Control of the latent image formed as a combination of variously oriented textures

Andrey A. Zharkih
Information Systems
and Technologies Dept.
Stavropol City, NCFU
azh89@mail.ru

Galina V. Shagrova
Information Systems
and Technologies Dept.
Stavropol City, NCFU
shagrovagv@mail.ru

Oksana I. Maslova
Information Systems
and Technologies Dept.
Stavropol City, NCFU
oksmaslova@inbox.ru

Dmitry R. Sinitsin
Information Systems
and Technologies Dept.
Stavropol City, NCFU
ist@stv.runnet.ru

Abstract

A method for segmentation of latent image objects is suggested, regardless of the method of its implementation based on the wavelet analysis of the latent image using the experimentally selected wavelet function. A software package for controlling latent images formed by variously oriented structures is developed on the basis of the proposed method.

1 Introduction

A set of methods and tools for embedding information is usually attributed to the field of steganography. A set of terms used in the western literature on steganography, adopted following the results of the first open symposium in Cambridge devoted to the problem of data concealment [Phi96] describes a basic set of terms for steganography. The emergence of new types of transmission and processing of information led to the formation of a new direction in the field of information security: digital steganography, whose methods are conventionally divided into data concealment methods, header methods and digital watermarks. A digital watermark is a label embedding technique that is a narrowband signal over a wide frequency range of the image to be marked. [Cox08, Fri10, Gri02]

At present, digital steganography continues to evolve: a theoretical basis is being formed, new, more persistent methods of embedding information are being developed. Modern authors introduce the concept of "latent image", which is a digital watermark, into which, as an embedded label, a different image is introduced, different from the labeled one. [She09, Met04, Gor99]

There are many methods for protecting printing products with latent images, which are divided into graphic and technological ones. Graphic latent images are an inexpensive and at the same time a reliable security element

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and, at present, are widely used by leading printing houses that produce protected printed products, including securities, banknotes, control tickets. Methods for the formation of latent images (LI) can be divided into three groups [Fed14]:

1. Variations of the direction of the lines. A hidden image is constructed by thin unidirectional lines on a background made up of lines of the same thickness and frequency, but of an another directionality;

2. Variations in scale. A hidden image is built by single raster blocks on a background composed of raster blocks of the same saturation that are different in texture;

3. Phase variations. The hidden image and the background are constructed with the same textures, but with a phase shift relative to each other.

To protect securities and banknotes, the methods of the first type are usually used. For example, own methods of forming companies that issue banknotes of many countries: Multicolor Latent Image by Austrian OeBS factory, LIFT - De La Rue (Great Britain), kipp effect - Goznak (Russia) [Mar14].

Currently, latent images are used mainly to protect particularly valuable printing products, such as banknotes, securities, control documents. Since these images refer to human readable features, their control is not automated.

According to the Central Bank of Russia for the year 2014, the number of counterfeit Russian banknotes amounted to 0.0012% of the total money supply, while the number of false alarms of automatic control devices of valid banknotes to date is 6% [CBR1].

Existing software does not allow automatic control of latent images, since modern recognition methods depend on the method of forming such images and require the development of an individual filter for each type of LI [CBR2]. A new method for segmentation of hidden image objects is proposed to realize automatic control of LI regardless of the combination of differently directed structures of the main and hidden images.

2 Method of control

The task of controlling any image of the capture received from the device and passed the preliminary processing, including the recognition of the latent image in latent, can be divided into the following subtasks: segmentation, description, recognition, interpretation. By segmentation is meant the process of selecting the objects of interest in the image, i.e. division of the field of view D into regions of objects $D_1,\ldots,D_s$ and the background region D_f. The description of recognizable objects assumes the definition of the characteristic parameters necessary for the selection of the required object against the background of others, ie the definition of class boundaries. Recognition is the identification of objects. Interpretation determines the belonging to the group of recognized objects. [Gor84]

The set of objects $D_1,\ldots,D_s$ on which it is necessary to split the latent image obtained by the method of variation of the direction of the lines is represented by lines of different slope. Considering that significant geometric deformations of the image are possible when obtaining an image from the capture device, it has been experimentally established that a sufficient step of the variation of the slope of the line is 5°. Figure 1 shows the totality of objects on which the image is segmented.

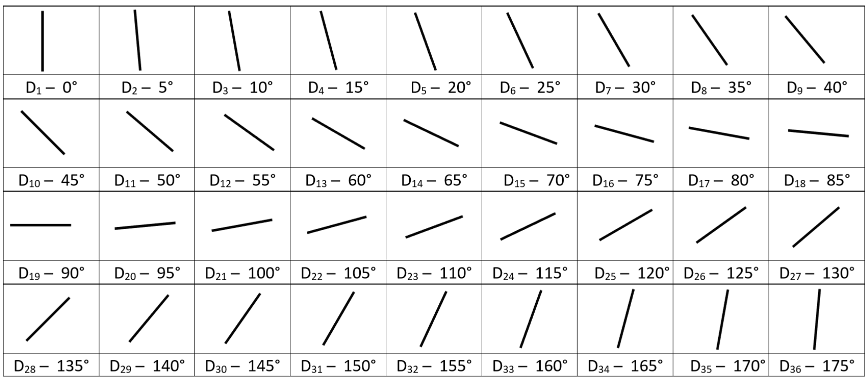


Figure 1: The collection of objects to be segmented

To detect hidden information in a latent image, methods based on Fourier analysis, wavelet analysis, image filtering methods, and image transformation methods based on the methods of implantation of hidden images are used [Sha99, Gor99].

Significant disadvantages of the first two methods include the difficulty of interpreting the results of analysis, for the first three - the inability to separate the hidden image from the background image in the coinciding period of the textures that form them. Modern methods that use information on methods of implementation are suitable only for solving particular control tasks by constructing an individual filter for visualization of latent images.

The proposed method, unlike known ones, does not depend on the specific method of forming latent images formed by differently oriented structures or formed by structures with a coinciding period of background and latent image. When implementing the developed method for segmentation, the results of wavelet analysis obtained by wavelet transformation of an image with hidden information are used.

In the wavelet decomposition, the image $I(x,y)$, where x and y are the coordinates of each point along the horizontal and vertical lines, is represented as a set of approximating and detailing coefficients using the scaling function$\varphi\left(x\right)$ and the wavelet $\psi\left(y\right)$. The scaling function for the two-dimensional signal, which determines the approximating image coefficients $I(x,y)$, is defined as follows:

$$\varphi_j\left(x,y\right)=\varphi\left(x\right)\varphi\left(y\right) \tag{1}$$

The detailing coefficients, in turn, can be represented in the form of three separable two-dimensional wavelets that provide image segmentation:

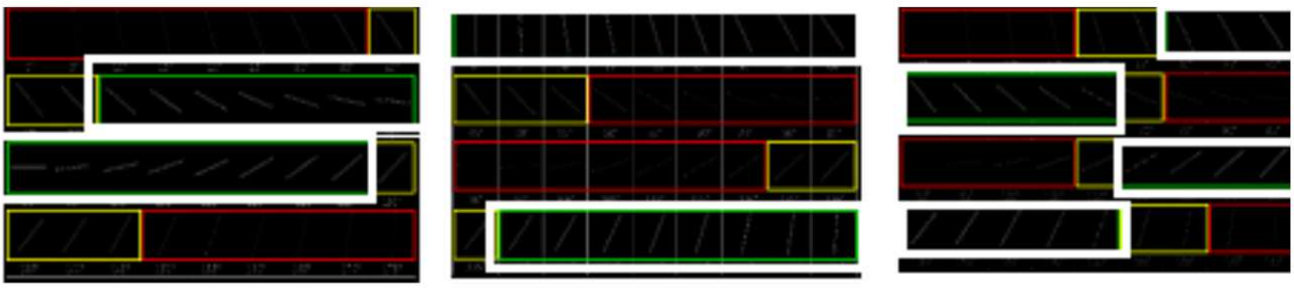
$$\psi_j^H\left(x,y\right)=\psi\left(x\right)\varphi\left(y\right),\psi_j^V\left(x,y\right)=\varphi\left(x\right)\psi\left(y\right),\psi_j^D\left(x,y\right)=\psi\left(x\right)\psi\left(y\right), \tag{2}$$

where $\psi_j^H\left(x,y\right),\ \psi_j^V\left(x,y\right)\ and\ \psi_j^D\left(x,y\right)$ - the horizontal, vertical and diagonal wavelets, j - the decomposition level.

Since the best frequency localization of the signal can be obtained by decomposition of wavelets (2), applying the packet wavelet transform [Smo05], it is proposed to decompose to the third level of decomposition, which will achieve the required level of segmentation of the objects under study.

To solve the problem, it is necessary to select a wavelet function with high localization, both in frequency and in time, the application of which will allow us to determine groups of objects with approximately the same number of elements and the minimum number of elements simultaneously entering into different groups. To determine the optimal wavelet function, the wavelet transformation of the control image was performed (fig. 1), based on various basic wavelets: Haar, Daubechies (*db*), Simplet (*sym*), Coiflet (*coif*), biorthogonal wavelets (*bior*) and rebiorthogonal wavelet (*rbio*) and Meyer wavelets in discrete form (*dmey*).

As a result of the computational experiments, a biorthogonal wavelet was chosen for the basis 2.8, which is best suited for solving this problem. Figure 2 shows the results of segmentation of a control image containing multidirectional lines obtained with this wavelet. The white color in figure 2 denotes the segmented groups of objects under study.



a *b* *c*

Figure 2: Segmentation of the control image into groups of objects, marked with white color, visualized the detailing coefficients: a - horizontal, b - vertical, c - diagonal

As can be seen in Figure 2, various visualized detailing coefficients allow us to designate groups with clear boundaries of the slopes of the objects included in these groups.

An example of segmentation of a latent image containing hidden "*PP*" information on a bill of 1,000 Russian rubles of the 2004 model is shown in Figure 3. This note has a hidden image made with lines located at an angle of 110°, which corresponds to an object of class D_{22} of the control images (Figure 1).

According to the results obtained in the study, in order to identify the object of class D_{22} proposed by the method, it is necessary to perform successive transformations in accordance with the formulas (2): $\psi_1^H(x,y) \rightarrow \psi_2^H(x,y) \rightarrow \psi_3^V(x,y)$.

a *b*

Figure 3: An example of visualization of hidden information proposed by the method of latent image segmentation *L(x,y)*

The obtained results showed that objects with the same period of the proposed segmentation method are classified identically. Also, from Figure 2, it can be seen that the maximum range of objects with different angle of inclination pertaining to the same group is 60°. If the background image and the hidden image are formed by objects with relative positions relative to each other at an angle greater than 30° and the background and hidden image areas are segmented at the first level of decomposition into one group, then the latent image rotated by 30° $L_{Rot30}(x,y)$ is guaranteed to contain objects of the background and hidden images belonging to different classes, even at the first level of decomposition. On this basis, a method for segmenting hidden object images is proposed, which consists of the following:

1. The diagonal $\psi_j^D(x,y)$, vertical $\psi_j^V(x,y)$ and horizontal wavelet coefficients of the first level of decomposition are sequentially calculated using a biorthogonal wavelet with basis 2.8 by wavelet transform of the image $L(x,y)$. The visualized wavelet coefficients form an image of $E(x,y)$.

2. If the hidden image is not detected, the image $L(x,y)$ rotates by 30 degrees, which allows you to divide objects with the same period, and also change the class of objects of the background or hidden image.

3. Step 1 is executed for the image $L_{Rot30}(x,y)$.

To perform a subtask of describing hidden images and constructing a base of control images, a list of characteristic parameters such as color, shape, localization, etc. it is advisable to minimize to the shape of the object. For this, the objects [16] of the segmented image $E(x,y)$ are closed and its binarization is completed.

The obtained latent image is compared with the standard from the database of the control samples corresponding to this type of latent image, one of the image analysis methods. If the percentage of the correspondence of the latent image with the standard is higher than the threshold value, established depending on the problem being solved, the sample to be examined is recognized as genuine.

On the basis of the proposed method, a software package has been developed that allows automatic and semi-automatic modes to control latent images formed by differently oriented structures regardless of the specific method of implantation of the latent image.

In automatic detection of the authenticity of a document protected by a latent image, the type of the document on the visualized hidden image is established and real-time operational control is performed.

Figure 4 shows the results of monitoring latent images of various types with the help of a developed software package.

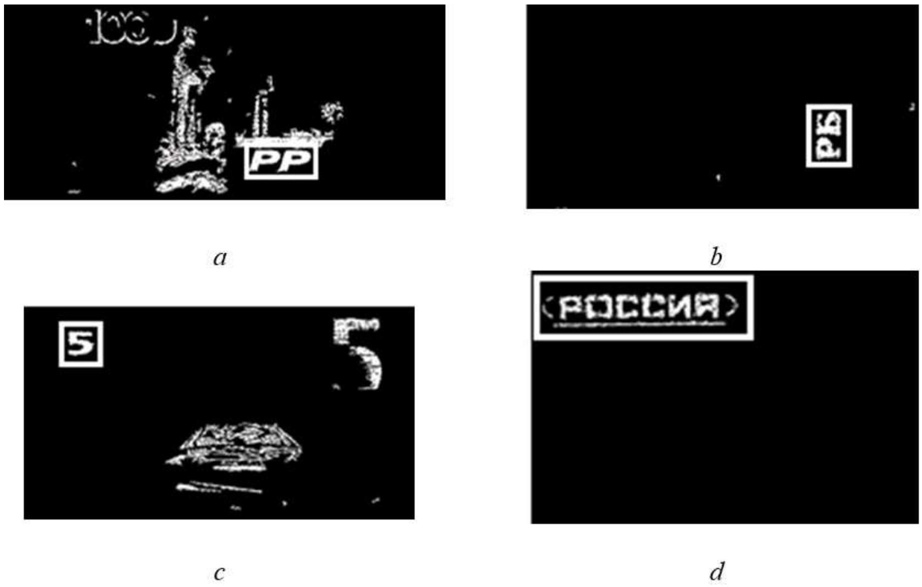


Figure 4: The result of revealing latent images by the proposed method: a - a banknote of 1000 Russian rubles, b - a banknote of 50 Belarusian rubles, - a banknote of 5 Azerbaijan manats, d - a Russian passport. The visualized hidden information is framed

3 Conclusions

A method for segmentation of hidden image objects is proposed on the basis of the analysis of the results of revealing hidden information, using various basis wavelets.

As a result of the computational experiments it was established that the biorthogonal wavelet with respect to the basis 2.8, in comparison with other wavelets, has a higher localization, both in frequency and in time. This wavelet is best suited for solving the tasks posed, since it allows you to segment objects into groups with approximately the same number of elements and the minimum number of elements that simultaneously enter into different groups.

Batch wavelet transformation allows for higher frequency location and segment latent image components to a larger number of groups, but higher resolution images are required to examine images at higher decomposition levels.

When analyzing the image, it is suggested to use the image rotation to solve the problems associated with the coincident period of textures of the background and hidden images and the poor quality of the sample under study.

Based on the proposed segmentation method, a method for controlling latent images formed by differently oriented structures or formed structures with a coinciding period of background and latent image is developed. The developed method does not depend on the specific method of embedding the hidden information and allows to establish the fact of the presence of hidden information in the sample under study, and also in automatic mode to establish the type of the latent image being monitored.

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