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INFORMATION SYNTHESIS OF ADAPTIVE SYSTEM FOR VISUAL DIAGNOSTICS OF EMOTIONAL AND MENTAL STATE OF A PERSON

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Розглянуто процес візуального визначення емоційно-психічного стану, що базується на оцінці подібності лівопівкульного та правопівкульного портретів людини. Запропоновано метод аналізу подібності таких портретів за модифікованою ентропійною мірою Шеннона в рамках інформаційно-екстремальної інтелектуальної технології. Доведено, що запропонований метод дозволив зменшити поріг чутливості системи психодіагностування до зміни емоційно-психічного стану через визначення в процесі навчання оптимальних в інформаційному розумінні співвідношень RGB-складових зображень обличчя

Ключові слова: оптимізація, інформаційно-екстремальна інтелектуальна технологія, інформаційний критерій, психодіагностування, навчання, критерій функціональної ефективності

Рассмотрен процесс визуального определения эмоционально-психического состояния, который базируется на оценке сходства левополушарного и правополушарного портретов человека. Предложен метод анализа сходства таких портретов с использованием модифицированной энтропийной меры Шеннона в рамках информационно-экстремальной интеллектуальной технологии. Доказано, что предложенный метод позволил уменьшить порог чувствительности системы психодиагностики к изменению эмоционально-психического состояния путем определения в процессе обучения оптимальных в информационном смысле соотношений RGB-составляющих изображений лица

Ключевые слова: оптимизация, информационно-экстремальная интеллектуальная технология, информационный критерий, психодиагностирование, обучение, критерий функциональной эффективности

1. Introduction

As technogenic catastrophes are significantly influenced by the human factor, the actual problem is the evaluation in a monitoring mode of psychological and emotional state of operators of potentially dangerous plants and production facilities with the aim of determining their current functional state and the ability to continue performing their functions.

Besides, in psychodiagnostics, during testing on polygraphic devices, etc., the detection of the untrue behavior of the diagnosed person is becoming increasingly important. The current trend of automation of methodologies of psychodiagnostics is characterized by a wide implementation of intelligent information technologies for the analysis of the results of psychological research. Intelligent components allow not only intensifying processing and interpretation of the results of psychological testing, but also provide a possibility to adapt a range of parameters of the applied methodology, taking into account peculiarities of a tested person. In this case, unlike the traditional verbal (contact) methods, using visual psychodiagnostics provides an opportunity of continuous observation of the EMS of a person in the mode of monitoring his behavior.

The information-extreme algorithm of training a computerized system of diagnostics (CSD) of EMS of a person using the halftone and full-color raster face images is examined.

2. Literature review and problem statement

The main drawback of the known methods of intelligent analysis is the use of distance measures of proximity [1, 2] or similarity [3, 4], which in practice decreases the probability of making correct diagnostic decisions considering emotional and mental state (EMS) of a person. In the works of [5, 6], the methods for evaluating EMS of a person with the use of his halftone raster face images are considered. Since face images of a person for different EMS have minor differences, the validity of the proposed methods of psychodiagnostics essentially depends on the choice of the recognition method [7, 8]. The most suitable are the methods of the image recognition with decision rules based on the shared functions of the radial-basis type [9, 10], which include the methods, developed in the framework of information-extreme intelligent technology (IEI-technology) of the data analysis [11, 12].

One of the promising ways of improving reliability of the non-verbal intelligent diagnostics of the EMS of a person is using an input mathematical description of the psychodiagnostic system, which is formed both by the halftone and full-color images of a patient's face [13, 14]. In this case, the problem of exploring the influence of the RGB-components of images on the functional efficiency of the psychodiagnostic system is becoming more important.

Let us consider within the IEI technology a formalized statement of the problem of information synthesis of the diagnostic system of EMS of a person by his face image, the main component of which is capable of training decision support system (DSS). Let us have the alphabet $\{X_m^o \mid m=\overline{1,M}\}$ of recognition classes that characterize various emotional and mental states of a patient, and a training matrix of the brightness of the pixels of the receptor field of face images of a patient.

$$\| y_{m,i}^{(j)} \|, i=\overline{1,N}, j=\overline{1,n},$$

where N, n are the number of features of the image recognition and implementation, respectively. In this case, the line of the matrix $\{y_{m,i}^{(j)} \mid i=\overline{1,N}\}$ means j-th implementation, and the column $\{y_{m,i}^{(j)} \mid j=\overline{1,n}\}$ means the training sample of values of i feature. The structured vector of training parameters of DSS is known

$$g=<x_m, d_m, W_i>, \quad (1)$$

where x_m is the reference (averaged) vector-implementation of the image, the vertex of which defines geometric center of the container of class X_m^o; d_m is the radius of the container of class X_m^o, which is restored in a radial basis of the space of recognition features; W_i are the parameters of converting color images to half-tone ones. It is necessary at the stage of training DSS to optimize the coordinates of the vector (1) through an iterative search for the global maximum of the averaged by the alphabet of recognition classes of the information criterion of functional efficiency (CFE) of training the system in operational (permissible) area of determining its function.

$$\overline{E}=\frac{1}{M}\sum_{m=1}^{M}\max_{G_E \cap G_d} E_m(d_m), \quad (2)$$

where $E_m(d_m)$ is the information CFE, calculated during training at the current value d_m of the radius of the hyperspheric container of class X_m^o; G_E is the operational (permissible) area of determining a CFE function; G_d is the permissible area of values of radii of containers of recognition classes.

At the stage of examination, i. e., of direct diagnosing, it is necessary to make a decision about membership of the recognized realization to one of the classes of the given alphabet.

3. The aim and tasks of the study

The aim of the conducted studies was to develop an algorithm of estimation of the diversity of the left and the right hemisphere portraits for assessing the EMS of a tested person in line with the IEI technology.

To achieve the set aim, the following tasks were solved:

– formation of the training matrices by the results of processing color and halftone left and right hemisphere portraits of a person who is diagnosed;

– development of a mathematical model and the algorithm of training CSD in line with the IEI technology;

– program implementation of the algorithm of training CSD using the images of the patients of the Center of Ecology of Human NIKAR [14];

– testing the workability of CSD and determining its optimum parameters

4. Materials and methods of the study

Since the process of psychodiagnostics is poorly formalized, we will consider a mathematical category model of the psychodiagnostic system capable to learn in the form of a diagram of representation of the sets by correspondent operators that are used in the process of information-extreme training [11]. In this case, an input mathematical description of CSD will be presented in the form of the structure of sets

$$\Delta_B =< G, T, \Omega, Z, Y, X; \Phi_1, \Phi_2 >,$$

where G is the set of the input factors; T is the set of the moments of reading information; Ω is the space of features of recognition; Z is the space of possible EMS of a person; Y is the set of the signals after initial processing of the information; $\Phi_1: G\times T\times\Omega\times Z\to Y$ is the operator of image processing (forming the sample set Y at the input of CSD); $\Phi_2: Y\to X$ is the operator of forming the binary training matrix X.

A category mathematical model of CSD, capable of training, for recognizing the EMS of a person is shown in Fig. 1.

In Fig. 1, the following sets, basic for IEI technology, are shown [11]: $\Re^{|M|}$ is the partition of space Ω; $I^{|l|}$ is the set of statistical hypotheses, where l=2; $\Im^{|q|}$ is the set of precise characteristics, where $q=l^2$; E is the information CFE of training CSD; V is the set of dividing functions of the radial-basis type. In this case, the additional set C was introduced, which allows considering components of the color palette of the images. Taking into account the introduced set, the basic operators were modified: θ is the construction of partition $\Re^{|M|}$, Ψ is the verification of the hypotheses of belonging of the implementations of the image, γ is the formation of the set $\Im^{|q|}$, ϕ is the calculation of the values of the set E, r is the implementation of iteration process of searching for the optimal partition parameters $\Re^{|M|}$, v is the determination of the type of decision rules and u is the regulation of the training process.

$$
\begin{tikzcd}
V \arrow[d, "u"'] & & & E \arrow[lll, "v"'] \arrow[d, "r"] & \Im^{|q|} \arrow[l, "\varphi"'] \\
T\times G\times\Omega\times C\times Z \arrow[r, "\Phi_1"] & Y \arrow[r, "\Phi_2"] & X \arrow[r, "\theta"] & \Re^{|M|} \arrow[r, "\Psi"] & I^{|l|} \arrow[u, "\gamma"']
\end{tikzcd}
$$

Fig. 1. Category model of training CSD

Information-extreme training of CDS in general case is performed by a multi-cycle iteration procedure of the search for the global maximum of information CFE in the operating (permissible) area of determining its functions, which generally has the form

$$g_\xi^* = \arg\max_{G_\xi}\{\max_{G_{\xi-1}}\{...\{\max_{G_E\cap G_1}\overline{E}\}...\}\}, \tag{3}$$

where G_ξ is the permissible area of brightness values; ξ is the feature of recognition.

The inner cycle of the algorithm (3) implements the so-called basic algorithm of training, in which the radius of hyperspheric classifier is the parameter of functioning that is optimized:

$$d_m^* = \arg\max_{G_E\cap G_d} E_m(d_m). \tag{4}$$

The main stages of implementation of the information-extreme algorithm (4) of CSD training are explored in the paper [12]. In order to increase functional efficiency of CDS, capable to learn, modification of the algorithm of formation of the input data was carried out, which consisted in the application of structural vectors-implementations of recognition classes, which took into account not only the RGB-components, but also halftone elements in the recognition of color images. This made it possible to increase the amount of conditional information and, consequently, reliability of the recognition of EMS of a person.

The normalized entropic measure of Shannon [12] was used as CFE of training CSD, which for the equiprobable bialternative decisions has the form

$$
\begin{aligned}
E_m(d_m) = 1+\frac{1}{2}\Bigg(&\frac{\alpha(d_m)}{\alpha(d_m)+D_2(d_m)}\log_2\frac{\alpha(d_m)}{\alpha(d_m)+D_2(d_m)}+\\
&+\frac{\beta(d_m)}{D_1(d_m)+\beta(d_m)}\log_2\frac{\beta(d_m)}{D_1(d_m)+\beta(d_m)}+\\
&+\frac{D_1(d_m)}{D_1(d_m)+\beta(d_m)}\log_2\frac{D_1(d_m)}{D_1(d_m)+\beta(d_m)}+\\
&+\frac{D_2(d_m)}{\alpha(d_m)+D_2(d_m)}\log_2\frac{D_2(d_m)}{\alpha(d_m)+D_2(d_m)}\Bigg),
\end{aligned} \tag{5}
$$

where $D_1(d_m)$, $D_2(d_m)$ are the first and the second reliabilities, respectively, calculated in the training process at the current radius of the container of recognition class; $\alpha(d_m)$, $\beta(d_m)$ is the error of the first and second kind, respectively.

In the expression (5), the danger of dividing by zero is absent because the criterion value is calculated by assuming that the values of precise characteristics are located in the working (permissible) area of determining its functions, where the first and second reliabilities take the values over 0.5.

The formation of the training matrix was carried out by the well-known technology of video-computer psychodiagnostics and correction, which is based on comparison of the left and the right hemisphere portraits to assess the EMS of a person [14].

To improve the efficiency of the training process, the conversion of color images to halftone images was made by the formula:

$$x_{Grey}=W_R X+W_G Y+W_B Z, \tag{6}$$

where x_{Grey} is the brightness of a pixel in a halftone image, X, Y, Z are the brightness of the red, green, and blue colors in a color image, W_R, W_G, W_B are the coefficients that determine impact of the corresponding color on the resulting brightness of a pixel. The coefficients in the expression (6), according to the paper [15], were limited in the following way:

$$
\begin{cases}
0\le W_R\le 1;\\
0\le W_G\le 1;\\
0\le W_B\le 1;\\
W_R+W_G+W_B=1.
\end{cases} \tag{7}
$$

An input mathematical description was formed by a patient's images, presented in the article [14]. In this case, the photographs of a person were divided into the right and the left hemisphere images, each of which was mirrored along the line of division and matched its copy. The structure of the training matrix consisted of three color components, which characterized the red, green and blue components of the brightness of each pixel for the left and the right hemisphere portraits. Thus, with the image size of 170×170 pixels, the total number of features for the three RGB-components was 510.

The study was carried out on the example of recognition of two classes: X_1^o, the class that characterized stable EMS of a patient and class X_2^o that characterized unstable state.

The original images were divided into three color components – red, green and blue as it is shown in Fig. 2.

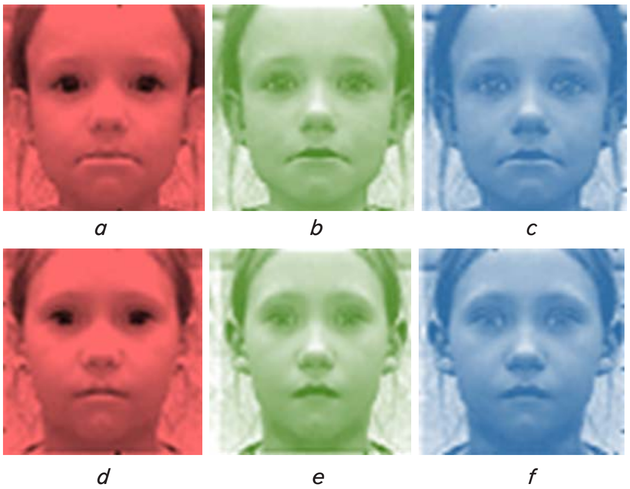

Fig. 2. Graphic representation of training matrices: left hemisphere portrait (*a* – red, *b* – green, *c* – blue component), right hemisphere portrait (*d* – red, *e* – green, *f* – blue component)

Thus, optimization of the hyperspheric containers of the recognition classes comes down to iterative procedure of searching for the global maximum of the criterion (5) in the operating (permissible) area of determining its function.

5. Results of machine training of a computerized system of diagnostics

The result of optimization by criterion (5) of geometric parameters of the containers of recognition classes, updated in the radial basis of the space of features by the iterative procedure of the basic algorithm of training for portraits, which includes the brightnesses of all three colors (Fig. 2) is shown in Fig. 3.

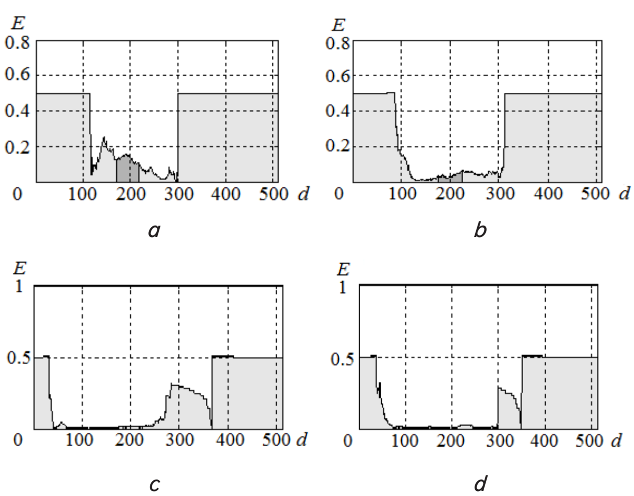

Fig. 3. Diagrams of dependencies of CFE (5) on the radii of containers of recognition classes for portrait, which includes brightnesses of all three colors: *a* is the left hemisphere portrait of class X_2^{o}; *b* is the right hemisphere portrait of class X_2^{o}; *c* is the left hemisphere portrait of class X_1^{o}; *d* is the right hemisphere portrait of class X_1^{o}

In Fig. 3, the operating (permissible) areas of determining the CFE function are shown by dark color, in which the first and the second reliabilities exceed the errors of the first and second kind, respectively. The analysis of Fig. 3 shows that the maximum values of CFE, calculated in the operating area are minimal for a person with the stable EMS (class X_1^{o}), which is explained by the similarity of the left and right hemisphere portraits (Fig. 3, *c*, *d*). The portraits of people formed with the left (Fig. 3, *a*) and right hemisphere portraits (Fig. 3, *b*) characterize unstable EMS of a patient (class X_2^{o}).

With the purpose of evaluating the influence of the RGB-component on the reliability of EMS diagnosing of a patient, the input training matrices using only one color for representing the full left and right hemisphere portraits were formed.

The diagrams of dependencies of CFE on the radii of hyperspheric containers of recognition classes, obtained by the training matrix of brightness, formed with the use of red R-component of the images before and after psychocorrection, are shown in Fig. 4.

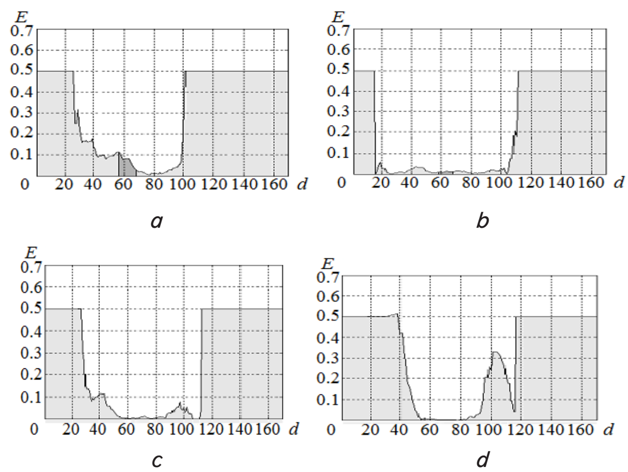

Fig. 4. Diagrams of dependencies of CFE (5) on the radii of containers of recognition classes for portraits with the use of red R-component: *a* is the left hemisphere portrait of class X_2^{o}; *b* is the right hemisphere portrait of class X_2^{o}; *c* is the left hemisphere portrait of class X_1^{o}; *d* is the right hemisphere portrait of class X_1^{o}

The analysis of Fig. 4, *a*, *b*, obtained by the left and right hemisphere portrait of a person with unstable EMS, points to the possibility of creating decision rules because the first and second reliabilities in the operating area exceed 0.5. The results of training for a person with a stable EMS, which are shown in Fig. 4, *c*, *d*, testify to the impossibility of forming relevant decision rules because of the high degree of similarity of the left and right hemisphere portraits. Thus, the use of halftone images, formed only with the use of the red color brightness, allows conducting psychodiagnostics similar to the variant when a training matrix includes the brightnesses of all three colors.

The diagrams of dependencies of CFE on the radii of hyperspheric containers of the recognition classes, obtained by the training matrix of brightness, formed with the use of green G-component of the images before and after psychocorrection are shown in Fig. 5.

Comparing the maximum value of the CFE in the operating area of its determining, obtained during training of the system, one can conclude that a variety of portraits of a person with stable EMS (Fig. 5, *a, b*) is larger than a variety of portraits of a person with unstable EMS (Fig. 5, *c, d*), which contradicts the results of the previous stages.

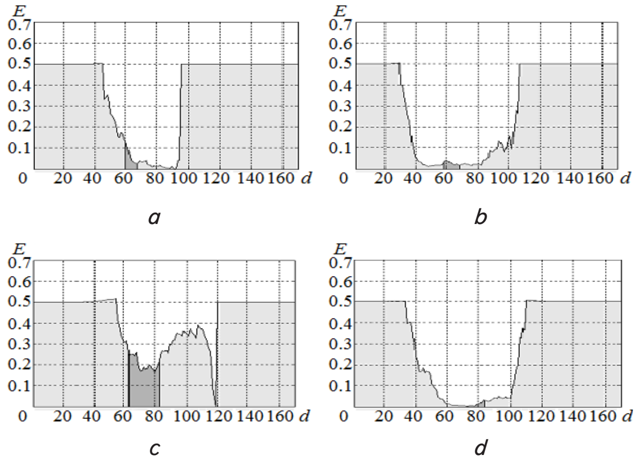

Fig. 5. Diagrams of dependencies of CFE (5) on the radii of containers of recognition classes for portraits with the use of red G-component: *a* is the left hemisphere portrait of class X_2^o; *b* is the right hemisphere portrait of class X_2^o; *c* is the left hemisphere portrait of class X_1^o; *d* is the right hemisphere portrait of class X_1^o

Thus, the use of halftone image, formed only with the use of the green color brightness does not allow performing psychodiagnostics similar to the variant when training matrix includes the brightnesses of all three colors, or only with the brightness of the red color.

The diagrams of dependencies of CFE on the radii of hyperspheric containers of the recognition classes, obtained by the training matrix of brightness, formed for the halftone image with the use of only blue B-component of the color spectrum before and after psychocorrection are shown in Fig. 6.

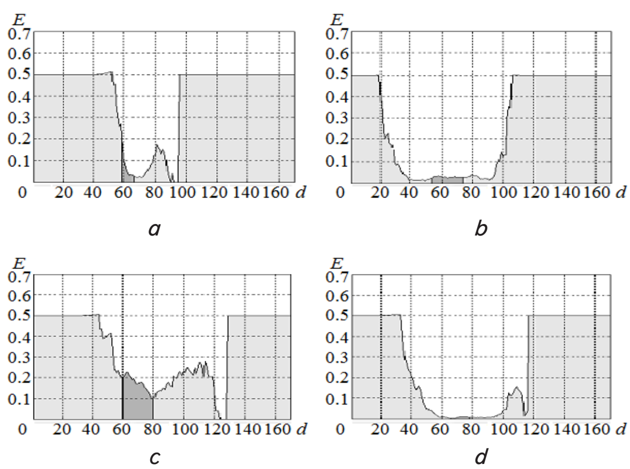

Fig. 6. Diagrams of dependencies of CFE (5) on the radii of containers of recognition classes for portraits with the use of B-component: *a* is the left hemisphere portrait of class X_2^o; *b* is the right hemisphere portrait of class X_2^o; *c* is the left hemisphere portrait of class X_1^o; *d* is the right hemisphere portrait of class X_1^o

The analysis of Fig. 6 shows that in the operating area, after psychocorrection (Fig. 6, *c, d*), the maximum value of CFE is different from zero, indicating the lack of diagnostic value of the blue B-component of the images, since the difference between the left and the right hemisphere portraits before and after psychocorrection is insignificant.

Thus, the use of the halftone image, formed only with the use of the brightness of the blue color, does not allow performing psychodiagnostics in contrast to the variant when a training matrix includes the brightnesses of all three colors or with only the brightness of the red color.

6. Discussion of results of the study of a computerized system of diagnostics

The solution of the main problem of the research in the framework of implementing an information-extreme algorithm of machine training of the system of diagnosing the EPS of a person is in the optimization of the coefficients W_R, W_G, W_B, which determine the influence of the correspondent color component on the resulting brightness of a pixel. In this case, the value of the coefficients of the red W_R and the green W_G components changed in the area of their determination [0, 1] with the step of 0.1 and were calculated considering the limitations (7) by formulas

$$W_B=1-W_R-W_G;$$

$$W_R=1-W_B-W_G;$$

$$W_G=1-W_R-W_B. \quad (8)$$

Fig. 7 shows a three-dimensional diagram of the dependency of the entropic CFE (5), averaged by the alphabet of recognition classes, on the coefficients of the red and green components of the RGB-spectrum, obtained at the renewal in the process of machine training of hyperspheric containers of recognition classes, built in the radial basis of the features space.

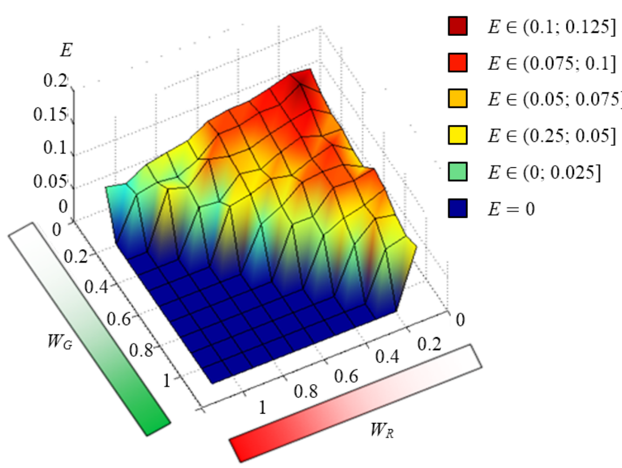

Fig. 7. Diagram of dependency of averaged CFE on the coefficients W_R and W_G

The analysis of Fig. 7 shows that the averaged CFE acquires the maximum value at the optimal values of the coefficients $W_R^*=0.1$ and $W_G^*=0.1$. In this case, the optimal coefficient of the blue component is calculated by the formula (8) and equals $W_B^*=0.8$.

The diagrams of dependency of CFE on the radii of hyperspheric containers of recognition classes, obtained at the optimal values of the coefficients of the RGB-components for portraits of a patient before and after psychocorrection are shown in Fig. 8.

The analysis of Fig. 8, *a, b,* obtained by the left and the right hemisphere portrait of a person with unstable EMS, shows that the optimal value of the radius of the hyperspheric container for the left hemisphere portrait is d^*=59 at the maximum value of entropic CFE (5) E^*=0.23. The optimal value of the radius of the hyperspheric container for the right hemisphere portrait is d^*=72 at the maximum value of entropic CFE (5) E^*=0.04.

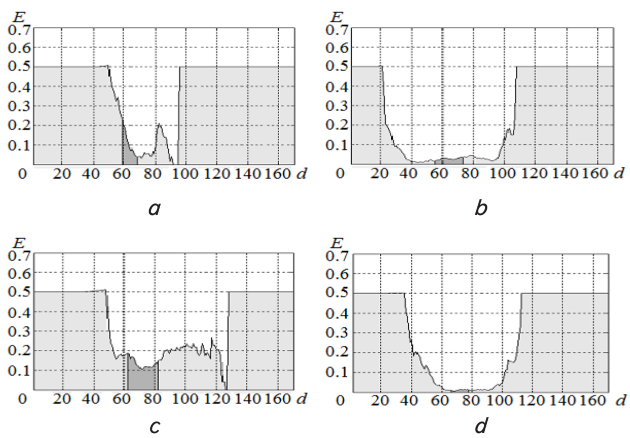

Fig. 8. Diagrams of dependencies of CFE (5) on the radii of containers of recognition classes at the optimal coefficients of color components: *a* is the left hemisphere portrait of class X_2^o; *b* is the right hemisphere portrait of class X_2^o; *c* is the left hemisphere portrait of class X_1^o; *d* is the right hemisphere portrait of class X_1^o

Fig. 8, *c, d* shows the diagrams of dependency of CFE (5) on the radii of the hyperspheric containers of the recognition classes, obtained at the optimal values of the coefficients of RGB-components for portraits of a patient after conducting psychocorrection. The analysis of these diagrams shows that for the left hemisphere portrait, the maximum value of entropic KFE equals E*=0.19 at the optimal value of the radius of the hyperspheric container d*=62, for the right hemisphere portrait, the maximum value of entropic KFE equals E*=0.01 at the optimum value of the radius of the hyperspheric container d*=73.

Thus, the comparative analysis of the values of information criteria, obtained at maximizing the information capability of diagnostic system before and after psychocorrection, shows that for both the left and the right hemisphere portraits after conducting psychocorrection, there was a decrease in the maximum values of entropic criterion, calculated in the operating (permissible) area of determining its function. Since the information criterion is a measure of diversity, this fact testifies to the decrease in the differences between the left and the right hemisphere portraits and the presence of the effect of psychocorrection.

In addition, if the blue and the green components of the color RGB-spectrum of the images do not influence the value of the information CFE of machine training, they cannot be excluded from this spectrum, as they become informative in the complex.

7. Conclusions

1. The modification of the known technology of video-computer psychodiagnostics and correction was proposed by maximization of the information capacity of psychodiagnostic system in the training process, which allowed assessing emotional and mental state of a person by the magnitude of information criterion of the functional efficiency of training.

2. A mathematical model and the algorithm of machine training (category model of the capability to learn) of psychodiagnostic system and the algorithm of optimizing its functional parameters were developed in the framework of information-extreme intelligence technology of data analysis, which allows evaluating emotional and mental state of a patient by identifying the differences of his/her left and right hemisphere portraits.

3. The verification of the algorithm efficiency was conducted by training CSD to recognize two emotional and mental states of a patient by the training matrices, formed according to the results of processing color and halftone images of patients.

4. In the process of training a psychodiagnostic system, the influence of the RGB-components of the left and the right hemisphere portraits of a patient on the reliability of psychodiagnostics was explored, and the optimal ratio (defined by the information ratio criterion) of components of the color images, with which the largest difference of the left and the right hemisphere portraits before and after psychocorrection is achieved. It was shown that the optimization of the RGB-components is an important stage of preliminary color images processing.

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