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Creation of technical expert system on the basis of the diagram of Vyshnegradsky

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Article describes whole methods of the creation computer-technical ES, basing on diagram Vyshnegradsky. This methods itself is founded on positions of the theories pulsating characteristics (TPCh), offered *Aubakir D. A.* in 80th years XX centuries. ES in ambience of the program system Delphi created магистрант *Kaliev Arnay* in 2009. The technical side of the project managed *AUBAKIR Daurenbek*, consultant on mathematician was *Karimov Sabit*. The Idea has voiced the known specialist on robotics *Timofeev Adil* (1991). The Technical realization for automation of the diagnostic checking on operating the complex technology is entrusted on *AZEN Erabylai*.

Introduction. As it is known, the schematic design i.e. the diagram Vyshnegradsky (DV) which received subsequently his name, for the first time *Ivan Vyshnegradsky* had constructed it in 1876 in the work which originated the automatic regulation theory. It had the further development in other basic works, in particular, in [1, p. 121], and also appendices in other sections of cybernetics. Attractiveness of this concept is not transforming. The reasons for that are his exhaustive character and presentation of geometrical interpretation of the investigated characteristics of dynamic systems of the third order by means of this concept. It is quite natural to assume, that the DV will find not primitive application and in technical diagnostics, in the stabilization theory, in the theory of adaptive systems. We will show further also that this concept can find with not smaller success appendices in such sections of cybernetics what the theory of intellectual systems and the theory of self-trained systems are insufficiently developed for today.

Problem statement:

Let's preliminary formulate a number of the problem problems realizing idea of the appendix of the diagram Vyshnegradsky in technical diagnostics and in a problem of adaptation of technical systems [2-3], prompted by the known expert of the theory of adaptive systems, by Professor *A.V. Timofeev* in 1991. It was found out that this idea is fruitful also in creation of a technical variant of expert system, i.e. it also enclosed in the theory of an artificial intellect (AI) [4].

Let's consider as an object of research of a condition of the technical system, described by the diagram of Vyshnegradsky.

Within the limits of an investigated problem we will try to solve the following problems:

- to find expression of diagnostic function by means of DV depending on system parameters with the help of which it would be possible to forecast its correct (desirable) functioning, i.e. working capacity of system (Problem **P1**);

- to express unknown parameters of a required intellectual regulator through object parameters so that dynamics of the grouped closed system: IR+RO = (an intellectual regulator plus regulation object) submitted to the working capacity requirement (Problem **P2**);

- to investigate fluctuation of parameters in the established mode of system functioning, and also their drift from one mode to another, being in a plane of Vyshnegradsky (PV) parameters, which would promote to organize automatically adjustable transitions of system from one condition (undesirable) to another condition (wished) (Problem **P3**).

The note: Anticipating things, we take a note that through the known concepts of technical diagnostics (TD) we lay a way to more capacious theory - to cybernetic diagnostics (CnD). Therefore, though expected results of the decision above the formulated problems are intended for the decision of private problems TD, actually we intend to construct a technical variant of expert system (ES) intellectual, self-trained control of functioning DS of 3rd order. In other words, we aspire to the decision more the general problems of cybernetics of the technical content.

§ 1. Steady-prognostic indexation of working capacity dynamic systems

For the decision of the problem **P1** we shall address to the DV on fig. 1: it is constructed based on standardized characteristic equation DS of the third order

$$g^3 + a \cdot g^2 + b \cdot g + 1 = 0 \tag{1}$$

where factors a and b, are called as parameters of system or Vyshnegradsky parameters.

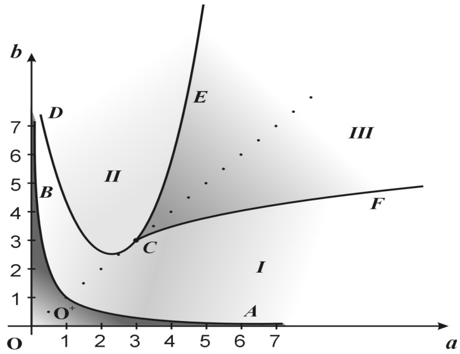

Figure 1. Diagram of Vyshnegradsky

Here lines of the diagram are marked in the manner of functional dependencies: AB: $b = W_{11}(a)$, $CD : b = W_{12}(a)$, $CE : b = W_{22}(a)$, $CF : b = W_{21}(a)$.

The Line AB, presenting branch of the single hyperbole, expresses the border of stability; line CD, presenting border between areas I and II, is expressed by formula

$$b = (2 \cdot a^3 + 27)/(9 \cdot a) \tag{2}$$

lines CE, CF present two out of three actual radix of the cubic equation

$$a^2 \cdot b^2 - 4 \cdot (a^3 + b^3) + 18 \cdot a \cdot b - 27 = 0 \tag{3}$$

These lines split the first quadrant to planes parameter systems on 4 zones with determined formed cut operation DS in each zone. The Zone between axises of the coordinates and hyperbole shall name the zero zone and shall mark 0^+ , but rest zones we shall mark with Roman numeral.

We shall add a numeric importance to each zone, coinciding with its serial numbers, and we shall define the sought-for diagnostic function of DS work capacity:

$$\mathbf{v}(a,b)=\begin{cases} 0, \text{ if } (a\cdot b)<1 \\ \quad \text{(Mode of dispersing processes)} \\ 1, \text{ if } [(a\cdot b>1) \text{ and } (a<3) \text{ and } (2\cdot a^3\text{-}9\cdot a\cdot b+27)>0] \text{ or} \\ \quad [(a>3) \text{ and } (a\cdot b>1)] \text{ and } [(a^2\cdot b^2\text{-}4\cdot(a^3+b^3)+18\cdot a\cdot b\text{-}27<0) \text{ and } (a>=b)] \\ \quad \text{(Mode of oscillatory-steady processes)} \\ 2, \text{ if } [(2\cdot a^3\text{-}9\cdot a\cdot b+27<0) \text{ and } (a<=3)] \text{ or} \\ \quad [(a^2\cdot b^2\text{-}4\cdot(a^3+b^3)+18\cdot a\cdot b\text{-}27<0) \text{ and } (a>3) \text{ and } (b>=a)] \\ \quad \text{(Mode of monotonously-steady processes)} \\ 3, \text{ if } [a^2\cdot b^2\text{-}4\cdot(a^3+b^3)+18\cdot a\cdot b\text{-}27>=0] \\ \quad \text{(Mode of aperiodic-steady processes)} \end{cases}$$

§ 2. Algorithms of self-adjustment, stabilization and forecasting working capacity dynamic systems on the basis of a method of pulsating characteristics

At the decision of problem **P3** we will adhere to following assumptions:

- Evolution of functioning dynamic system is accompanied by degradation processes at a parametrical level, i.e. the system undergoes structural transformations that, in turn, will cause changes of some parameters. These changes can have natural or casual character. One of problems TD is the problem of forecasting of working capacity, which is frequently identified with a forecasting problem technical conditions of object of diagnosing. The first assumption from here follows: parameters a, b serve as indirect diagnostic indicators DS, adequate to investigated system of the third order, and as consequence from this assumption research of the problems connected with diagnosing of technical condition DS is replaced with research condition of systems in space of parameters a, b.

- The Second assumption is connected with possibility of active intervention in some processes in space of parameters, in particulars in process of change of parameters a, b or their tracing.

- Thirdly, it is supposed that hierarchy DS is enough highly complex, and it possesses such properties, as parametrical controllability, at least - as parametrical adjustability or adjusting. In other words, in it should be inherent diagnosing besides, we lay down one more condition: smooth transition from TD to possibilities of cybernetic diagnostics (CnD). And it assigns to the CS, in general, to a synthesized regulator, in particular, additional requirements of the intellectual maintenance, consisting that, finally, and working out should lead to creation of the technical version of expert system (ES).

In connection with the accepted assumptions we quite purposely are declined towards applied aspects of a discussed problem and we put them in the head of the undertaken researches.

It is necessary to stipulate in advance about an agreement before starting the process of the decision of problem **P3**. Change of parameters DS - hardly controlled process, therefore it becomes traditional not absolutely scientific approach to treatments of accompanying concepts. Here it is enough to recollect such concepts, as "fluctuation"(in some sources - fluctuation) parameters, "drift"of parameters, "threshold value"parameters. Even "rating value"(sometimes - face value) parameters yet quite scientifically sounding concept. But, so far as for today there are no quite scientifically well-founded alternatives to these treatments, wish to stipulate the agreement: About parameter fluctuation we will speak, if it is a question of approach of its values to any threshold (frontier) value, about drift of parameter we will tell, if values of parameter, having left some the established mode, pass in another established mode, and presence of several similar modes will be clear on a context.

Now, for the purpose of the decision of problem P3 we will return to the diagram Vyshnegradsky with the values of the up-index of working capacity specified to it (fig. 1 see!). Naturally, it is possible to judge "deterioration"or "improvement"of a condition of system in what (big or smaller) the party value of an index changes at drift of parametrical pair (a, b), i.e. points in space of parameters a, b. If there will be a drift from a zone III in a zone II, or in a zone I the SP-index (stable-prognostic-index) will decrease; if there will be a drift upside-down the SP-index will increase. In the first case (a case of reduction of an index) we have deterioration, in the second case (a case of growth of an index) we have improvement of a condition of system. Naturally, words "improvement", "deterioration"of conditions of system have conditional character, but in practice these words can bear in themselves certain semantic loading.

Drifts of parameters can happen from zone II to zone I and, on the contrary, from I to II. And here if there is a pair drift (a, b) from zone I to zero zone (a zone of unstable dispersing processes where SP-index $\nu = 0$), deterioration of a condition of system will be almost perceived, really, in it of cases the system from a stability mode "rolls down"in an instability mode. While we answer such question: how and on which trajectory to withdraw a point (a, b) "far away"from threshold values and if it is possible, with simultaneous increase in the SP-index? Here there is a collateral question: where and how much "far away"? Yes, the answer arises: towards rating values. But, then - still a question: where and how to choose these face values? Somehow to discharge this situation with a never-ending chain of questions we will construct a working capacity SP-index:

$$\upsilon(a,b)=\begin{cases} 0, & \text{mode of dispersing processes (zone } 0+\text{):} \\ & \text{- key: } a\cdot b=1; \\ 1, & \text{mode of oscillatory-steady processes (zone I):} \\ & \text{- threshold: } a\cdot b=1, \\ & \text{- key:} \\ & \text{-- first: } 2\cdot a^3-9\cdot a\cdot b+27=0, \\ & \text{-- second: } b=W_{21}(a); \\ 2, & \text{mode monotonously-steady processes (zone II):} \\ & \text{- threshold: } 2\cdot a^3-9\cdot a\cdot b+27=0, \\ & \text{- key: } b=W_{22}(a); \\ 3, & \text{mode aperiodic-steady processes (zone III):} \\ & \text{- threshold: } a^2\cdot b^2-4\cdot(a^3+b^3)+18\cdot a\cdot b-27=0 \end{cases}$$

Here the word "threshold"designates signs of reduction SP-index, i.e. - deterioration of a condition of system; a word "key signs increase the SP-index, i.e. improvement of a condition of system; functions $W_{21}(a)$, $W_{22}(a)$ represent accordingly bottom and top border lines of a zone III in the diagram Vyshnegradsky, they are roots of the cubic equation received by equating to zero of a discriminant of a cubic multinomial from the right part of characteristic equation DS

$$a^2\cdot b^2-4\cdot(a^3+b^3)+18\cdot a\cdot b-27=0$$

Apparently, from the last definition of the SP-index (4) same parity (for example, $a\cdot b=1$) in one case plays a role "threshold", i.e. a deterioration sign, and in another case - "a key"role, i.e. improvements of a condition of system, at the same time it is impossible to admit and that if the system approaches the "threshold"spontaneously, then the key can give the chance to active interventions in evolutionary-degradation processes, occurring in system, and turn them back.

Let's recollect, now, that parameters *a, b* vary continuously. Consequently, to achieve the key parity instantly is not possible. As one of possible ways of overcoming ways of arisen problems is to use the method of pulsating and portional characteristics. This method allows to construct a trajectory, connecting two free points, and if both points belong to one zone and the constructed line connecting these points, will be entirely in this zone. Such quality pulsating in two points of characteristic is capable to guarantee demanded quality of transition from a starting point to the target point, concluded in that during transition was not supposed deterioration of system conditions, including loss of working capacity by it.

If the point $(a,\ b)$ appears in a zero zone $0^+=[(a,b)|a\geq 0,\ b\geq 0,\ a\cdot b<1]$, that depending on what of two inequalities: $a>b,\ a<b$ will take place, as base we take one of strips:

$$P^0{}_{0a}=\{(a,b)\,|\,a\in[0,+\infty],\ 0\leq b\leq\frac{1}{a}\}$$

$$P^0{}_{0b}=\{(a,b)\,|\,b\in[0,+\infty],\ 0\leq a\leq\frac{1}{b}\}$$

accordingly. These two strips though mean the same zero zone 0^+, differ that for the front page in required functional dependence of the pulsating characteristic the parameter a is argument, parameter b is function, and for the second strip, on the contrary, b is argument, a is function. If the point $(a,\ b)$ appears on a bisector it is necessary to try to carry out transition of parametrical condition DS along a bisector and to make values $a=b\geq 3$, i.e. as much as big, than 3.

Let's admit, the starting point of M with co-ordinates a_0, b_0 has appeared in P^0_{0a}. Then it is possible to assume different trajectories for improvement of a condition of system. We will undertake some possibilities of such improvement:

1. let's connect point M with point Q(1, 1);
2. let's connect point M with point C(3, 3);
3. let's connect point M with point G(c, c), c>3.

For the decision of this problem it is possible to take advantage of following formulas:

$$g_1(a) = \frac{-W_{11}(a) + r_1 \cdot W_{11}(a_0 + 1 - a)}{r_1^2 - 1} \equiv \frac{r_1/(a_0 + 1 - a) - 1/a}{r_1^2 - 1};$$

$$g_2(a) = \frac{r_2 \cdot W^0{}_{12}(a_0 + 3 - a) - W^0{}_{12}(a)}{r_2^2 - 1}$$

$$g_3(a) = \frac{r_3 \cdot W^0{}_{22}(a_0 + 1 - a) - W^0{}_{22}(a)}{r_3^2 - 1}$$

where scalar values $r_i \neq 1, i = 1, 2, 3$ constant along line $b = g_1(a)$, $a_0 < a < 1$; $b = g_2(a)$, $a_0 < a < 3$; $b = g_3(a)$, $a_0 < a < c$ accordingly.

Each of these line when performing the certain conditions will wholly be kept in band accordingly, limited by rulers: b=0 - from below, b=1/a - overhand; $b = W^0_{12}(a)$ - overhand; b=0 - from below, $b = W^0_{22}(a)$ - overhand, as well as allows to build to trajectories

$[(a, b)|\ a_0 < a < 1,\ b = g_1(a)]$,

$[(a, b)|\ a_0 < a < 3,\ b = g_2(a)]$,

$[(a, b)|\ a_0 < a < c,\ b = g_3(a)]$,

accordingly solving problem in events **a**, **b**, **c**. Possible, source point $M(a_0, b_0)$ turned out to be in band P^0_1, limited from below line $b = W^0_{11}(a) \equiv 1/a,\ a \in A^0$, overhand line

$$b = W^0{}_{12}(a) \equiv \begin{cases} W_{12}(a), & a \in A_1 \\ W_{21}(a), & a \in A_2 \end{cases}$$

where $A_1 = [0, 3]$, $A_2 = [3, +\infty)$, $A_1 \cup A_2 = A^0$; $W^0_{12} \equiv (2 \cdot a^3 + 27)/(9 \cdot a)$ - *CD* line on the diagram Vyshnegradsky. Then as trajectories of transition from this point in points *C*, *G* accordingly can serve

$[(a, b)|\ a_0 < a < 3,\ b = g_4(a)]$,

$[(a, b)|\ a_0 < a < c,\ b = g_5(a)]$,

where

$$g_4(a) = \frac{r_4 \cdot W^0{}_{11}(a) - W^0{}_{12}(a) + r_4 \cdot (W^0{}_{12}(a_0 + 3 - a) - W^0{}_{12}(a_0 + 3 - a))}{r_4^2 - 1}$$

$$g_5(a)=\frac{r_5\cdot W^0{}_{21}(a)-W^0{}_{22}(a)+r_5\cdot(W^0{}_{22}(a_0+1-a)-W^0{}_{21}(a_0+1-a))}{r_5^2-1}$$

Here scalar sizes $r_4 \neq 1, r_5 \neq 1$ are constant along a line $b = g_4(a),\ a_0 < a < 3;\ b = g_5(a),\ a_0 < a < c$ accordingly, and at performance of certain conditions these lines accordingly contain in strips $P_1^0,\ P_2^0:\ P_2^0$ - it is limited from below by a line $b = W_{21}^0(a) \equiv 1/a,\ a \in A^0$, from above a line

$$b= W^0{}_{22}(a) \equiv \begin{cases} W_{12}(a), & a \in A_1 \\ W_{22}(a), & a \in A_2 \end{cases}$$

Let's admit, it is required to translate a system condition from point $M(a_0,\ b_0) \in P_{22} = [(a,b)|a \in A_2, W_{21}(a) \leq b \leq W_{22}(a)]$ in desirable point $G(c,c),\ c \geq 3$, belonging bisector, and on the trajectory which are not falling outside the limits given strip P_{22} . A trajectory necessary for it also we will construct, having taken advantage of the formula:

$$g_6(a)=\frac{r_6\cdot W^0{}_{21}(a)-W^0{}_{22}(a)+r_6\cdot(W^0{}_{22}(a_0+1-a)-W^0{}_{21}(a_0+1-a))}{r_6^2-1}$$

where the scalar size r6 is defined, how

$$r_6 = \frac{W_{22}(1)-1}{a_0 - W_{21}(a_0)} \neq 1$$

and remains to a constant along a required trajectory $[(a,b)|a_0 < a < c,\ b = g_6(a)]$.

That this trajectory entirely belonged to strip $_{22}$ it is necessary and enough the performing calculations:

1) under $0 < r_6 < 1$ condition

$$min \quad [W^*;\ W^{**}] \geq r_6\ ;$$

$$a_0 < a < c$$

2) under $r_6 > 1$ condition

$$max \quad [W^*;\ W^{**}] \leq r_6\ ;$$

$$a_0 < a < c$$

where $W^* \equiv (W_{22}(a_0+c-a) - W_{21}(a_0+c-a))/(W_{22}(a) - W_{21}(a));\ W^{**} \equiv 1/W^*$.

The note: For the purpose of improvement of a condition of system and its transfer into a bisector it is possible to take advantage also "exportional"of a curve concerning strip $P_1^0:\ b = W_1'(a) \equiv s'\cdot W_{21}^0(a) + (1-s')\cdot W_{11}^0(a), a \in A^0$ where the scalar size $s' > 1$ is constant along a curve and it is defined by a starting point:

$$s' = (b_0 - W_{11}^0(a_0))/(W_{12}^0(a_0) - W_{11}^0(a_0)) \tag{4}$$

If to move on a trajectory $[(a,b)|\ a \geq a_0,\ b = W_1'(a)]$ towards increase of parameter a the bisector as soon as becomes $b = a$ is by all means reached. Thus in a point of intersection of the characteristic with a bisector it has $b = a > 3$ if only the M starting point is located strictly inside II.

REFERENCES

1. Nejmark J.A., Kogan N.J., Savelyev V.P. Dynamic models of the theory of control. (In Russian). - M.: Science, 1985. - 400 p.

2. Timofeev A.V. Robots control. (In Russian). - Leningrad, 1986. - 240 p.

3. Timofeev A.V. Adaptive robot-technical complexes. (In Russian). - Leningrad, 1988. - 332 p.

4. Hant E. Artificial intelligence. (In Russian). - M.: Mir, 1978. - 523 p.

5. Aubakirov D.A. Theory of pulsating characteristics and a problem complex united model descriptions of processes in cybernetic systems. (In Russian). - Akmola: Science, 1998. - 250 p.

Әубәкір Д.Ә., Қалиев А., Кәрімов С., Әзен Е.

Вышнеградский диаграммасына негізделген техникалық сарапшылық жүйені жасақтау

Мақалада Вышнеградский диаграммасына негізделген компьютерлік-техникалық сараптау жүйені жасақтаудың әдістемесі берілген. Бұл әдістеме өз кезегінде XX ғасырдың 80-ші жылдары негізін *Әубәкір Д. Ә.* қалаған құбылмалы сипаттамалар теориясына (ҚСТ) сүйенеді. СЖ Delphi бағдарламалық жүйесі ортасында 2009 жылы магистрант *Арнай Қалиев* жасақтаған. Осы жобаның техникалық жағына *Дәуренбек ӘУБӘКІР* жетекшілік етті, математикадық жағынан кеңесші болған *Сәбит Кәрімов* те, ал идеяны ұсынған құлтемірлер теориясының белгілі маманы *Әділ Тимофеев* болған (1991 ж.). Күрделі техниканың жұмысын диагностикалық қадағалауды автоматтандыру мақсатында осы сараптау жобасын техникалық түрде іске асыру *Ерабылай Әзенге* жүктеледі.

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Создание технической экспертной системы на базе диаграммы Вышнеградского

Статья описывает всю методику создания компьютерно-технической ЭС, базирующейся на диаграмме Вышнеградского. Сама эта методика основывается на положениях теории пульсирующих характеристик (ТПХ), предложенной *Аубакиром Д. А.* в 80-ые годы XX столетия. ЭС в среде программной системы Delphi создал магистрант *Калиев Арнай* в 2009 году. Технической стороной проекта руководил *АУБАКИР Дауренбек*, консультантом по математике был *Каримов Сабит.* Идею высказал известный специалист по робототехнике *Тимофеев Адиль*(1991 г.). Техническая реализация для автоматизации диагностического контроля над функционированием сложной техники возложена на *Азена Ерабылая.*

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