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DEVELOPMENT OF MODIFIED AMPLITUDE-MODULATED SCREENING METHOD FOR IMPROVING PRINTING QUALITY

A new screening method for improving printing quality is considered. The method application for the protection of textual, tabular and graphical information is discussed. Printing quality is an essential parameter when incorporating specially designed security features into the electronic file from which printing is done. The opportunity of applying the proposed method for information protection on physical media is analyzed.

Keywords: *data protection for physical media; print quality; amplitude-modulated screening; hyperbolic Ateb-functions.*

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РОЗРОБКА МОДИФІКОВАНОГО АВТОТИПНОГО МЕТОДУ РАСТРУВАННЯ ДЛЯ ПОКРАЩЕННЯ ЯКОСТІ ДРУКУ*

У статті розглянуто новий метод растрування для покращення якості друку. Передбачається його застосування для захисту текстової, табличної та графічної інформації. При вбудовуванні спеціально розроблених захисних елементів у відповідний електронний файл, з якого реалізується друк, для ефективності захисту важливою є висока якість друку. Проаналізовано можливість використання запропонованого методу для захисту інформації на матеріальних носіях.

Ключові слова: *захист інформації на матеріальних носіях; якість друку; автотипне растрування; гіперболічні Ateb-фунції.*

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РАЗРАБОТКА МОДИФИЦИРОВАННОГО АВТОТИПНОГО МЕТОДА РАСТРИРОВАНИЯ ДЛЯ УЛУЧШЕНИЯ КАЧЕСТВА ПЕЧАТИ

В статье рассмотрен новый метод растрирования для улучшения качества печати. Предполагается его применение для защиты текстовой, табличной и графической информации. При монтировании специально разработанных защитных элементов в соответствующий электронный файл, из которого осуществляется печать, важным параметром надежности графической защиты является качество печати. Анализируется возможность использования рассматриваемого метода для защиты информации на материальных носителях.

Ключевые слова: *защита информации на материальных носителях; качество печати; автотипное растрирование; гиперболические Ateb-фунции.*

Problem statement. Documents play an important role in social life, as they are the means of evidence, affirmation of certain facts (Shevchuk, 2002), identification, and money turnover support. As data carriers, documents help to improve internal organization of enterprises and institutions, form the basis for decision making etc. In international practice there exist the following major product groups of securities and documents of strict accountability: forms of market and state forms, departmental,

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industry and documentary forms, letterhead documents that directly or indirectly are the means of payment and receipt services, excise, customs and revenue stamps and envelopes, lottery, ticket products, label products. Inadequate protection of these documents can inflict damage upon a state and its citizens. This raises the problem of developing methods and facilities to protect data on physical media.

Recent research and publications analysis. As indicated in (Yudin, 2009) development of information security methods is an extremely important issue closely linked to the creation of information security system of a company, a particular industry, or even the entire state. Encryption methods and information coding are being developed for that purpose (Korchenko, 2011; Yudin, 2010). One of the important components of this system is the protection of information on physical media.

The work (Shevchuk, 2013) is devoted to the development of security models for printed documents. It is shown that there are 6 factors of influence on consumer characteristics: size of copies of a document, the time of existence of documents, documents' velocity, depth of control, the intensity of exchange, and the available degree of protection of a printed document. Using the models of protection facilities allows creating the best protection facilities for a specific document with its functional features, and calculating system effects on the level of documents' security.

Method of coding graphics and development of a new technology to protect securities based on coding Hadamard matrices are considered in (Shovgeniuk, 2009). Information security based on fuzzy sets formalism are proposed in (Karpinskyy, 2011). Heuristic algorithms for constructing secure information networks are available in (Dudykevych, 2006). Determining factors of importance for the expert evaluation of information security are presented in (Korchenko, 2012). Analysis of relevant data shows that because of documents forgery, the USA industry annually loses 200–250 bln USD (Kyrychok, 2008). This process takes considerable intensity with the distribution of computer methods of falsifying documents. Therefore, all countries take preventive measures for documents security with the use of a printing method.

The objective of this study is to develop a modified amplitude-modulated screening method to improve print quality. Improving the screening process can more accurately reflect the subtle elements of an image or a text which makes protection of printed information on physical media more reliable. In the process of achieving the goal, the following main objectives were set and reached:

To implement the task, special protective graphics based on hyperbolic Ateb-functions are built and the method of modified amplitude-modulated screening that allows realization of printing fine detail and halftones with greater clarity is proposed.

Key research findings. ***Technological characteristics of the developed method of protection.*** A secure document must comply with the State Standard (ISO 4010-2001), whereby safety elements should be made within 40–50 microns positive play and 60–80 microns reversed, and microprint size should be within 200–250 microns, which guarantees high quality of printing and helps to reduce the likelihood of fraud. The authors have developed a new method for protecting information on physical media. Figure 1 shows a block diagram of the proposed method. The developed software realizes a combination of relevant information with security elements and creates an electronic file in the PostScript format with protected information which enables the highest quality printing permitted by a given output device. That is, you can implement a secure print data with the resolution of 3000 dpi or higher. Resolution ability of print is restricted by the capacities of the output printing device. Block diagram of information technology is presented in Figure 1.

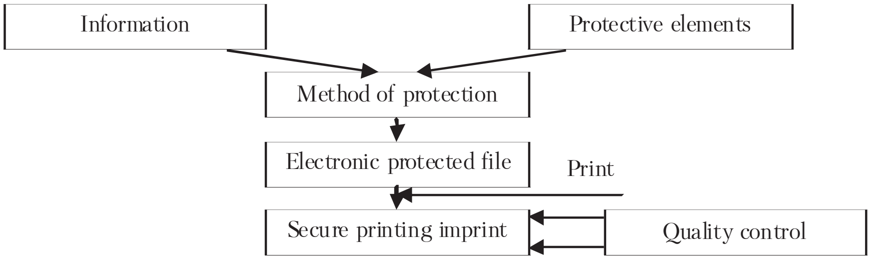
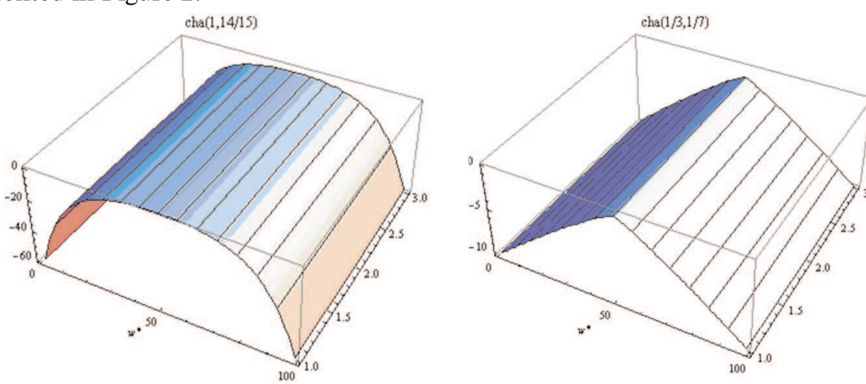


Figure 1. **Block diagram of information technology,** *authors' development*

Images of hyperbolic Ateb-functions depending on different parameters are presented in Figure 2.



a) parameters m = 1, n = 14/15   b) parameters m = 1/3, n = 1/7

Figure 2. **Graphics hyperbolic Ateb-cosine with different parameters,** *authors' development*

Consider the expression

$$\omega^* = \frac{n+1}{2} \int_{0}^{0 \le \bar{V} \le \infty} \left(1+\bar{V}^{n+1}\right)^{-\frac{m}{m+1}} d\bar{V}. \quad (1)$$

Dependency V from ω*, as well as parameters n and m determined by the integral (1) is called the hyperbolic Ateb-sine

$$V = sha(n, m, \omega^*). \quad (2)$$

From the expression

$$\omega^* = \frac{m+1}{2} \int_{1}^{1 \le \bar{U} \le \infty} \left(\bar{U}^{m+1} - 1\right)^{-\frac{n}{n+1}} d\bar{U}. \quad (3)$$

We obtain the dependence U from ω* and from the parameters n and m entitled hyperbolic Ateb-cosine

$$U = cha(m,n,\omega^*). \tag{4}$$

For hyperbolic Ateb-sine and hyperbolic Ateb-cosine is valid the next identity

$$cha^{m+1}(m,n,\omega^*) - sha^{n+1}(n,m,\omega^*) = 1. \tag{5}$$

The length of the domain hyperbolic Ateb-functions is defined by the formula:

$$2\Pi^*(m,n) = \frac{2\Gamma\left(\frac{1}{n+1}\right)\Gamma\left(1-\frac{2+n+m}{(n+1)(m+1)}\right)}{\Gamma(m^2+m)}. \tag{6}$$

Hyperbolic Ateb-function is defined on the interval $[-\Pi^*,\ \Pi^*]$.

Given function *F(x)* can be expanded on the interval $[-\Pi^*,\ \Pi^*]$ in Fourier series.

As hyperbolic Ateb-cosine $cha^{m+1}(m,n,\omega^*)$ is even, then decomposition in Fourier series takes the form

$$cha^{m+1}(m,n,\omega^*) = \frac{a_0}{2} + \sum_{k=1}^{\infty} a_k \cos\frac{k\pi\omega^*}{\Pi^*}, \tag{7}$$

where

$$a_k = \frac{1}{\Pi^*}\int_{-\Pi^*}^{\Pi^*} cha(m,n,x)\cos\frac{k\pi x}{\Pi^*}dx = -\frac{m+1}{2\Pi^*}\int_1^x \frac{d\bar{x}}{\left(1-\bar{x}^{m+1}\right)^{\frac{n}{n+1}}}dx;$$

$$a_0 = \frac{1}{\Pi^*}\int_{-\Pi^*}^{\Pi^*} cha(m,n,x)\,dx = -\frac{m+1}{2\Pi^*}\int_{-\Pi^*}^{\Pi^*}\int_1^{-1\le x\le 1} \frac{d\bar{x}}{\left(1-\bar{x}^{m+1}\right)^{\frac{n}{n+1}}}dx. \tag{8}$$

Since the function hyperbolic Ateb-sine $sha(m,n,\omega^*)$ is odd, then the expansion in Fourier series hyperbolic Ateb-sine function has the form

$$sha^{m+1}(n,m,\omega^*) = \sum_{k=1}^{\infty} b_k \sin\frac{k\pi\omega^*}{\Pi^*}, \tag{9}$$

where

$$b_k = \frac{1}{\Pi^*}\int_{-\Pi^*}^{\Pi^*} sha(n,m,y)\sin\frac{k\pi y}{\Pi^*}dy =$$

$$= \frac{n+1}{2\Pi^*}\int_{-\Pi^*}^{\Pi^*}\sin\frac{k\pi y}{\Pi^*}\int_0^{-1\le y\le 1}\frac{d\bar{y}}{\left(1-\bar{y}^{n+1}\right)^{\frac{m}{m+1}}}dy. \tag{10}$$

As hyperbolic Ateb-functions are differentiable functions, and then the series (7), (9) is converging. Formulas (7), (9) are used to calculate a graphic element of protective mesh. Protective elements take the form of hyperbolic Ateb-functions, images of which are presented in Figure 3.

Quality control. To effectively protect data on physical media, it is important to ensure high quality of printing imprint. The better printed information is, the harder it is to forge it. Modern technologies allow faking everything, but there arises a question of economic criteria, namely time and costs of creating a fake. The main purpose of defense is to make the fake unprofitable. It is clear that the increase of print quality leads to higher cost of printed impression, and thus the cost of fraud rises. This is especially important for full-color prints, which are the most important documents (passport, driving licence etc.).

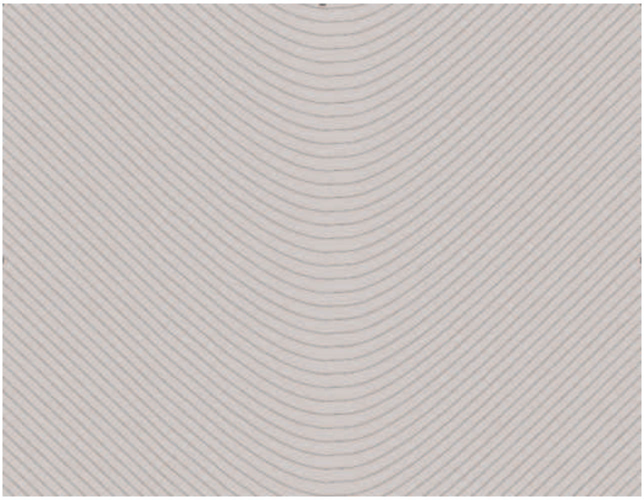


Figure 3. **Protective graphics based on hyperbolic Ateb-cosine,** *authors' development*

There is a problem of converting structure images in the process of printing, which is related to the difficulty of rendering fine detail and halftones. One of the most significant shortcomings of modern methods of structure transformation is much smaller resolution of prints compared to the resolving ability of printing. This is due to the amplitude-modulated principle with binary halftone reproduction means of printing in which tone values in a particular area of the original play with relative area of the colored area of print. Raster points are destroying contours and fine detail of halftone original, reducing the quality of the prints. Thus, raster distortions are formed (Kuznetsov, 2008). The magnitude and the visibility of raster distortion depend on screen frequency, frequency scanning function, and bitmap structure geometry and raster points. These raster distortions are associated with the parameters of amplitude-modulated screening such as pressure in printing apparatus, ink supply, dot gain, sliding and double vision.

A new screening method is developed that can reproduce more accurately fine picture elements important for protection. Improvement is achieved by the special structure of raster points which is better adapted to display halftones. Formation of raster point $T(I,j)$ does by the formula:

$$T(i,j) = cha(m_1,n_1,i)cha(m_2,n_2,j), \tag{11}$$

where i, j – the current coordinates of raster points m_1, n_1 – the options of hyperbolic Ateb-cosine horizontally m_2, n_2 – the options of hyperbolic Ateb-cosine vertically. To send 8 bits of color depth raster point can take from 1 to 256 values, namely $j = 1,...,16$; $i = 1, ..., 16$.

An example of the formation of raster points based on hyperbolic Ateb-functions is shown in Figure 4.

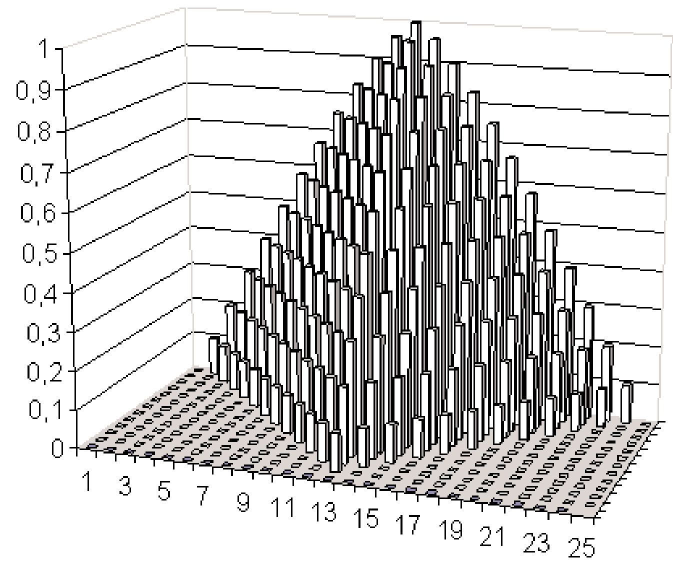
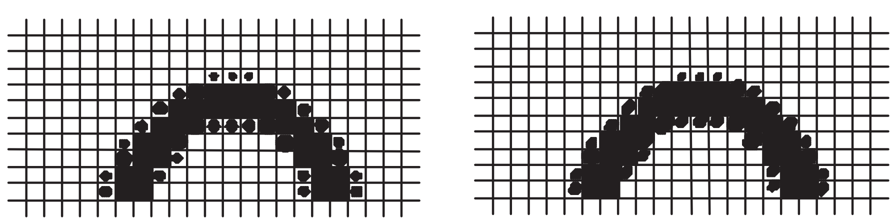


Figure 4. **Structure of raster point based on hyperbolic Ateb-functions,** *authors' development*

Development of the modified method of autotypical screening allows printing fine details and alftones for text or graphical information on physical media more precisely as it is shown in Figure 5.



a) Small detail printing with standart autotypical screening

b) Small detail printing with proposed autotypical screening

Figure 5. **The better quality printing the fine details and halftone with proposed autotypical screening,** *authors' development*

Conclusions. A new method of forming a raster structure based on hyperbolic Ateb-functions is proposed. This structure is specially adapted for the transmission of fine protective graphical elements and halftones while printing, which greatly improves the print quality. The advantages of this method are shown on some experimental images. The developed method can be used for improving the effectiveness of protection of information on paper, plastic or other material media.

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