A Steganographic Method Based On The Modification Of Regions Of The Image With Different Saturation

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Abstract— In this article, a method for steganographic implementation through the use of direct and indirect conversion for different image areas is developed.

Keywords— steganographic embedding, modifying image, embedded message.

I. INTRODUCTION

The most developed and often used in practice approaches to ensure information security are methods of guaranteed protection based on cryptographic algorithms. However, such approaches have some limitations. This is due to the fact that cryptographically transformed messages that are transmitted over telecommunications networks are visible to the attacker.

To eliminate these limitations, steganographic approaches can be used to hide information.

Such methods allow you to seamlessly integrate information into neutral containers that do not attract attention.

To date, the most common are steganographic methods of embedding using static and dynamic images as containers [1-3, 6].

Steganographic approaches can be divided into methods of indirect and direct integration, which are represented by a large number of existing [5] algorithms. Common shortcomings for them are:

- restrictions on the amount of embedded data;
- introducing significant distortion into the container;
- the need for a key to remove information on the receiving side.

A possible approach to eliminate the identified shortcomings, namely, to increase the amount of embedded information at the same time as ensuring a given level of distortion introduced into the container is the simultaneous use of an indirect and direct approach to embedding.

For this, it is necessary to ensure the allocation of two groups of image areas: for indirect and direct embedding.

As an algorithm for direct embedding it is proposed to use the method of the least significant bit (LSB).

This method provides a hidden 1 bit of data in each element of the container's spatial representation, regardless of its value [4].

At the same time, it is proposed to develop an indirect embedding method for areas with minor changes in elements.

II. MAIN PART

It is necessary to formulate the requirements that should be satisfied by the development of the steganographic method of indirect embedding:

1. Minimization of introduced distortions. Integration should not be accompanied by a change in the values of the elements $\{a^{(\tau)}\}$ of the space-time representation of the container by more than k value (modification coefficient).

2. Distribution of introduced distortions between elements of the image-container, which participates in steganographic embedding. This requirement is given by the following expression:

$$a'^{(\tau)} = a^{(\tau)} + \Delta k \text{, where } \Delta k = \frac{k}{T}.$$

Here $a^{(\tau)}$ is the τ-th modified element of the container image, $\tau = \overline{1, T}$; $a'^{(\tau)}$ - element $a^{(\tau)}$ modified as a result of steganographic embedding.

Realization of this condition will ensure a "smooth" modification of the elements by an amount Δk.

A graphic interpretation of this condition is shown in Fig. 1.

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Consider an array (block) A of image elements $\{a_{i,j}\}$ of the container. The elements $\{a_{i,j}\}$ of the space-time representation of the block are characterized by changes in the values of the elements of the spatial representation [7]. In other words, the dynamic range of the values ψ of the elements $\{a_{i,j}\}$ of the rows and columns in the block A can take different values:

$$\psi_i = a_{i,max} - a_{i,min} = 0...255;$$
$$\psi_j = a_{j,max} - a_{j,min} = 0...255.$$

Here ψ_i and ψ_j the dynamic range, respectively, of the i-th row and j-the column of the elements of the block A; $a_{i,max}$ and $a_{i,min}$, respectively, the maximum and minimum values of elements of the i-th row of the block; and respectively the maximum and minimum values of the elements of the j-the column of the block.

Requirements for minimization are due to the following aspects.

On the one hand, indirect embedding involves modifying some elements of the spatial representation blocks of the image and leaving them unchanged.

On the other hand, in order to ensure minimal distortion as a result of embedding, it is necessary that the elements of the image blocks have minimal differences in the block [8].

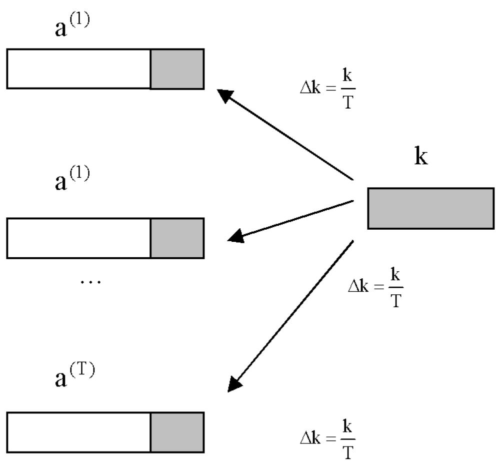

Fig 1. Graphical interpretation of the distribution condition of distortions introduced as a result of steganographic embedding

To determine the block that can potentially be used for steganographic embedding based on the developed method, it is suggested that when the original container image is divided into work blocks for each block, calculate the value of the dynamic range of its rows and all its columns [9].

In this case, if:

- the maximum value of the dynamic range of rows ψ_i and columns ψ_j of the block A takes values from zero to two

$$\psi_{i,max} = \overline{0,2} \text{ and } \psi_{j,max} = \overline{0,2}$$

the selected block is used for indirect steganographic embedding on the basis of the proposed method;

- the value of the dynamic ranges of rows ψ_i and ψ_j columns of the block takes a value greater than two

$$\psi_{i,max} > 2 \quad \text{and} \quad \psi_{j,max} > 2,$$

then the block in question is not suitable for indirect steganographic integration and is transformed on the basis of the method of the least significant bit (LSB).

The next step involves selecting a reference element $a^{(\sigma)}_{i,j}$ in block A.

This element serves to determine the level of modification of the remaining elements $\{a^{(\tau)}_{i,j}\}$ (operation points). The reference element will be called the reference point.

It is necessary to estimate the amount of information that can be built into the block A by the size $n \times m$ elements provided that the following requirements are fulfilled:

1) the number of operation modified points takes on a value $\tau = \overline{1, (n \cdot m) - 1}$;

2) the level of distortion k, which is introduced as a result of the modification of the operating points $\{a^{(\tau)}_{i,j}\}$, should take a minimum value, ie:

$$a'^{(\tau)}_{i,j} = a^{(\tau)}_{i,j} \pm k \quad \text{at} \quad k \to \min .$$

Then the level of distortion will take on value $k \in [-1, 0, 1]$. In this case, the number of options for modifying one operating point $a^{(\tau)}_{i,j}$ will be three, namely:

- 1 variant $a'^{(\tau)}_{i,j} = a^{(\tau)}_{i,j} - k = a^{(\tau)}_{i,j} - 1$;
- 2 variant $a'^{(\tau)}_{i,j} = a^{(\tau)}_{i,j} + k = a^{(\tau)}_{i,j} + 0 = a^{(\tau)}_{i,j}$;
- 3 variant $a'^{(\tau)}_{i,j} = a^{(\tau)}_{i,j} + k = a^{(\tau)}_{i,j} + 1$.

We estimate the amount of information that can be embedded in a block A with size $n \times m$ based on the multi-position variation [10,11].

Let the embedded message $B = \{b_1, b_2, ..., b_\xi, ..., b_\Xi\}$ be indirectly built in a ternary form, i.e $b_\xi \in [0, 1, 2]$.

Then the amount of information d_b that can be built into the block A will be determined by the next expression:

$$d_b = \log_3 3^{n \cdot m - 1}.$$

Consider the block A with size 3×3 elements. The position of the reference point is suggested to be chosen on the basis of the following rule:

1) the position i of the comparative point in the line is selected based on the expression:

$$i = [\frac{n}{2} + 1];$$

2) the position of the comparative point $a_{i,j}^{(\sigma)}$ in the column is selected based on the expression:

$$i = [\frac{n}{2} + 1].$$

Then the reference point will have the view $a_{2,2}^{(\sigma)}$. The operation point can take any position except the position of the reference point. (Fig. 2).

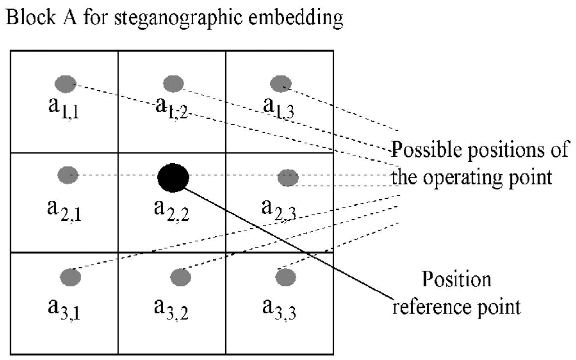

Fig 2. Possible positions of the operation and reference points in the block

Consider the stage of steganographic embedding. This step involves changing the value of the operating point $a_{i,j}^{(\tau)}$ relative to the value of the reference element $a_{2,2}^{(\sigma)}$ according to the following rule:

$$a_{i,j}'^{(\tau)} = \begin{cases} a_{2,2}^{(\sigma)} - 1, & b_\xi = 0; \\ a_{2,2}^{(\sigma)}, & b_\xi = 1; \\ a_{2,2}^{(\sigma)} + 1, & b_\xi = 2. \end{cases}$$

Here $a_{i,j}'^{(\tau)}$ - the modified element $a_{i,j}^{(\tau)}$ of the original image is in accordance with the rule of indirect embedding, b_ξ - the embedded element.

To ensure minimal distortion with indirect embedding it is necessary that the value of the reference element be equal to the values of the other operating points - ideal conditions. In realistic images, the values of some elements can have an impulsive nature [12,13].

Therefore, the element of the working block at the position of the reference point is proposed to be subjected to median filtration according to the formula:

$$a_{2,2}^{(\sigma)} = \left[\frac{\sum_{i=1}^{m} \sum_{j=1}^{n} a_{i,j}^{(\tau)}}{n \cdot m} \right].$$

Considering that modern digital devices operate exclusively in the binary system, the preprocessing step of the embedded message will include the conversion of the embedded binary message into a ternary message.

In this case, at the position of 8 working points in the ternary system, 13 bits can be embedded in the binary system.

On the basis of the proposed method of sharing the direct and indirect approach it is possible to steganographically integrate into an image block with the size 3×3 of the elements:

- 9 bits based on the LSB method;
- 13 bits based on the developed method of indirect embedding.

The method of reverse steganographic transformation involves the indirect withdrawal of the built-in data based on the comparison of the reference and operation points of the selected blocks. This comparison will be carried out according to the following rule:

$$b_\xi' = \begin{cases} 0, & a_{2,2}'^{(\sigma)} > a_{i,j}''^{(\tau)}; \\ 1, & a_{2,2}'^{(\sigma)} = a_{i,j}''^{(\tau)}; \\ 2, & a_{2,2}'^{(\sigma)} < a_{i,j}''^{(\tau)}. \end{cases}$$

Here b_ξ' - is the restored value of the built-in element b_ξ, $a_{2,2}'^{(\sigma)}$ - the value of the reference point in the block of the steganogram, $a_{i,j}''^{(\tau)}$ - the working point in the i -th row, j –th column of the steganogram.

In the case of unauthorized access, the intruder does not have information on the presence of a hidden message in the steganogram. At the same time, the level of distortions introduced as a result of the embedding is visually not noticeable, which allows us to use the proposed method of steganographic integration.

The algorithm for implementing the method includes the following steps:

1. Split the original image into blocks with size 3×3 elements.
2. Selection of blocks for embedding. At this stage, all image blocks are divided into blocks for indirect embedding and embedding based on the LSB method.
3. Steganographic embedding messages in ternary form in blocks for indirect transformation. The remaining blocks are converted to blocks based on the LSB method.

4. Reconstruction of the image with embedded data.

Based on the program implementation of the developed method, the following results were obtained:

- in case of using highly saturated image as a container, the amount of embedded data is increased up to 7% in comparison with the LSB method;

- in case of using low saturated image, an increase in the amount of embedded data is achieved up to 22% in comparison with the LSB method.

III. CONCLUSION

The analysis of approaches for the protection of information based on steganography is carried out.

The weak points of the methods of direct and indirect steganographic integration are revealed.

In order to eliminate the identified drawbacks, an approach that involves the simultaneous use of indirect and direct embedding within a single method with the selection of homogeneous and saturated areas of the image is proposed.

The requirements for the method, which are used for minimization distortions of the output image container as a result of embedding information are formed.

The rule of determining areas for indirect steganographic integration is formulated.

Scientific novelty. The method of indirect steganographic integration is developed, which consists in modifying the operation elements of the block relative to the reference point at three levels.

The rule for selecting the position of the reference point in the block is formulated.

Scientific novelty. A system of direct and reverse steganographic transformation is created on the basis of the developed method of indirect embedding.

A distinctive feature of the system is the simultaneous use for embedding the developed method and the method of LSB for areas with different saturations.

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