THE METHOD OF SYSTEM ANALYSIS IN THE SYSTEMATIC SPACE. THE OBJECTIVE QUALITY CRITERION OF TV REPRODUCTIONS.

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Abstract.

In the report there offered for the discussion the vector analysis method of arbitrary structure systems in 4-dimensional space, dimencions of which are: power index E, information index I, system order index (in the sense of subsystems hierarhity) N and system steadiness index S. Below there have been presented the theoretical theses and one of the practical appliance varian of system analysis. On the example of working-out the way TV images quality estimation, perceived by the operator, there have been demonstrated the effectiveness of the system analysis method offered. On the concrete examples there have been shown, that the worked-out method of quality estimation steadily works both with non-correlative and strongly-correlative hindrances.

Introduction.

The further increase of the effectiveness of various information transmission systems, in particular the aviation and cosmic ones, having the intellectual recipient, needs the consideration of information exchange processes on the systematic level. It relates especially to the many-graduated TV images, the compact production of which ,conjugation with the operator and the quality estimation on the receiving end are the subject for many investigators. The aim of the very report is to make specialists acquainted with the vectorial analysis method in the systematic spaces by the example of operator interaction analysis with the rasteral images, and also by the demonstration of quality estimation functioning of visual information transmittion channel.

Let's assume that operator visual system can be presented as a functional diagram (fig.1) based on the research by D.Hubell, R.Gregory, P.Lindsay and D.Norman [1,2,3].

Existing today objective reproduction quality measures ,reproduced before the operator, are based on the precondition that the recipient is the closing link of the radiotechnical system. Such point of view allows us to consider the operator only from the radiotechnical system positions, that results in the number of essential inaccuracies.

From our point of view, TV highway can be considered no more than artificial prefixes to the optical part of the operator's visual system, and TV highway work quality can be objectively valued only from a position of abstraction, which can formalize the system interaction between the operator and the optical picture of the surrounding world.

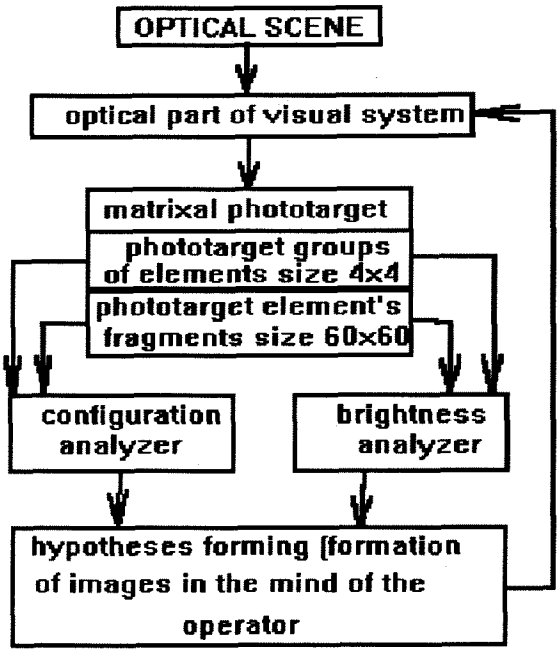

Fig.1. Operator visual system presented as a functional diagram.

The system spaces idea.

Many investigators tried to give the full and exact determination of this difficult conception - "system", as well as to determine the difference between system and simply "a sum of elements". Nevertheless, let's try to determine "system", at least as a working hypothesis, using the determination working-out method ,that was used by G.Holton in his work "How to think about "Anti-Science" phenomenon"[4].

For the aims of our research the operational and working determination of "system" is enough. Such a

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determination appears when intersectioning just two points ov view, that is material and abstract. Let's consider if the results of each of these points of view have convergent character.

Among all multiformity of material systems one can point out simple ones, the connections between elements of which are often based on purely power interaction (for example, crystalline bodies), and also difficult ones, the connections between elements of which have either power component and information one, which allows elements of system show their properties according to the information context of current situation (for example, ecological systems). The general thing for simple and difficult material systems is in their hightened steadiness to the external influence comparably to the separate elements, and that increase of steadiness which can be obtained by simple system owing to the quantitative increase of connections between elements, can be acquired by difficult systems by means of quantitative increase or qualitative perflection of information component of inter-element connections.

Now let's turn to the abstract systems. They are the product of thinking and have as their elements some views, ideas, models, associations etc., which are united into the steady unity by means of information connections. As it was in the above mentioned case, ideal systems, thanks to logical, rational unity (information connection systems) are more steady to abstract-critical "attacks", then ideas and models taken separately. The increase of ideal system steadiness is possible as owing to the joint of it's elements, as owing to the introduction of extra meaning into the inter-element's connections.

Let's look now, where our ideas of material and ideal systems convergate. First of all it is the steadiness increase to the shocking influence, that is the increase of inertiality, and the steadiness increase is supplied by two-component (information-power) inter-element connections complex presence, which degenerates into purely power complex in the simplest systems. The peculiarity of system connections is in the fact, that information component is a variable (unstable) part of power component. (The peculiarities of system-creation interactions between system elements will be considered in my second report.)

As a result we offer you the following determination:the system is the totality of elements (or subsystems) united by the information-power inter-element connections complex into functional unity to increase there own inertial properties concerning the shocking interactions of stable conditions.

It's important to notice, that determination offered allows to outline an alternative to the given, but also "working" determination. It can be called "anti-system determination".In notice [4] it is underlined that "every picture of the world can be "turned inside" and written in the language of opposite alternative". In other words, it's enough to draw up a negative sense determination, where the antitheses are formulated, and there appears automatically the determination which rejects the initial one. The idealized anti-system version can be formulated the following way: the anti-system is a number of separate elements dispersed by means of mutual information-power interactions in order to decrease the total inertial properties concerning the stabilizing influences of shocking condition. In fact, we have a real opportunity of watching anti-systems, and the results of their functioning are, for example, heat explosions.

Striving to get the "system" term determination we have got the two-pole space with pure systems and anti-systems on the poles and mixed structures between them, which more or less gravitate towards the inertial or dispersion basis.

It's logical to suppose that the space obtained is devided into system and anti-system semi-spaces by the neutral "equator", on which the full compensation of information-power interactions between elements is going on, and it leads to the identical equality of element's totality to the sum of these elements.

The system-antisystem space (SAS) was not full without power and information status, which determine the difficulty of system. The more so SAS fully formed can not be imagined without a dimension, which determines an order or hierarhity of system.

We have to mention that power, information and order SAS dimensions exist either in the field of positive and negative values. Let's designate the field of positive SAS dimentions as SAS of rational system existing. All the other systems we shall understand as irrational.

So, SAS is at least 4-dimention system existing space. Any rational system can be presented by SAS vector, and the movement of this vector within SAS determines by the evolution (development dynamics) of definite system in the time.

Finally the operational determination of system assumes the following form: system is the totality of elements (or subsystems) united by the information-power general complex of interactions in the functional unity, which determines the reaction on the stabilizing or unstabilizing influences. The system existing dynamics determines as trajectory of system vector in 4-dimension SAS.

Let's decipher the 4-dimension SAS dimensions:

- power is a force component of element interactions, which practically does not depend on time for the system existing period.
- information is a variation component of element interaction, which determines as fast changes of interaction energy, incommensurably shorten than system existing period.
- systemity-antisystemity (stability-instability) determines the character of inter-element interaction's complex functioning, which can direct either at the system formation or at the system distruction.
- order (hierarhity) determines the system structure in the sense of its hierarhity. So, the 1-st level system consists of indivisible elements; the 2-nd level system consists of subsystems, which, in their turn, consist of indivisible elements and so on.

Let's consider now, how one can practically use the determination obtauned for the interaction analysis of operator with the rasteral images.

Operator-image system.

In the aspect of concept offered one can have a fresh-outlook on the visual perception process,which, as is known, includes three successive processes: detection, recognition and extreem solution.The difference of these processes consists of various spatial frequency regions, passing by the optical part of visual system (see fig.1), and of various width of visual region.

The rates presented here are realized in a visual system in the following way:

- detection is on the level of all visual field (about 180 angles);
- recognition is 15-20 angles of visual field;
- extreem solution is 1-5 angles of visual field.

Spectator, as an element of outer world system, takes part in the interaction with the other elements by optical channel. From the positions of the idea about systems, offered above, one can say, that the detection rate allows to detect certain systems in the observed optical scene (N-level). The recognition rate allows to analyse these systems on the subsystem level (N-1). The extreem solution rate allows to detect the subsystems of the objects found (N-2). Such reasoning offers to reveal the optical scene hierarhity, which are the information-energy flows in the channel of spectator optical connection with the outer world system.

Taking into consideration the system analysis succession, realised by the visual system in the process of optical scene perception let us suppose the latter in the vector form in the SAS. Such a presentation will allow to determine not only qualitatively but also quantitatively the influence of distortions put by TV highways on rasteral image at every ordinal level: detection, recognition and extreem solution. As a result we get the vectorial structure represented at fig.2.

It's obvious that quality measure of rasteral images can be presented in the form of detection, recognition and extreem solution measures of reproduction vectors removal from the standard image vectors. By this let's suppose the standard images take place on analog-digital converter outlet, and images analysed on the screen before the operator.

The way of rasteral images quality estimation.

It's obvious, when considering the optical scenes we have got at least three signals analysed by the operator, each of which have it's own power and informationsaturation. Let's determine two last terms for our case. In the detection rate, realized within all optical scene, the power perceived by the operator corresponds to the power of all optical scene, that is it corresponds to the maximum of two-dimensional auto-correlative function (ACF).

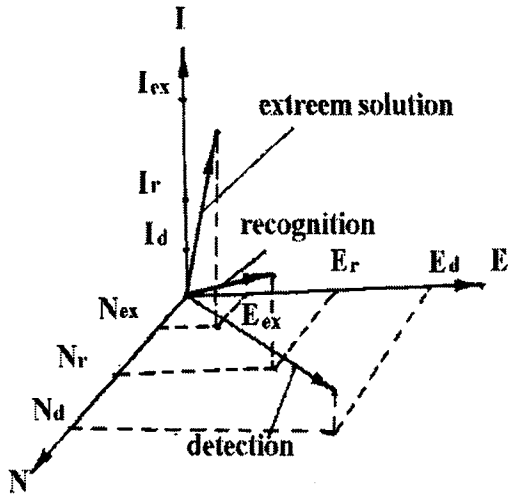

Fig.2. The illustration of the optical scene vectorial presentation in the system-antisystem space. N, I and P - dimentions, presenting the order, information and power accordingly.

In the recognition rate operator analyses the alternative component of the image. The middle value of this component can be obtained, if we take into consideration that operator perceives the image through the watching window, the limpidity of which is 1. The limpidity is 0 over the bounds of the window. One can present it in the following form:

$$B(x,y) = K_1(x,y)[B_i(x,y) + B_{mid}],$$

where: B(x,y) - is the brightness distributionon in the flat image;

$$K_1(x,y) = \begin{cases} 1 & \text{when } x \le X,\ y \le Y \\ 0 & \text{when } x > X,\ y > Y \end{cases}$$

K_1 - the function of watching window limpidity;
X,Y - the size of rectangular watching window;
$B_i(x,y)$ - the alternative component of brightness distribution;
B_{mid} - the middle value of image brightness.

Accordingly ACF of $B_i(x,y)$ will have the following form:

$$A_i(z,s) = \frac{\sum_{x=1}^{N}\sum_{y=1}^{M} B(x,y)B(x-z,y-s)}{\sum_{x=1}^{N}\sum_{y=1}^{M} K_1(x,y)K_1(x-z,y-s)} - B_{mid}^2$$

The result has the sigh-alternative character, hence the power perceived by the operator during the

recognition process, breakes down into the energy of dark and light object recognition. Let's determine these powers as the middle ACF maximum of light objects and the middle maximum of dark objects, if there are naturally several objects within the optical scene.

The power, perceived by the operator in the extreem solution rate also breaks down into the dark and light components and presents itself the middle power overfall within the light and dark objects.

Now let's turn to the information. It's obvious the informational interaction of operator-image system elements is far from being a bit-exchange as in the artificial information systems.

According to the familiar experiments [5] we can offer the following determination: videoinformation, which is potentially contained in the optical scene is the sum of values of two- dimentional Furier phase spectrum, each element of which is weighed by the value of corresponding element of amplitude spectrum; the videoinformation realizes in the visual system according to the work rates of linear part of the latter.

We can't but mention that according to the passing stripes of visual system linear part there have been used for the calculation the corresponding parts of Furier two-dimention spectrum.

Before coming to the quality measure synthesis, it's necessary to throw some light on Krasilnikov quality measure [6]. He considered the image as an indivisible signal and taking the human visual analyzer as an optimum reciever, solved the problem of signal recognition against a background of incorrelative Gauss noise (in case of flat optical scenes). The shortcomings of such an approach are the considerable errors in quality estimation when the mistake spectrum is uneven, and the non-linear transformations presence when getting the reproduction estimated.

In the aspect of the above given system presentations, the quality reproduction parameter can be considered in the systematic space as the steadiness dimension value, and undistorted reproduction realizes the absolutely steady connection between the operator and standard image. On increasing the distortion this connection is getting more and more steady and strives to the zero. In other words, the reproduction quality can be determined in the form of detection probability, recognition probability and the extreem solution probability, if the absolute steadiness is 1.

Now it seems that one can consider the standard image vectors in the systematic space and it's distorted reproduction and determine the quality measure by the distance between them, but however one should take into consideration here quite an important factor of perceiving images by the operator in the form of hypotheses forming about the optical scene observed, as is shown in fig.1. Hypotheses forming determines the perception subjectivity degree and works in different ways with different people. With due regard to it let's introduce the concept of "experienced" and "inexperienced" operator, and an "experienced" operator is the one, who is able to notice the distortions of Furier Phase spectrum, and "inexperienced" one is unable to do it.

This way, our measure will give us a "plug" of values which are corresponding to the subjective estimations of various spectators.

Let's consider the method of getting the quality measure for the detection rate, so far as for the recognition and extreem solution rates it has no principle difference.

The detection rate in the vectorial form is presented on fig.3, where OA vector is the standard image. OB vector is the distorted image reproduction.

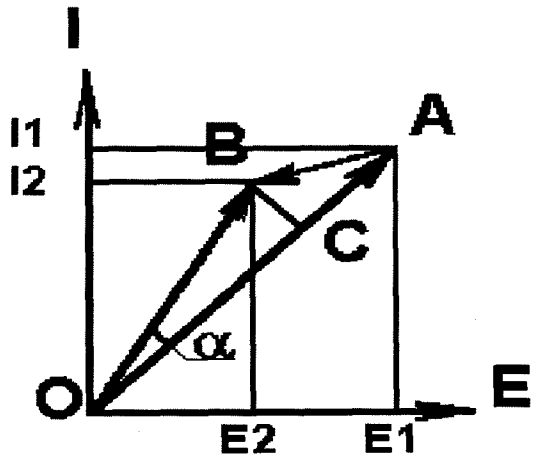

Fig.3. The vectorial presentation of detection rate. The explanations are given in the text.

Judging by this figure one can see that AB vector corresponds to the distortion influence, which can be presented in the form of co-ordinated and unco-ordinated with the standard components of AC and BC, and the former calls for the reduction of standard vector, and the latter carries out it's rotation on angle "α".

Ortogonality of AC and BC shows the independence of hindrance influences, meaning the opportunity of independent consideration of detection probability,got only due to the AC influence and only due to BC influence.

For getting the detection probability in case of the unco-ordinated hindrance, one can use popular methodics of determination of signal recognition probability against a background of uncorrelative Gauss noise.

For getting the detection probability in case of co-ordinated hindrance it's enough to take the standard vector length ratio to the co-ordinated hindrance vector.

As a result we get: $P_d=P_{d1}P_{d2}$,

where P_{d1} is detection probability in case of unco-ordinated hindrance; P_{d2} is detection probability in case of co-ordinated hindrance.

Similarly we can determine the recognition probability and extreem solution probability.

The differences in getting estimations for "experienced" and "inexperienced" operator are just in various ways of getting the informational component of distorted image reproduction vector.

As the result of consideration of the "experienced" and "inexperienced" operators there have been worked out the probable quality measure of distorted images, taking into consideration the peculiarities of image perceiving by the operator which allows to estimate the quality of TV highways work objectively and operatively and in particular the image compression devices with no dependence of the hindrance carried in.

The results of imitational experiments and their discussion.

The imitational experiments have been carried out for the image compressing algorithms using block trunctation coding, having the limited number of base configurations, that is 1, 9, 25, 49, 101, 161, 225 and 65536 pieces. In the work presented for your consideration there have been used the computer IBM PC/AT-386; operational system DOS 5.0; programm language Turbo Paskal 5.0.

As a standards there have been used 11 images with ACF radiuses from 7 to 94 pixels.

The calculation of detection, recognition and extreem solution probabilities have been carried out by means of the above mentioned method. The result of the calculation for one of the images (fig.4.A) is shown on fig.5 in the form of dependence of probabilities depend on the number of supporting configurations. One of the reproductions encoded under 101 configurations is presented in fig.4.B.

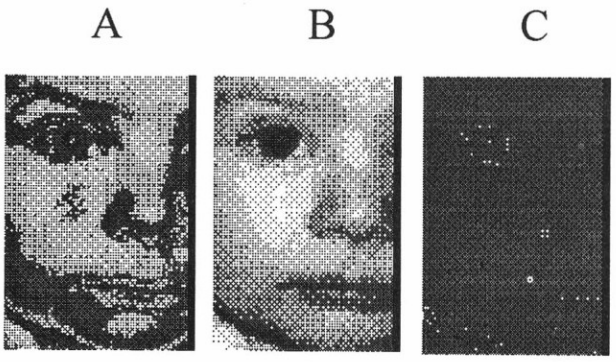

Fig.4. An example of images, used in imitational experiments. A - standard; B - restored after the encoding reproduction (the number of supporting configurations is 101); C - reproduction of encoding error.

Judging by the fact that every-element difference of standard image and coding result, that is the coding error introduces itself the reproduction affected by the highly-correlative hindrance, let's try to determine P_{d1}, P_r and P_{ex} for this very case. On the monitor screen one can recognize the content of this image (see fig.4.C), hence only the P_{r1} (the recognizing probability of "experienced" operator) can exceed the 0,5 level. On fig.6 there have been shown the experimental results for this case. As we can see, our quality measure have successfully coped with the problem raised.

The last experiments demonstrate a possibility of using the quality measure offered for the quality estimation of TV highways work even in case of strongly-correlative hindrance.

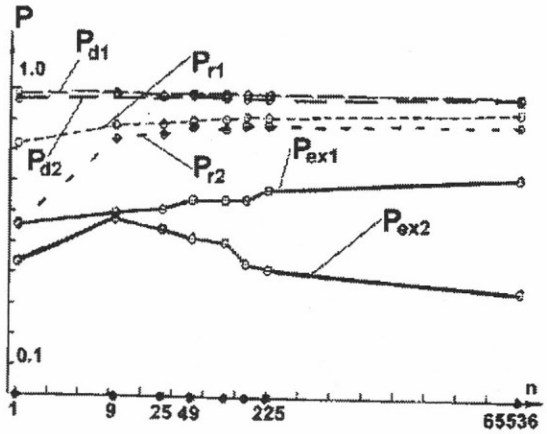

Fig.5. The dependence of detection (P_d), recognition (P_r) and extreem solution (P_{ex}) probabilities on the number of supporting configurations, used during the image coding. Index "1" corresponds to the "experienced" operator; index "2" corresponds to "inexperienced" one; "n" is the number of configurations used when coding.

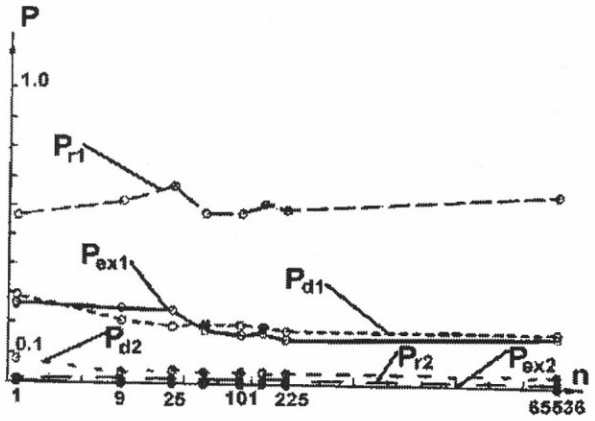

Fig.6. The same dependences, as on fig.5, but for the errors.

The essential advantage of our measure is the opportunity of separate determination of P_d, P_r and P_{ex}, and these probabilities can be calculated for the "experienced" and for the "inexperienced" operators, that is, one can get a "plug" of values within which practically all possible variations of probabilities of real operator perception are concentrated.

The measure, got by us is not hard to correspond with Johnson's criterion, for example. It's easy to show that for this is enough to use the following formula:

$$P_{dJ} = 0,5(P_d + P_r); \quad P_{rJ} = 0,5(P_r + P_{ex}) ,$$

where P_{dJ} and P_{rJ} - the detection and recognition probabilities, corresponding to the Johnsson's criterion treatment.

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