of quantities is unabsolute goal achieving or executing. They are variables and consider as quantities which will be maximized or minimized in during its functioning. As for the vector of effectiveness, its com-

ponents should be evaluated using the certain demand of uniqueness which can be fulfilled under the terms of monotonicity.

Monotonicity is equivalent to the demand according to which the effectiveness value is bigger for bigger value of physical quantity as one from its component and under the fixed of others. To provide such ability it's enough for example for the physical quantity which impact is pointed by the index of the component and value of which is minimized, as the component of effectiveness vector inverse value of physical quantity is chosen; if it never does not accept a value of zero. If it is will accept «zero», then the problem of possible zero division can be solved by shifting origin of axis on the value of calculation mistake.

LET'S DISCUSS TWO APPROACHES

Based on the idea of existence of n-dimensional functional space where the value of dimension for any point determined by the type of metric in according to primary of effectiveness hypothesis, is considered as a uniqueness and n-dimensional space of real numbers which includes all mentioned criteria is to be created. Let's insert a single metric which is able convert all n-dimensional functional space into n-dimensional metric space. If for all value of effectiveness vector sum of modules of components is chosen as the norm of metric, then effectiveness vector can be obtained:

$$E = \left|\overline{G}\right| + \left|\frac{1}{\overline{C}}\right| + \left|\frac{1}{\overline{T}}\right| + \left|P\right|,$$

where denoted G,C,T,P – the appropriate of value dimensional physical quantity, measured the results of technology conducting, the resource consumption and time expenses as well as probability of its fulfilling with the required quality being from interval of real number from zero till one. However, in according with geometrical inequality, let's find out its minimum – the low bound value of physical quantity:

$$E = \frac{1}{4}\left(\left|\overline{G}\right| + \left|\frac{1}{\overline{C}}\right| + \left|\frac{1}{\overline{T}}\right| + \left|P\right|\right) \geq$$

$$\left(\frac{\overline{G}}{\delta_1}\right)^{\delta_1}\left(\frac{1}{\overline{C}\delta_2}\right)^{\delta_2}\left(\frac{1}{\overline{T}\delta_3}\right)^{\delta_3}\left(\frac{P}{\delta_4}\right)^{\delta_4}$$

Such approach allows to consider the impact of weight of different factors on the value of physical quantity of effectiveness. Its usage and quality of gained result directly connected with reasonableness of weight coefficients determining, which calculating is considered as the second difficult task and additionally makes more complicated solving out the first one. Never the less, based on the hypothesis of factors influence equality, their determines the upper and low bounds of possible value of physical quantity may be written:

$$\left(\frac{\overline{G}P}{\overline{C}\overline{T}}\right) \leq E \leq 4\left(\frac{\overline{G}P}{\overline{C}\overline{T}}\right)^{1/4}.$$

The second approach to the problem of choice metric is based on the hypothesis of influence of number subspaces. So let's introduce metric

$$N^n = \sum_{i=1}^{n} \left|F\right|_i^n,$$

then for the case of four equivalent units and according to the geometric inequality after simple algebraic transformation there will obtained the relation:

$$E = \frac{1}{4}\left(\left|\overline{G}\right|^4 + \left|\frac{1}{\overline{C}}\right|^4 + \left|\frac{1}{\overline{T}}\right|^4 + \left|P\right|^4\right) \geq \left|\overline{G}\right|\left|\frac{1}{\overline{C}}\right|\left|\frac{1}{\overline{T}}\right|\left|P\right|.$$

For the case when the impact of different factors is not equal but is pointed by of weight coefficients, the minimum of effectiveness value can be evaluated using renewed form of the same geometrical inequality

$$\left(\left|\overline{G}\right|^4 + \left|\frac{1}{\overline{C}}\right|^4 + \left|\frac{1}{\overline{T}}\right|^4 + \left|P\right|^4\right) \geq$$

$$\left(\frac{1}{k_1}\right)^{k_1}\left(\frac{1}{k_2}\right)^{k_2}\left(\frac{1}{k_3}\right)^{k_3}\left(\frac{1}{k_4}\right)^{k_4}.$$

$$\left|\overline{G}\right|^{4k_1}\left|\frac{1}{\overline{C}}\right|^{4k_2}\left|\frac{1}{\overline{T}}\right|^{4k_3}\left|P\right|^{4k_4}$$

So, in according to the properties of power function, the gained formula allows to evaluate the upper and lower bounds of effectiveness index

$$\left|\overline{G}\right|\left|\frac{1}{\overline{C}}\right|\left|\frac{1}{\overline{T}}\right|\left|P\right| \leq E \leq 4\left|\overline{G}\right|\left|\frac{1}{\overline{C}}\right|\left|\frac{1}{\overline{T}}\right|\left|P\right| \quad (1)$$

Let's demonstrate that the created approach gives the monosemantic (unequivocal) results, which coincides with the traditional expressions of effectiveness index for the known technological processes. To create the effectiveness criteria let's discover a few systems dealing with technological processes.

GENERATING SYSTEMS

Let's suppose that the result of work of the engine is usefull mechanic work *A*, but consumptions for it's conducting are valuated by the expenditure of heat energy *Q*, under the conditions of equal influence with 100% - probability of conducting without time impact the following formula is given

$$E \geq \frac{A}{Q} = \eta , \qquad (2)$$

with the precision up to constant multiplier. It coincides with the wide-known notion of heat-engine effectiveness evaluation – the coefficient of efficiency of heating machine. Counting the time impact *T*, let's write down

$$E \geq \frac{A}{qT} = \frac{N}{q}, \qquad (3)$$

when *N* is usefull power, given by an engine and *q* is heat power given by combustion chamber

System of economic activity. Suppose that in the result of economic activity a company got profit P_r without counting the time impact under 100% probability of conducting process, having expenses *C*, the effectiveness is calculated by relation:

$$E \geq \frac{P_r}{C}, \qquad (4)$$

which also coincides with the generally used relation of effectiveness of economic activity profitability. To count the impact of *T* let's write down:

$$E \geq \frac{P_r}{CT}, \qquad (5)$$

such index although have less wide spread but it fully evaluates the effectiveness as it considers the speed of money circle. Inserting the probability points the amount of risk *R* which considers the probability of commodities

$$E \geq \frac{P_r}{CT}, \qquad (6)$$

presents the index of effectiveness under risk

$$P = 1 - R$$

pointing

$$E \geq \frac{P_r}{CT} P = \frac{P_r}{CT}(1 - R). \qquad (7)$$

INFORMATION TECHNOLOGIES

Let's consider information technology in the result of which the volume of data V_d for time limit *T* is gained; but general expenses for conducting the technology algorithm is valuated by C_s, the probability of algorithm conducting P_d is pointed by the probability of possible rejections or bags R_d lead ing to failure results, the minimum evaluation of effectiveness is pointed

$$E \geq \frac{V_d}{C_s T} P_d = \frac{V_d}{C_s T}(1 - R_d). \qquad (8)$$

So, the effectiveness evaluation of information technology is determined by the quality of algorithm, reliability of written software and the type of chosen hardware. Last time because of increasing number of operations, the difficulty levels and time limits required for creating software, the principle of team making under certain modules is used more often. There are advantages of such approach which are determined by reducing the required time for fulfilling the project it self. However, the increased number of bags appearing as rule in the result of technology by team creating of synthesized software usually demands more time for its of search out and rewriting code of the programme. The dynamic of the process of defects elimination and influence of different factor was discovered in a number of researches [9-12]. It allow to investigate the dynamic of effectiveness evaluation for informational technologies with the synthesized software throughout time.

EDUCATIONAL TECHNOLOGY

Suppose, in the result of conducted educational technology, N specialists were prepared; they were gained a number of skills and knowledge to provide K competences with probable evaluation of achieved level objectiveness P_t, for training period of time T_t, with general expenses C_t.

Under these terms the effectiveness defined as

$$E \geq \frac{NK}{C_t T_t} P_t . \quad (9)$$

SEARCH-INSPECTION WORKS

Underwater technology conducting a search, for example of defects by the inspection and measuring the condition of width of tube and isolation on the surfaces S_i, with probability of finding the search object or defects P_i for the period of time T_i, with the total cost of inspection work C_{is}. Under these terms the effectiveness evaluation is

$$E \geq \frac{S_i P_i}{C_{is} T_i} = \frac{S_0(1-\alpha)(1-\beta)\left(T_a - T_з - T_в - \sum_{j=1}^{m} T_j\right) P_i}{C_{is}\left(T + T_e\right) T_i}, \quad (10)$$

where T_a is value of autonomy which measured in units of time work of underwater robots, $T_з$ is time of immersion to working depth, $T_в, T$ is time of emersion and motion due to using own energy resources, T_j - is time of technology number - j of diagnostic process, α and β are indexes of overlapping on mutually perpendicular directions, S_0 is area of examining during one exposition.

EMERGENCY-REPAIRING WORKS

Underwater technology conducting the repairing work the result of which can be valuated by laboriousness T_t or qualitative for monotypes technological operation N_o, conducting with the probability evaluation P_i and for period of time T_i, under it the quantity of general expenses is C_0. Under such terms the effectiveness evaluation is

$$E \geq \frac{T_t P_i}{C_o T_i} = \frac{T_t P_i}{C_o\left(T_a - T_з - T_в - \sum_{j=1}^{m} T_j\right)}. \quad (11)$$

DISCUSSING THE RESULTS

Discovered examples of choice metric are not to be considered as single possible from set of approaches. However, the low bound of evaluation of effectiveness coincides for two out of mentioned examples of its choice. Examples of six technologies allow to show the possibility of such approach as the standard method for creating of the effectiveness criteria. At the same time, presented examples are considered as one – stage of process. Mainly under the management strategy choice in the process of designing for complicated automatic systems, technological process is considered as the unity of followed and parallel operations, effectiveness evaluation of each of them is made using the offered method

$$C_{total} = \sum_{i=1}^{N} C_i , \quad (12)$$

where C_{total}, C_i, i, N are expenses of general re source and of certain operation, number of operations and their number. Then general effectiveness is calculated via its value of physical quantity for alternative operation.

$$E_{total} = \frac{A_{total} P_{total}}{T_{total}} \left(\sum_{i=1}^{N} Ci\right)^{-1} = \frac{A_{total} P_{total}}{T_{total}} \left(\sum_{i=1}^{N} \frac{A_i P_i}{T_i E_i}\right)^{-1} .$$

CONCLUSIONS:

1. Offered methods due to choice of special metric allow to get evaluation of low and the upper bounds of the effectiveness index which determine their qualitative in according with any variation of weight coefficients influencing the quantity.
2. Pointing the effectiveness index coincide with the traditional formulas of effectiveness index for known technological process and are considered as the simple algorithm which can be used as a standard.
3. Discovered law allowed to determine the effectiveness of a complex technological process via of efficiency values of it's components.

REFERENCES:

1. Bardachov Ju.M., Sokolova N.A., Hodakov V.E. Diskretna matematika //Pidruchnik. – K.: Vishha shkola, 2007. – 328 s.
2. Kovalenko I.I., Dragan S.V., Sagan' V.Ja. Sistemnij analiz zadach sudovogo korpusostroenija: Monografija. – Nikolaev: NUK, 2010. – 175 s.

3. Kovalenko I.I. Analiz i sistematizacija modelej i metodov prinjatija reshenij //Vestnik Hersonskogo nacional'nogo tehnicheskogo universiteta. – 2005. – №1. – S.25-30.
4. Kovalenko I.I. Informacionnoe opisanie soglasovannosti jekspertnyh ocenok proektov //Zb. nauk. prac' NUK. – 2003. – №6. – S.141-149.
5. Kovalenko I.I. Scenarnyj podhod v analize innovacionnyh proektov. – Nikolaev: Izd-vo UGMTU im. adm. Makarova, 2003. – 60 s.
6. Fedorov Ju.N. Spravochnik inzhenera po ASUTP: proektirovanie i razrabotka. – M.: Infa-Inzhenerija, 2008. – 928 s.
7. Paklin N.B., Oreshkov V.I. Biznes-analitika: ot dannyh k znanijam (+ SD). – SPb: Piter, 2009. – 624 s.
8. Trunov A.N. Rekurentna aproksimacija u zadachah modeljuvannja ta proektuvannja: Monografija. – Mikolaïv, 2012. – 270 s.
9. Trunov O.M. Rozvitok metodiv ocinki efektivnosti sistem upravlinnja robotizovanimi kompleksami u glibokovodnih tehnologijah //Vestnik Hersonskogo nacional'nogo tehnicheskogo universiteta. – 2013. – №1 (46). – S.328-337.
10. Trunov O.M., Volkova S.O. Osoblivosti zastosuvannja kriteriïv ocinki sintezovanogo programnogo zabezpechennja sistem giperspektral'nogo analizu viznachennja skladu rechovin //Zbirnik naukovih prac' NUK. – 2007. – №5 (416). – S.121-130.
11. Trunov O.M., Volkova S.O. Analiz metodiv i zasobiv pidvishhennja jakosti ta nadijnosti sistem medichnoï diagnostiki //Naukovij zhurnal. – №2. Matematichni mashini i sistemi. – 2008. – S.158-164.
12. Trunov O.M., Volkova S.O. Modeljuvannja nadijnosti strukturovanogo programnogo zabezpechennja //Matematichne ta komp'juterne modeljuvannja. Serija: Tehnichni nauki: zb.nauk.prac' /Institut kibernetiki im.. V.M.Glushkova Nacional'noï akademiï nauk Ukraïni. – Kam'janec'-Podil's'kij: Kam'janec'-Podil's'kij nacional'nij universitet, 2008. – Vip.1. – S.156-164.
13. Remzi Sanver M. Strategy-proofness of the plurality rule over restricted domains/Remzi Sanver M. Economic Theory, June 2009, Volume 39, Issue 3, pp.461-471.
14. Tariq Samad The Impact of Control Technology //Overview, Success Stories, and Research Challenges //Edited by:Tariq Samad and Anuradha Annaswamy, This report is available online at http://ieeecss.org/main/IoCT-report. February 2011, p.234.

Рецензент: *д.т.н., проф. Крючковский В.В., Херсонский национальный технический университет*