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APPLICATION OF MORPHOLOGICAL AND NEURAL NETWORK ALGORITHMS BASED ON NONLINEAR EQUIVALENTY METRICS FOR RECOGNITION OF MULTI-LEVEL IMAGES OF MULTI-CHARACTER IDENTIFICATION OBJECTS IN TRANSPORT SYSTEMS

Abstract. The work is devoted to the development of new integrated morphological-neural network algorithms based on nonlinear equivalence metrics for recognizing halftone black-and-white images of multi-symbol identification objects, which are widely used in automated production and various logistics transport systems for the purpose of ensuring the accounting and security of transport units or their identification objects. These algorithms are based on the use of linear (nonlinear) equivalence (non-equivalence) metrics and normalized spatially dependent similarity functions (similarity or dissimilarity) of matrix arrays or data in the form of images, as criterion (discriminant) functions. Based on the review of related works, the aspects, specifics and advantages of using such metrics and functions to solve research problems were analyzed, the necessity and relevance of which were technically justified and formulated. Two groups of algorithms for recognizing images of multi-symbol identification objects have been developed and presented, the main procedures in these algorithms have been described, their features and differences have been shown. In the article, the authors present the results of model experiments of the proposed algorithms using the created auxiliary program for studying the features of the application of algorithms, for checking the quality and accuracy characteristics of image recognition when exposed to various types and

strengths of interference, for verifying the adequacy of models and metrics. A comparative analysis of the obtained modeling results has been performed taking into account various conditions and interference. A program for recognizing identification numbers on locking and sealing devices has been developed and tested in real production conditions. The operation of the program and its user interface are demonstrated by screenshots. The results obtained showed that such proposed integrated morphological-neural network algorithms based on equivalent nonlinear metrics have better discriminant properties, accuracy and performance characteristics, especially in the case of a significant (up to 40%) conditional level of interference power acting on the recognized images.

Keywords: neural-network algorithms, matrix continuous logic, image recognition, multi-character digital identification objects, intelligent multifunctional continuous logic devices, parallel high-performance processing, nonlinear metrics, normalized continuous-logic spatial functions, equivalence and non-equivalence operations.

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ЗАСТОСУВАННЯ МОРФОЛОГІЧНИХ ТА НЕЙРОМЕРЕЖЕВИХ АЛГОРИТМІВ НА ОСНОВІ НЕЛІНІЙНИХ ЕКВІВАЛЕНТНІСТНИХ МЕТРИК ДЛЯ РОЗПІЗНАВАННЯ БАГАТОРІВНЕВИХ ЗОБРАЖЕНЬ БАГАТОСИМВОЛЬНИХ ОБ'ЄКТІВ ІДЕНТИФІКАЦІЇ В ТРАНСПОРТНИХ СИСТЕМАХ

Анотація. Робота присвячена розробці нових інтегрованих морфологічно-нейромережових алгоритмів на основі нелінійних еквівалентністних метрик для розпізнавання напівтонових чорно-білих зображень багато-символьних об'єктів ідентифікації, що широко використовуються у автоматизованих виробництвах продукції та різноманітних логістичних транспортних

системах перевезень з метою забезпечення обліку та безпеки транспортних одиниць чи їх об'єктів ідентифікації. Ці алгоритми базуються на застосуванні лінійних (нелінійних) еквівалентнісних (нееквівалентнісних) метрик та нормалізованих просторово-залежних функцій подібності (схожості чи несхожості) матричних масивів чи даних у вигляді зображень, як критеріальних (дискримінантних) функцій. На основі проведеного огляду пов'язаних робіт були проаналізовані аспекти, специфіка та переваги застосування таких метрик та функцій для вирішення завдань дослідження, необхідність та актуальність яких були технічно обґрунтовані та сформульовані. Розроблено та представлено дві групи алгоритмів розпізнавання зображень багато-символьних об'єктів ідентифікації, виконано опис основних процедур в цих алгоритмах, показані їх особливості та відмінності. У статті авторами наведені результати модельних експериментів запропонованих алгоритмів за допомогою створеної допоміжної програми для дослідження особливостей застосування алгоритмів, для перевірки якості та точнісних характеристик розпізнавання зображень при дії на них різного типу та потужності завад, для верифікації адекватності моделей та метрик. Виконано порівняльний аналіз отриманих результатів моделювання з урахуванням різних умов та завад. Розроблена та протестована в реальних виробничих умовах програма розпізнавання ідентифікаційних номерів на запірно-пломбувальних пристроях. Роботу програми та її користувацький інтерфейс продемонстровано скрінами. Отримані результати показали, що такі запропоновані інтегровані морфологічно-нейромережеві алгоритми на основі еквівалентнісних нелінійних метрик мають кращі дискримінантні властивості, точнісні та робочі характеристики, особливо у випадку значного (аж до 40%) умовного рівня потужності завад, що діють на розпізнаванні зображення.

Ключові слова: нейромережеві алгоритми, матрична неперервна логіка, розпізнавання зображень, багато-символьні цифрові ідентифікаційні об'єкти, інтелектуальні багатофункціональні пристрої неперервної логіки, паралельна високопродуктивна обробка, нелінійні метрики, нормалізовані неперервно-логічні просторові функції, операції еквівалентності та нееквівалентності.

Introduction. Today, for many types of logistics transport systems, including for the safe transportation of important cargo and control and protection against unauthorized access, locking and sealing devices are widely used. A characteristic feature of these devices, mainly single-use and strict accounting and reporting, is the presence of a significant set of digital codes, and sometimes letters and other signs, applied to such small-sized mechanical devices. There is an urgent need for quick recognition of such identification numbers, both during mass production of such devices and when fixing these numbers in their delivery batches, when conducting control and audit at intermediate or final destinations during transportation. Therefore,

the **purpose of our work** is to develop and demonstrate a software product that allows significantly improving and automating the processes of recognizing identification numbers on such devices and not only, but also on other products, on which the dates of manufacture of goods or other characteristics in the form of digital multi-character indicators are recorded.

Review and analysis of related works and problem statement. The main promising trend in the development of information and computing systems and computer technologies is to increase their intellectuality and similarity of functioning processes to human thinking and perception. Significant and cardinal achievements over the past two to three decades in the fields of neurophysiology, artificial intelligence, neurocybernetics, modeling of complex neural networks, including a number of promising advanced convolutional architectural models, transformers, etc., and the emergence of hardware and software tools, special high-performance accelerators with parallel distributed information processing, open up new immense prospects. Fundamental research, in addition to spontaneous intellectual qualities, reveals a number of important general principles. Among these features, one can mention the principle of associative parallel processing of information at all levels of its processing (the global behavior of the system, which is considered "intelligent"), the principles of self-organization, learning by examples, adaptation, aging, and the concept of active, rather than passive memory.

The great interest in neural models forces us to reassess the fundamental provisions in many fields of knowledge, including computer science. Neural models of brain activity and cognitive processes are likely to lead to promising results in neurophysiology, neurology, the emergence of systems with increased computing resources and intellectual qualities for solving problems in medical informatics and diagnostics. At the same time, in previous years there have been many failures on the path to improving artificial intelligence, since, firstly, the selected computational methods were previously insufficient for solving important and complex practical problems, and secondly, simple and imperfect neural models and networks were used.

Almost all advanced complex models and architectures of neural networks, especially deep ones with a significant number of layers of neural elements, and specialized parallel computing structures and MIMO systems, created for their implementation, require not only parallel processing of information but also its parallel input/output. Generalization of scalar two-valued logic on matrix case has led to intensive development of binary images algebra (BIA) and 2D Boolean elements for optic and optoelectronic processors [1-4]. Taking into account the well-known scientific facts that with the increase in the significance of logics and the number of input variables, the number of potentially possible implemented functions in these logics increases significantly, here we will note the relevance and prospects of expanding the functional capabilities of bioinspired neural structures precisely

through the use of generalized new multi-valued logics and corresponding algebras [5]. Therefore, for numerous promising implementations of optical self-learning neural networks (NNs), NNs with a two-dimensional structure [6], recurrent optical NNs [7], continuous logic equivalence models (CLEM) of NNs [8-10], not only elements of scalar binary logics are needed, but also matrix logics, and not only two-valued, but also multi-valued, continuous, neural-fuzzy logic and their new interesting modifications and extensions.

Therefore, one of the current additional promising research directions in this area is the search for means aimed at constructing 2D structures, especially universal or quasi-universal and also with programmable settings, capable of performing a whole range of logical operations of matrix logics (multi-valued, continuous) [2] and element-wise nonlinear transformations corresponding to certain activation functions of neurons or neuro-like elements of arrays. Some specific technical solutions to these problems were proposed and solved in the works [4, 5, 11], where time-pulse architectures (TPCA) were considered, and in [12], where their generalizations were proposed.

The approach proposed in them showed that even for various algebraic logics [11, 12-15] used for the synthesis of functional systems, it is possible to create more complex problem-oriented structures and processors, in which, due to the use of specific coding of time-pulse operands and only elements of matrix two-valued logic, it is possible to implement a wide range of functions of various logics, continuous, etc. and their code-controlled selection. And such intelligent multifunctional devices of continuous matrix logic significantly expand their functionality and the range of tasks performed.

Today, rapid progress in mathematical logic, especially matrix (multi-valued, continuous, fuzzy, neural) [1, 11, 12, 15-17], accumulation of data on continuous (analog) and clearly nonlinear functions of neurons [18-20], development of the theory of neural networks, neurobiology and neurocybernetics, as well as adequate algebraic-logical tools for mathematical description and modeling [17, 8, 9, 21-24], development of optical technologies have created conditions for construction of technical systems adequate for practically any task of artificial intelligence.

Works [21, 25], and especially [8, 9, 22, 23], solve the problem of increasing the capacity of artificial neural networks (ANNs) and associative memory (AM), even with limited storage of highly correlated images, and the problem of convergence of methods and rules of learning, using multi-level representation of signals. The use of operations of generalized biologically inspired neural logic, for example, its operations of "equivalence" and "non-equivalence" or their modifications, is typical of the works [8, 9, 22, 23] and allowed to create new models of neural networks and autoassociative memory with much better characteristics. In this regard, such models and theory were called "equivalenceist".

Such models allowed to describe negative and inhibitory weights along with excitatory ones and not only in bipolar, but also in unipolar coding. Neural bio-logic (NBL) (gnoseologically spirally developed and refined) [9, 12, 16, 21, 22] is an integration of known logics: multivalued, hybrid, continuous, fuzzy, etc. At the same time, integrated operations in fuzzy logic are: fuzzy negation operation, t-norms and s-norms, and they have a duality relation according to the general form of De Morgan's principle.

Examples of t-norms are: logical multiplication ($\min(a, b)$), algebraic multiplication ($a \cdot b$), bounded multiplication, etc. Examples of s-norms are: logical sum ($\max(a, b)$), algebraic sum ($a + b - a \cdot b$), bounded sum ($1 - (1 - a)(1 - b)$), contract sum, etc. [24, 26]. At the same time, the main basic NBL operations used in equivalenceist NNAM models [9, 21–23] are binary equivalence and non-equivalence operations, which have several variants [22], and normalized nonlinear auto-equivalence or auto-non-equivalence [22]. The variants of these equivalence operations are shown on Fig.1.

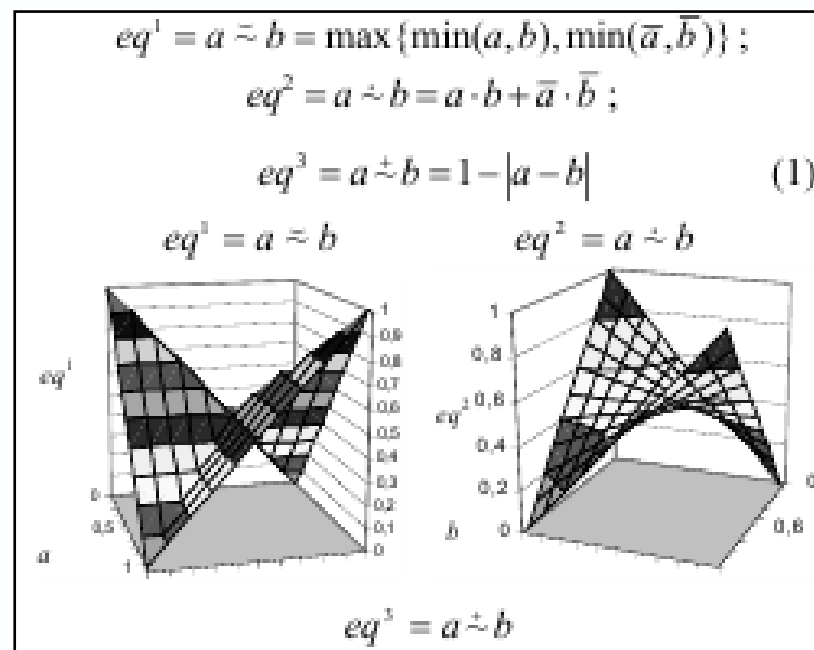


Fig. 1. Operations of equivalence (Screenshot from the modeling program)

Since, as was shown in [9, 22], when using equivalence (non-equivalence) operations to compare signals, the result does not depend on the constant shift (analogy to the constant component), on the scale factor k , or on the type of coding (bipolar or unipolar), these operations are a generalization of the XNOR and XOR operations of binary logic and allow logically comparing continuous-level (analog) signals and multilevel signals with unipolar and bipolar representation, including comparing signals in the formats of scalars, vectors, and image matrices.

For this, normalized equivalence and non-equivalence of vectors and matrices [8, 22, 9] are used, which for these two matrices $\mathbf{A} = [a_{i,j}]$, $\mathbf{B} = [b_{i,j}]$ are defined as follows:

$$\mathbf{A} \sim_{\alpha} \mathbf{B} = \frac{1}{I \times J} \sum_{i=1}^I \sum_{j=1}^J (a_{ij} \sim b_{ij}); \quad (2)$$

$$\mathbf{A} \sim_{\alpha}^{\sim} \mathbf{B} = \frac{1}{I \times J} \sum_{i=1}^I \sum_{j=1}^J (a_{ij} \sim^{\sim} b_{ij}). \quad (3)$$

Normalized equivalence and nonequivalence are more general new complementary metrics in metrical space R . In particular, is a normalized distance between matrices and it turns into normalized distance of Hamming. As can be seen from expressions (2) and (3), the component-wise NBL operations ($\sim$) or ($\sim^{\sim}$) are generalized for the matrix case, and the NBL logic becomes matrix NBL (MNBL). Depending on the variants of the used operations ($\sim$), ($\sim^{\sim}$) or on different types of t-norms and s-norms and integrated fuzzy operations of union and intersection used in them, we have proposed and extended set of corresponding equivalence algebras (EA) and their operational tools [9, 22] for creating an equivalence theory based on MNB and self-leaning neuro-paradigm [26].

In works [9, 22] new concepts of equivalence one-dimensional (1-D) and two-dimensional (2-D) functions were introduced, and in work [8] normalized space-dependent equivalence and non-equivalence functions were described (shown on Fig.2).

$$\begin{aligned} \tilde{\mathbf{e}} &= (\mathbf{A} * \mathbf{B}) / I \times J \text{ and} \\ \mathbf{e}^{\sim} &= (\mathbf{A} *^{\sim} \mathbf{B}) / I \times J = [\mathbf{1}] - \tilde{\mathbf{e}} = \\ &= [ne_{\xi, \eta}] \in [0, 1]^{(N-J+1)(M-J+1)}. \end{aligned}$$

Fig. 2. Operations normalized space-dependent equivalence and non-equivalence functions (Screenshot from the modeling program)

In this equation symbol ($\sim \square$) denotes the convolution (correlation) with operation of “equivalence”. The normalized space-dependent equivalence and non-equivalence functions reflect the measure of equivalence and nonequivalence of two images, depending on their mutual spatial shifting. The connection of space-dependent equivalence and non-equivalence functions with correlation functions (linear LCF and nonlinear NCF) was demonstrated [8, 22].

Using the connections of the proposed functions with linear and nonlinear correlation functions and the criterion functions of the mean absolute error (MAE) and the mean square error (MSE) allowed the authors of the work [27] to show, that two groups of mathematical constructions based on them determine two groups of parallel action architectures, namely: high-speed correlators with nonlinear autoequivalent and morphological image processing. Based on these approaches and functions, more generalized modified matrix-tensor neural equivalent models (MTNLEM) were synthesized for spatially invariant recognition of 2D images [8].

That is why, taking into account the justifications in the introduction regarding the need to solve the problems of recognizing multilevel, noise-damaged, images of identification digital objects on devices, documents, and products intended for various applications, and the above mentioned scientific facts and the possibility of using equivalence functions for this, we will propose in this paper **recognition algorithms based on nonlinear equivalence metrics** and show the results of research on these algorithms.

Presentation of the main material. Let us consider a brief description of these two groups of recognition algorithms. In the algorithms of the first group, there is no preliminary segmentation of the input image. The idea of nonlinear equivalence algorithms (NLEA) is to detect in the image of a multi-symbol object (based on a priori information) those fragments that correspond to individual symbols from the reference image, composed of a set of alphabet symbols to be recognized. For each i -th segment of the processed initial image, nonlinear equivalence functions (NLEF) are calculated with a common reference image, which are subsequently analyzed for decision-making using various discriminant criteria, which allows choosing more optimal parameters of criteria and functions during experimental testing on typical samples.

For the second group of NLEA implementation options, NLEFs are calculated for each i -th segment of the reference image with a common input multi-symbol image. Within each NLEA group, we also apply several modifications of the NLEF, depending on both the type of "equivalence" ("non-equivalence") and the parameters defining the type of nonlinearity and a number of auto-equivalence transformations. Moreover, the latter can be applied both to individual components of the compared images and to integrate individual NLEF-estimates and to the normalized NLEF-estimate as a whole.

In Fig. 3a shows the initial multi-level (256 levels) image **A** of size $I \times J$ for recognizing the image fragments, present on it, that correspond to the templates from the ordered set (alphabet) of symbols S_q $K \times L$ (see Fig. 3b). In this case, the criterion function (dependent on space) can be defined for each reference S_q , as shown in Fig. 3c. The presence of a priori information on the number R of symbols in the identification object (the number of fragments in the image **A**) or algorithms for

determining the number and possible deviations of the positions of symbols taking into account gaps allow dividing the image of the two-dimensional criterion function into R regions. In each r -th region there is an extremum (minimum or maximum) of the criterion function $\mathbf{B}_{q,r}$, namely $\mathbf{B}_{q,r}^{\max(\min)}$ and its coordinates.

By comparing all $\mathbf{B}_{q,r}^{\max(\min)}$ in the r -th region, we can find the index q' (the number of the reference pattern, i. e. a symbol or a number), which gives us the largest (smallest) value of the criterion function in this region. Thus, we determine (recognize) the symbol-pattern in each r -th region, and using the coordinate of the extremum of the best equivalence (similarity) or non-equivalence (dissimilarity), the position of the recognized reference symbol in the object is determined, and the coordinates of the next region (the location of the pattern) are searched for.

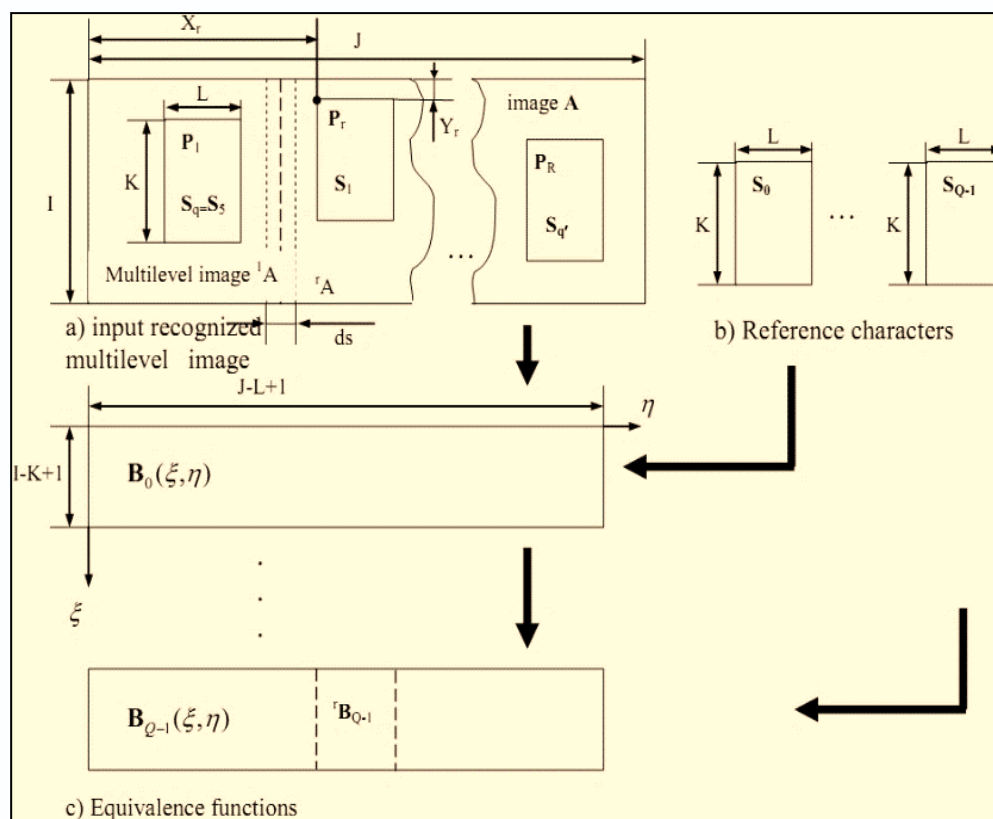


Fig. 3. Formation process of criterial functions

Before recognizing an input image of a set of recognition objects, preprocessing procedures are performed, namely morphological operations with small-sized structural elements to improve the visibility and quality of subsequent recognition.

To analyze the NLEF functions obtained after the first step, both as integral features, and for making decisions based on their set, we perform the transformation of 2-D NLEF into 1-D NLEF, performing component-wise minimum (maximum)

operations on vector arrays corresponding to the columns (or rows) of the obtained 2-D NLEF. Thus, we selection local spatial extremum of NLEF. Such information compression is possible and expedient and allow to significantly simplify further analysis of recognition. In the next step, based on the results of comparisons of 1-D transformed local extremums of NLEF (amplitude of samples) (the number of extremum correspond to the number of recognized reference symbols), we conclude about the presence or absence (most probable) of on of the reference symbols and about its coordinate location in the initial image being recognized. A modifications of these algorithms is algorithms, when the criterion functions are calculated only in r -th local regions (near the occurrence of a certain possible position of the extremum. This significantly reduces the time required for its implementation.

Let us describe the specifics of recognition algorithms that use the method of preliminary segmentation of the input image (algorithms of group II). First step: Image $\mathbf{P}_0$ is formed as an ordered set of all reference symbols. Second step: Image $\mathbf{A}$, which is recognized, is segmented into R sections, areas (locations of character signs) with sizes $I \times J$ pixels, taking into account a priori information about the location of symbols and possible deviations.

Third step: The criterion functions $\mathbf{B}(\square, \square \square \square \square \square F(\mathbf{A}, \mathbf{P}_0)$ for each r -th segment of the input image $\mathbf{A}$ and $\mathbf{P}_0$ (as a set of reference symbols) or the criterion functions $F(\mathbf{A}^r, \mathbf{P}_0^q)$ are calculated for each r -th segment $\mathbf{A}^r$ and the ordered set of the q -th conditional region $\mathbf{P}_0$, namely $\mathbf{P}_0^q$. Fourth step: For each segment $\mathbf{A}^r$ (its ordinal number), the number of the q -th conditional region of the reference ordered set $\mathbf{P}_0$ is determined, this number gives the largest (smallest) value of the criterion function for the best special mutual shift. According to this number q^{opt} , the r -th segment of the image of the identification object is recognized (a computer code or reference symbol is applied to the position, coordinate of the r -th segment).

For all possible groups of algorithms, we apply various spatially dependent equivalence criterion functions from two images, including the most optimal, as shown by our modeling and comparative experiments, criterion functions that were introduced and previously used in [8] and which were called “auto-equivalence” there. Using such spatial functions, nonlinear transformation is performed on the entire set of signal samples obtained before adding the corresponding indices in the region of change.

The differences between the recognition algorithms proposed here and the earlier ones, which were also based on equivalent neural network models [8], is that the input images to be recognized and the images of the reference symbols (during training and input) are not converted into a set of two-gradation images, but are processed in the original grayscale format. To form the reference symbols, we used averaged templates in this work, i. e. mathematical expectations, which were determined from significant samples-sets of representatives for each q -th symbol.

Fragments of individual symbols averaged over several implementations were used to form the references base and the reference generalized image. Taking into account possible minor shifts, a fuzzy (blurred) representation of each q -th symbol was essentially formed, which further improved the recognition quality even with significant image damage by interference.

Computer modeling and the results. To selection the best optimal criterion function, taking into account the influence of various noises and interference distorting the recognized image, to select the necessary algorithm from a group of algorithms, we developed the first program aimed at modeling the proposed recognition algorithms.

This program allowed us to set the desired type, type of algorithm, criterion function, display the results (final and intermediate) in a graphical interface (see Fig. 4), convenient for the research.

The recognized image, in particular, with a size of 164×46 pixels, was encoded with 256 gradation levels representing a 7-character identification number of the locking and sealing device. Other images were also used, for example, a 14-character object with gaps between them, etc. In the first case, the dimension of the reference image was 30×18 pixels.

During segmentation and processing, we selected a possible deviation from the predicted distance between symbols at the level of ± 10 pixels. Noise with different parameters was superimposed on the recognized image. For each parameter value and each type of criterion functions (NLEF), we calculated 1D-transformed NLEFs corresponding to all possible reference patterns.

Fig. 5, 6 show 2D and 1D NLEFs. By increasing the parameter characterizing the degree of nonlinearity in 2D NLEFs, it is possible to control the type of the latter and enhance their discriminant properties. Experiments have shown that using NLEF it was possible to recognize noisy images with significant interference powers, up to 40% (with a normal distribution law).

Noisy multilevel images and recognition results are shown in Fig. 7. Since an important problem is the development of parallel high-performance real-time systems for automating mass processes of recognition of identification numbers on devices, in the report we will consider, albeit briefly, the developed possible effective hardware implementations.

Additionally, we will show that for calculating the criterion functions it is possible to use the so-called image equivalentors, previously presented in [9, 22]. They are implemented on the basis of correlators (systems of convolution operations), which implement linear and nonlinear two-dimensional correlation functions that depend on space, on the input and additional to them (contrast complementary images).

Implementations of such equivalentors are described in [8, 27].

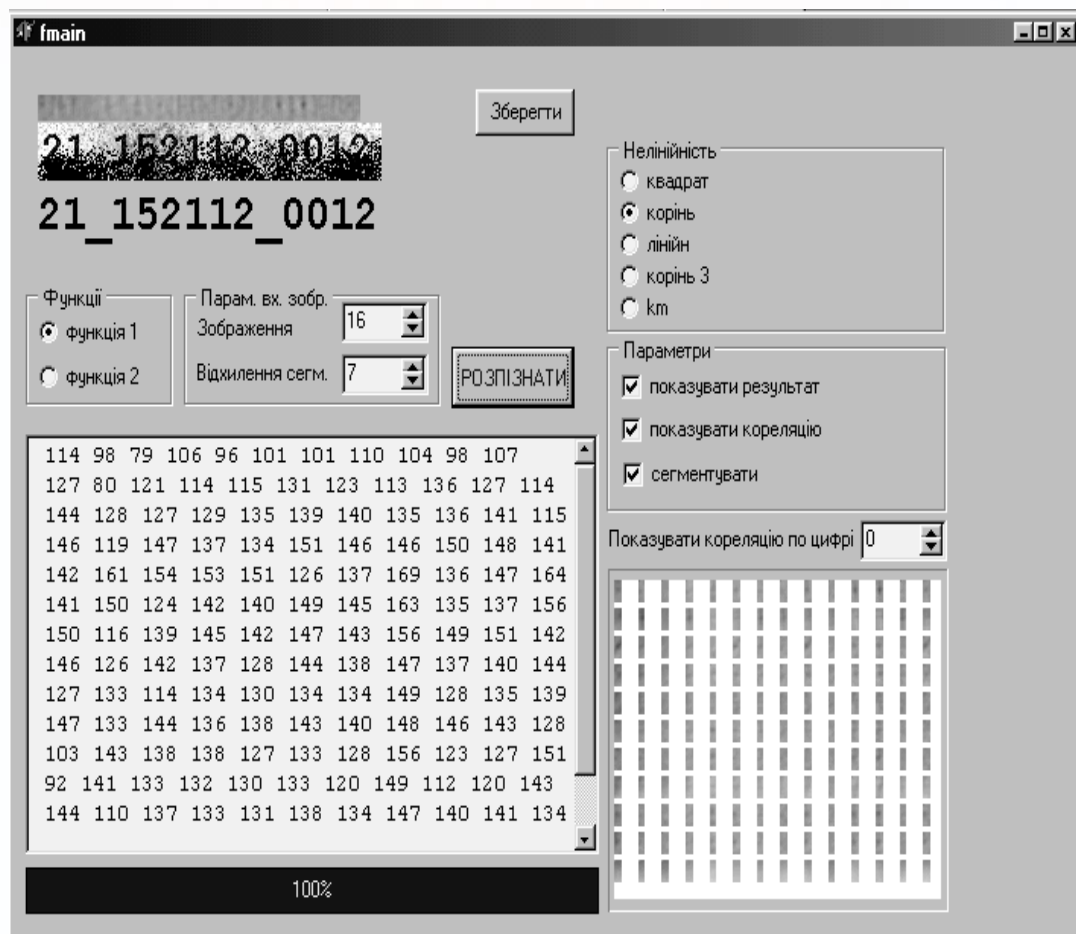


Fig. 4. Graphical interface of research program 1 for recognition algorithms simulation

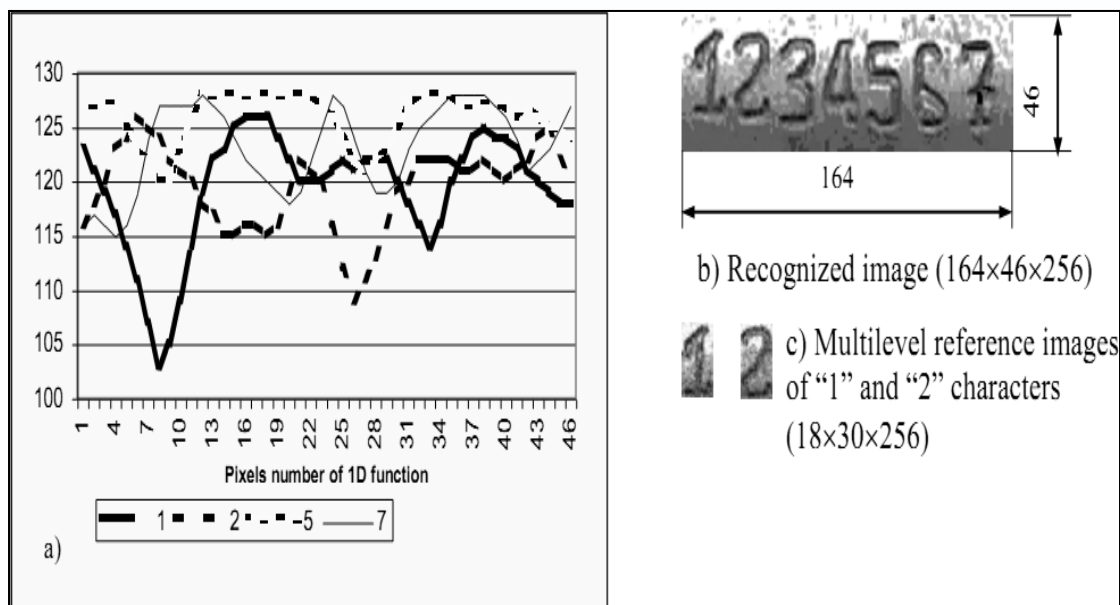
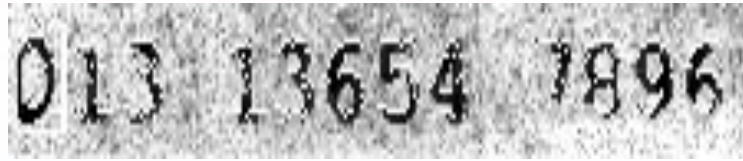


Fig. 5. Part of 1D NLEF function ($X_r=1=8$, $X_r=2=26$)



Input recognized multilevel image



Equivalence function (with character "1")

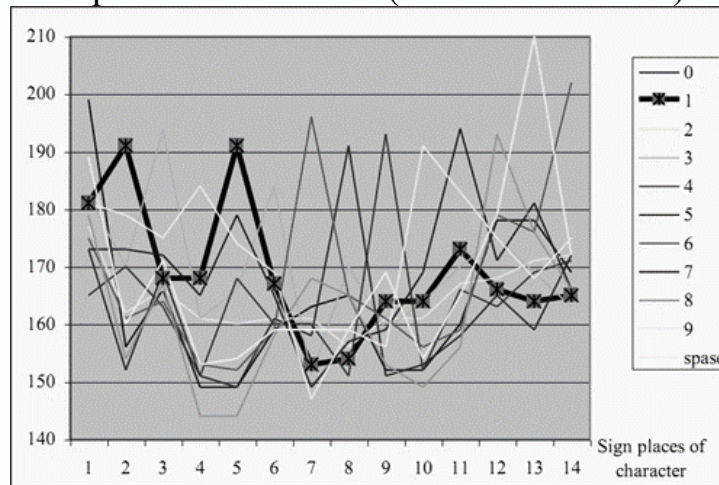
Dependency of function B_q^r

Fig. 6. Character «1» recognition processes are shown

To verify the proposed approach, auxiliary image reading-input devices and a second real program for quick identification of numbers on the housings of locking and sealing devices were developed. The program passed production tests at the state enterprise "Vinnytsiatransprilad" of the South-Western Railway.

System functionality:

- 1) Enters an integrated image with image fragments on 20 housings of locking and sealing devices using a matrix installed on the scanner;
- 2) Recognizes images of identification numbers that are invariant to the displacement and rotation of the housings of locking and sealing devices, the system is not sensitive to the displacement and rotation of the housings of locking and sealing devices themselves in the matrix;
- 3) Gives sound and visual signals about images or specific numbers (symbols) that are poorly recognized or not recognized at all;
- 4) Recognizes 7 digits in the image and exports the identification code from the device, provided by machine code, to the database;
- 5) Links and compares the recognized numbers of locking and sealing devices with the numbers already in the database for their unambiguous verification;

6) Recognizes the image of a seven-digit set of 20 images of locking and sealing devices in 1-2 seconds;

7) Has high resistance to images that are very damaged by various types of interference and lighting glare on the surface.

Graphical interface of the experimental manufacturing program for recognition algorithms simulation are shown on Fig. 8.

Results of computer modeling and laboratory studies, conducted on real objects have confirmed advantages of such algorithms. Additional entering of correlation factors in recognition models improves the quality and validity of algorithms. As our research shows, NLEA possess higher discriminant properties than correlation and other conventional algorithms.

When adding background component in the image being recognized in reasonable measures the character and quality of recognition doesn't change applying NLEA.

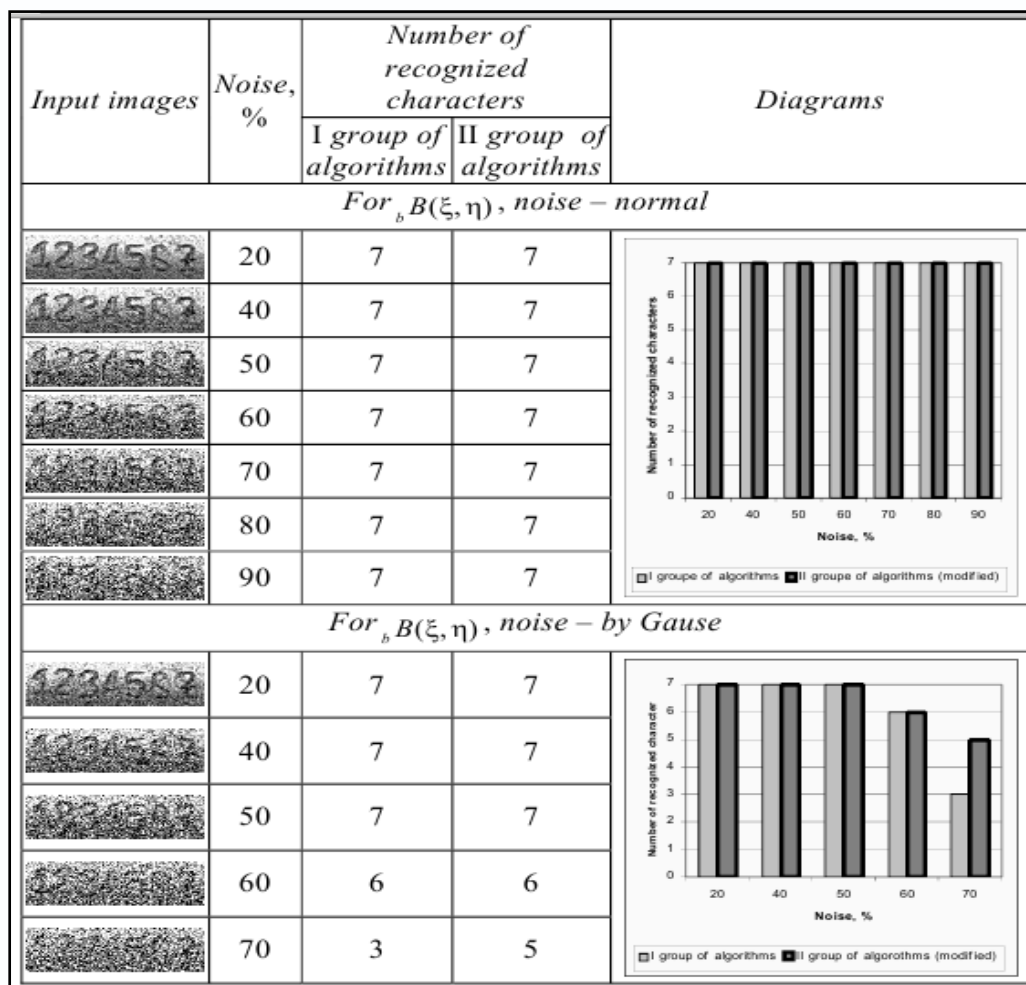


Fig. 7. Noised multilevel images for computer modeling and recognition results



Fig. 8. Graphical interface of testing program for recognition algorithms simulation

Conclusions. Improved algorithms for recognizing multi-level images of identification objects are proposed, which have good recognition quality, especially in situations where the objects being recognized are in a noise-damaged environment or if background noise is added. NLE algorithms allow recognition, as proven by laboratory tests, even at such noise strengths when traditional (correlation) algorithms do not work. The results of theoretical research are implemented in a software product designed for quick identification of numbers on sealing devices. The software product was tested at the Vinnytsiatransprilad production enterprise of the South-Western Railway. The interface, functionality and characteristics of this software product are presented. The results of its tests confirmed high performance and a very low proportion of unrecognized characters: less than 0.01%.

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