UDC 004.056.5

Informatics and Mathematical Methods in Simulation
Vol. 4 (2014), No. 3, pp. 278-284

IMPROVEMENT OF THE ACCURACY OF DETECTION OF CLONED REGIONS IN DIGITAL IMAGES

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In this work, modifications of the method for the detection and location of cloned regions were developed to improve the detection accuracy. Based on the results of experiments and observations performed, we proposed the block types which provide the highest accuracy of detection, with the accuracy assessed by the ratio of area of detected cloned region to actual area of cloned region.

Keywords: accuracy of detection, region area, image falsification, falsification detection, cloning.

Introduction

Digital images (DI) used in the printed media, medicine, science, forensic proceedings, etc., are of primary importance in cyberspace. Currently, various falsifications of digital images performed with graphics editors such as Adobe Photoshop, GIMP, etc., are very common. Digital falsification has become widespread due to the simplicity of use of these graphics editors. Cloning is one of the commonest methods used for falsification of digital images, because it is easily implemented and hardly detected due to the fact that the cloned region is a part of the digital image subjected to falsification. When being embedded into an original image, a cloned region (clone) may have an arbitrary (nonrectangular) shape ensuring its visual inconspicuousness. Therefore, the development of methods for the detection and location of cloned regions to improve the detection accuracy is of current importance.

Statement of the problem and purpose of the study

To create a cloned region with graphics editors such as Adobe Photoshop and GIMP, one can use *Rectangular Marquee Tool*, *Lasso Tool*, *Clone Stamp Tool*, etc. For improved visual embedding of cloned regions, *Eraser Tool* and *Blur Tool* can be used. All the tools mentioned make it possible to create a cloned region of an arbitrary (irregular) shape.

In [1, 2], a method has been developed to detect and locate cloned regions; with the first stage of that method, a digital image is divided into a set of standard-shape overlapping blocks. For the purpose of methodology, a standard block means a square-shape block of any size. The results of experiments have shown that the use of standard blocks does not make it possible to accurately estimate the dimensions and determine the location (shape) of detected falsification regions.

The *Purpose* of the study was to develop modifications of the method for the detection and location of cloned regions in order to improve the detection accuracy.

The detection accuracy was assessed by the percentage ratio of the area of detected cloned region to the actual area of cloned region. The actual area of cloned region was determined as the difference between the original image and the falsified image. The area was measured in pixels.

To accomplish the purpose of the work, the following problems were to be solved:

- to find the ways to improve the accuracy of detection of a cloned region,
- to modify the method for the detection and location of cloned regions in order to use the adaptive subdivision of the blocks,
- to modify the method for the detection and location of cloned regions in order to use non-standard blocks within the detection process, and
- to analyze the efficiency of the algorithms developed based on the accuracy of detection of cloned regions.

The ways to improve the accuracy of detection of a cloned region

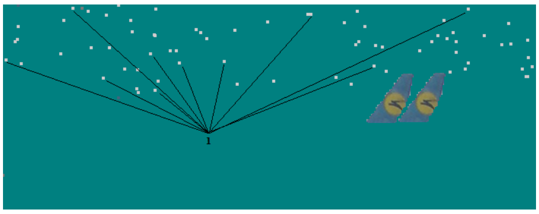
We assume that there is a digital image $I(m,n)$ with brightness matrix Y. Briefly, the procedure of the method for the detection and location of cloned regions in a DI is as follows [1, 2].

1. Divide the brightness matrix Y of a DI into $p \times p$ overlapping blocks $C = \{c_1, c_2, \ldots, c_s\}$, $\bigcup_{i=1}^{s} c_i = Y$, (here each block c_i is obtained by a single-pixel right shift, left shift, down-shift or up-shift of block c_{i-1}).
2. For each pair of blocks $c_i, c_j, i = 1,\ldots,s, j = i+1,\ldots,s$ calculate the proximity measure $\delta = Metrica(c_i, c_j)$.
3. Analyze the values of proximity measure δ to determine the pairs of blocks c_i, c_j belonging to cloned regions and to a clone prototype.

Square blocks of any size may be used to detect clones with the method proposed (hereinafter referred to as a “basic method”). The results obtained from the computational experiments proved that 8×8 blocks are the most efficient for the detection of cloned regions. Although the use of 4×4 blocks may improve the accuracy of located cloned regions, it may also result in appearance of false-positive blocks (Fig. 1).

a

b



c

Figure 1. An example of appearance of false-positive blocks: a – original image, b – falsified image, c – result of the use of 4×4 blocks for the detection of cloned regions (here 1 denotes false-positive blocks)

Therefore, the method presented operates with square-shape blocks of size $p \times p$, and this size remains unchanged during the procedure of the method. These features make the basic method non-effective in accuracy of detecting cloned regions.

Hence, the main ways to improve the accuracy of detection of cloned regions are as follows:

1. To use the non-square blocks;
2. To use different block sizes during the detection of cloned regions.

Method for the detection and location of cloned regions using the adaptive subdivision of the blocks

Although in the detection of cloned regions, the use of 4×4 blocks provides for the improvement in detection accuracy, it is reasonable to use this block size not for the entire digital image, but for the potentially falsified regions only.

Let us modify the basic method for the detection and location of cloned regions in a DI in the following way: if detected, the potentially falsified regions are divided into blocks of a smaller size, and the basic method is applied to the blocks newly obtained for the detection of cloned regions.

Briefly, the procedure of the method for the detection and location of cloned regions in a DI using the adaptive subdivision of the blocks is as follows.

1. Divide the brightness matrix Y of a DI into $p \times p$ overlapping blocks $C = \{c_1, c_2, \ldots, c_s\}$, $\bigcup_{i=1}^{s} c_i = Y$, (here each block c_i is obtained by a single-pixel right shift, left shift, down-shift or up-shift of block c_{i-1}).
2. For each pair of blocks $c_i, c_j, i = 1, \ldots, s, j = i+1, \ldots, s$ calculate the proximity measure $\delta = Metrica(c_i, c_j)$.
3. Analyze the value of proximity measure δ to determine the pairs of blocks c_i, c_j suspected for belonging to cloned regions and to a clone prototype.
4. If the potentially falsified blocks are found,
   4.1. divide pairs of blocks c_i, c_j into blocks of a smaller size, $C^i = \{c_1^i, c_2^i, \ldots, c_d^i\}$ and $C^j = \{c_1^j, c_2^j, \ldots, c_d^j\}$, $\bigcup_{n=1}^{d} c_n^i = c_i$, $\bigcup_{m=1}^{d} c_m^j = c_j$,
   4.2. calculate the proximity measure $\delta^{ij} = Metrica(c_n^i, c_m^j)$, and
   4.3. analyze the value of proximity measure δ^{ij} to determine pairs of blocks c_n^i and c_m^j suspected for belonging to cloned regions and to a clone prototype.

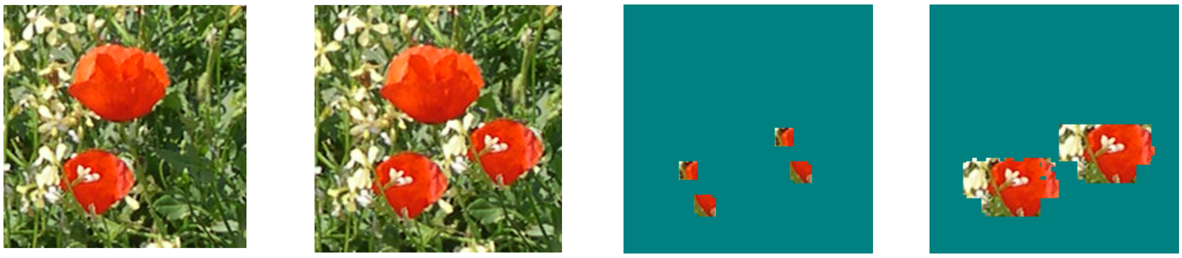
Figure 2 shows an example of the results of application of the method for the detection and location of cloned regions in a DI using the adaptive subdivision of the blocks.

Method for the detection and location of cloned regions using non-standard blocks

Let us consider the use of blocks of non-standard shape (such as triangular blocks and blocks of complex shape) for the detection of cloned blocks.

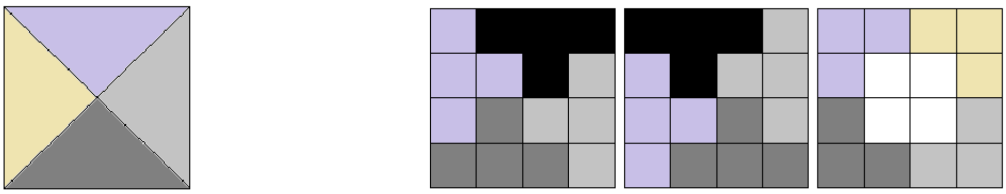
In [3, 4], the procedure of obtaining triangular-shaped blocks has been discussed in detail. During the experiment, we found the subdivision into triangular blocks that provides higher accuracy of detection with respect to other subdivisions (Fig. 3a).

To obtain blocks of complex shape, let us use square blocks (e.g., 16×16 blocks), and divide them into 4×4 blocks. Grouping of 4×4 blocks in a subblock determines the division of a square-shape block into blocks of complex shape. The computational experiment determined the divisions of blocks of complex shape that provide the highest accuracy of detection with respect to other blocks of complex shape (Fig. 3b).



a **b** **c** **d**

Figure 2. Results of the application of the method for the detection and location of cloned regions using the adaptive subdivision of the blocks: a – original image, b – falsified image, c – use of 16×16 blocks without the adaptive subdivision, d – use of 16×16 blocks with the adaptive subdivision



a **b**

Figure 3. DI matrix blocks that provide the highest accuracy of detection of a cloned region: a – blocks of triangular shape, b – blocks of complex shape.

Let us modify the basic method for the detection and location of cloned regions in a DI in order to use non-standard blocks while detecting the clones.

Briefly, the procedure of the method for the detection and location of cloned regions in a DI using the non-standard blocks is as follows.

1. Divide the brightness matrix Y of a DI into $p \times p$ overlapping blocks $C = \{c_1, c_2, \ldots, c_s\}$, $\bigcup_{i=1}^{s} c_i = Y$, (here each block c_i is obtained by a single-pixel right shift, left shift, down-shift or up-shift of block c_{i-1}).
2. For a block pair considered, $c_i, c_j, i = 1, \ldots, s,\ j = i+1, \ldots, s$, obtain non-standard subdivisions c_i^r and c_j^r, respectively, where r is a subdivision number. For each subdivision:
3. Calculate the proximity measure $\delta = Metrica(c_i^r, c_j^r)$.
4. Analyze the value of proximity measure δ .to determine pairs of blocks c_i^r and c_j^r suspected for belonging to cloned regions and to a clone prototype.

Analysis of the efficiency of the methods developed

A computational experiment was performed to analyze the efficiency of the methods developed based on the accuracy of detection of cloned regions. Within the experiment, the size of a cloned region was arbitrarily selected depending on the specific image, and irrespective of the size of subdivision blocks used in experiments.

All digital images had the varying depth resolution of the space depicted, and were subjected to falsification and postprocessing by means of Adobe Photoshop and GIMP. Original digital images had various compression ratios corresponding to quality Q setting 4 to 10 in Adobe Photoshop. After application of cloning technology, the falsified digital images obtained were saved using lossless BMP format. The cloned region boundary was subjected to blurring.

The experiment made it possible to obtain the following:

- digital images containing the cloned region detected with the use of non-standard blocks and the adaptive subdivision (Fig. 4),
- ratios of area of detected cloned region to actual area of cloned region for different block types and for the adaptive subdivision (Table 1), and
- detection of cloned regions if they failed to be detected with blocks of square shape (Fig. 5).

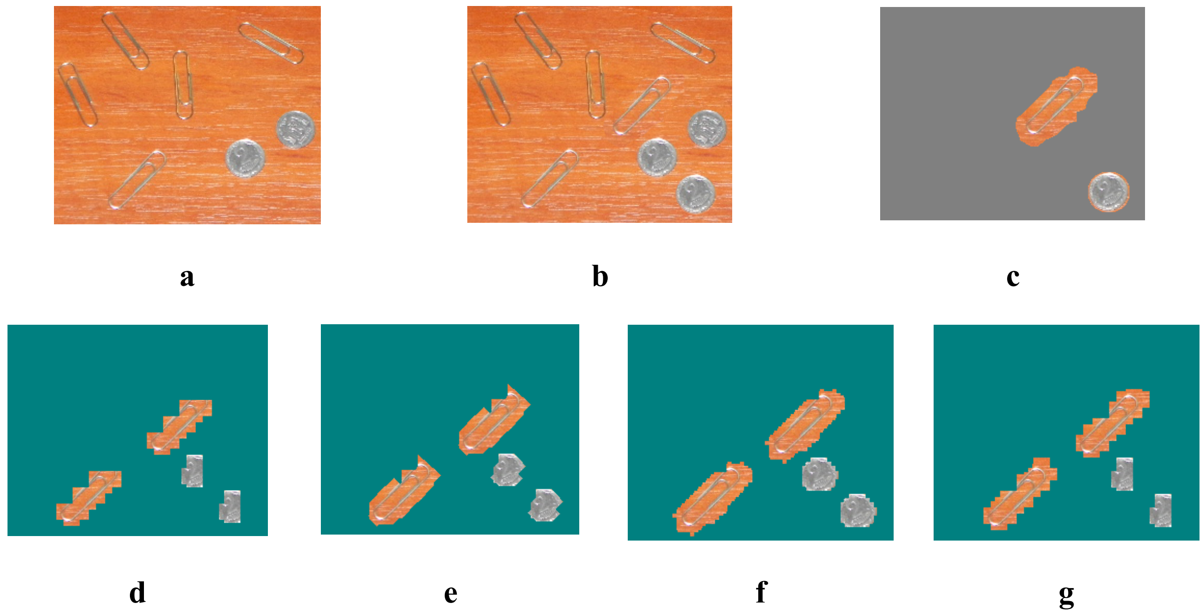


Figure 4. Results of the application of the method of detection of cloned regions using the blocks of non-standard shape and the adaptive subdivision of blocks: a – original image, b – falsified image, c – cloned region, d – use of 16×16 blocks of square shape, e – use of 16×16 blocks of triangular shape, f – use of 16×16 blocks of complex shape, g – use of the adaptive subdivision of 16×16 blocks

Table 1.

Accuracy of the detection of a cloned region with blurred boundaries using the blocks of various types of subdivision and adaptively subdivided blocks

Types of subdivision	Percentage ratios of area of detected cloned region to actual area of cloned region		
	Max.	Min.	Average
Blocks of square shape	56.63	8.58	29.07
Blocks of triangular shape	68.25	23.95	43.51
Blocks of complex shape	73.73	43.28	55.40
Adaptively subdivided blocks	65.00	35.20	53.02

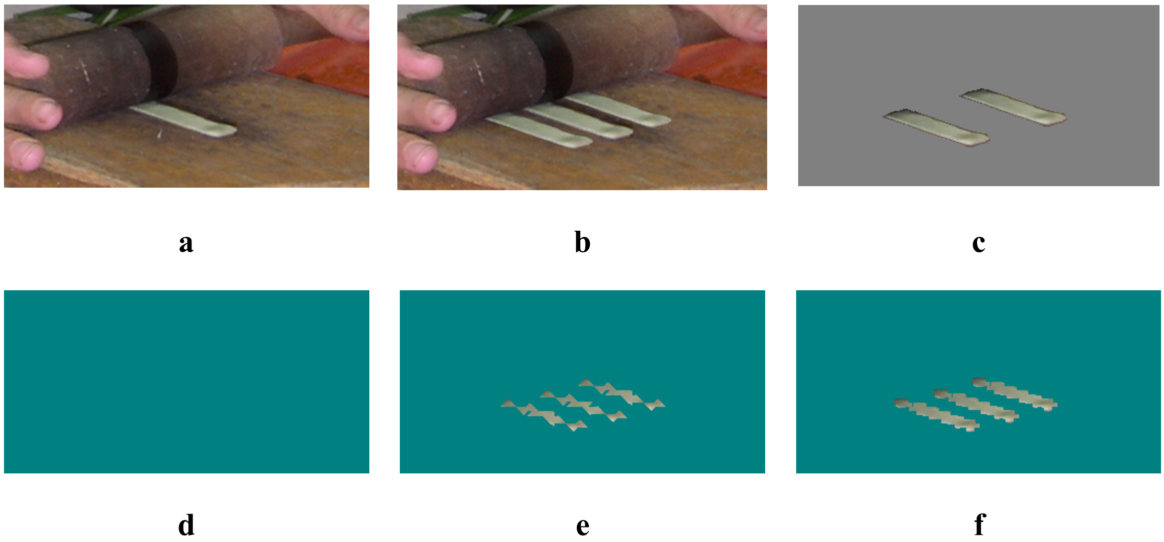


Figure 5. Results of the detection of cloned regions: a – original image, b – falsified image, c – cloned region, d – use of 16×16 blocks of square shape, e – use of 16×16 blocks of triangular shape, f – use of 16×16 blocks of complex shape

The results presented in Table 1 indicate that blocks of complex shape and adaptively subdivided blocks provide higher accuracy than those of square shape and triangular shape. If blocks of triangular shape, complex shape or adaptively subdivided blocks are used in the method for the detection and location of cloned regions, than the percentage ratio of area of detected cloned region to actual area of cloned region increases 1.5 times, 1.91 times and 1.82 times, respectively, compared with the use of standard subdivision.

Conclusions

The ways of modifying the basic method for the detection and location of cloned regions were found to improve the accuracy of detection of a cloned region.

By modifying the basic method, the following two methods were developed: the method for the detection and location of cloned regions using adaptively subdivided blocks, and the method for the detection and location of cloned regions using blocks of non-standard shape.

The efficiency of the algorithms developed was analyzed based on the accuracy of detection of cloned regions. The analysis has shown that the use of blocks of complex shape and adaptively subdivided blocks is more effective.

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ПІДВИЩЕННЯ ТОЧНОСТІ ВИЗНАЧЕННЯ ОБЛАСТІ КЛОНУВАННЯ В ЦИФРОВИХ ЗОБРАЖЕННЯХ

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У роботі розроблені модифікації метода виявлення і локалізації областей клонування для підвищення точності визначення клонованих областей. За результатами експериментів та спостереженнями запропоновані види блоків, що дають найкращу точність визначення, яка оцінюється відносною похибкою величини площі клона до реальної площі області клона.

Ключові слова: точність визначення, площа області, фальсифікація зображення, виявлення фальсифікації, клонування.

ПОВЫШЕНИЕ ТОЧНОСТИ ОБНАРУЖЕНИЯ КЛОНИРОВАННЫХ ОБЛАСТЕЙ В ЦИФРОВЫХ ИЗОБРАЖЕНИЯХ

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В работе разработаны модификации метода выявления и локализации областей клонирования для повышения точности обнаружения клонированных областей. По результатам экспериментов и наблюдений предложены виды блоков, дающие наилучшую точность обнаружения, оцениваемую относительной величиной площади выявленной области клона к реальной площади области клона.

Ключевые слова: точность обнаружения, площадь области, фальсификация изображения, выявление фальсификации, клонирование.