Performance of the VWM algorithm in presence of impulse noise

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Abstract –**The first part of the paper describes VVM (Visible Watermarking) algorithm for inserting - removing visible watermark in an image. Impulse noise is superimposed to visible watermarked image. In the second part of the paper, the results of the experiment are shown in which the image with the visible watermark is superimposed with the impulse noise. The experiment was performed for blocks dimension $k = \{2, 3, 4\}$ and coefficient of insertion $\upsilon = 40$, and noise is varied in the range $p = \{1, 5, 10, 20, 30, 40, 50, 60, 70\}$. Improving the quality of recovered image was performed using the MDB algorithm for removing impulse noise. A comparative analysis of the original and recovered image was performed. The comparison was performed on the basis of MSE and PSNR. The obtained results are detailed analysed and presented in a tabular and graphical manner.**

Keywords – **Visible watermark, Impulsive noise, Filtering.**

I. Introduction

In order to protect the copyrights of multimedia content (usually images), techniques based on the insertion of the digital watermark are used. The most widely used copyright protection technique is the technique for insertion the invisible digital watermark. Invisible watermark can be extracted later for ownership proofing. On the other hand, in order to identify ownership, the technique of inserting the visible watermark is also used. This technique has recently become a widely used technique to prevent the viewers for making unauthorized use. When visible watermark is inserted, it is most often impossible to remove the watermark from the image [1] - [3]. This is in order to protect it more efficiently [4], [5]. However, in certain situations, there may be a need to remove the visible watermark from the image [6]. Many researches were done by researching the techniques for inserting reversible watermark in an image but there was many difficulties. After recovering cover image was with visible damages. In the paper [7], scheme for visible-watermark removal and reversible image recovery are proposed. In this scheme, the image with embedded visible watermark is generated after embedding visible watermark into the original image. The recovered image is acquired after removing the visible watermark from the embedded image. Proposed method of inserting visible watermark is one of the most effective methods thus, original image can be exactly recovered.

During the image processing some level of degradation is inevitable. The authors of this paper came up with the idea to perform the VWM (Visible Watermarking) algorithm in presence of impulse noise. The authors set the question: the effect of applying the MDB (Modificated Decision - Based) algorithm for denoising [8] image with visible watermark to improve the quality of recovered image (image with removed watermark)? The answer on this question was sought through the realization of an experiment within which the VWM algorithm for inserting - removing visible watermark were performed, and after superimposing impulse noise MDB algorithm for removing impulse noise is applied. Standard test images was used: Lena, Boat and Girl and Watermark image. The experiment was performed by inserting the inverse binary watermark. The watermark is inserted into the blocks, dimensions $k = \{2, 3, 4\}$ with the coefficient of insertion $\upsilon = 40$. Watermarked images was superimposed with impulse noise, varied in the range $p = \{1, 5, 10, 20, 30, 40, 50, 60, 70\}$. The quality of improving recovered image was analyzed after superimposing impulse noise and after filtering the image using the MDB algorithm [8]. As a quality measure of improved quality of the recovered image was used Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR). The results are presented in tabular form and graphically.

The paper is organized as follows: Section II describes the VWM algorithm for inserting - removing visible watermark, and MDB filtering algorithm. Section III gives results and analysis of the results. Conclusion is given in section IV.

II. Algorithms

In the paper, two algorithms are used: a) VWM algorithm for watermarking [7], and b) MDB denoising algorithm [8].

A. VWM algorithm

The VWM embedding algorithm is realized through following steps:

Step 1: The original image I_0 size $M_0 \times N_0$ is divided into nonoverlapping blocks $k \times k$, where $2 \le k \le k_m$, $k_m \in \{\lfloor M_0 / M_w \rfloor, \lfloor N_0 / N_w \rfloor\}$, and $M_w \times N_w$ is size of embedded binary watermark image. The parameter k can be 2, 3 or 4.

Step 2: One bit of the watermark can be embedded in each block B of host image I_0. A manner how blocks can be partioned, depending of parameter k value is presented in Table 1.

Step 3: Calculate the mean value of the assigned visible watermark region in original image I_0:

$$avg_w = \frac{\sum_{m=0}^{k\times M_w - 1} \sum_{n=0}^{k\times N_w - 1} I_0(m+\mu_1, n+\mu_2)}{(k\times M_w)\times(k\times N_w)}, \qquad (1)$$

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where (μ_1, μ_2) present coordinate of watermark image W embedded in I_0, ($k \times M_w$, $k \times M_w$) denotes the region of embedded watermark.

Step 4: Threshold T_w is calculated:

$$T_w = \begin{cases} awg_w + 30, \text{ if } awg_w \le 128, \\ awg_w - 30, \text{ if } awg_w > 128. \end{cases} \quad (2)$$

Step 5: Mean value of each block B is calculated:

$$avg_B = \frac{1}{k^2} \sum_{j=1}^{k} \sum_{i=1}^{k} B(i,j). \quad (3)$$

Step 6: Embedding procedure of each bit of the Watermark into corresponding block is done:

$$B'(i,j) = \begin{cases} B(i,j) + \omega \times \nu, \text{ if } awg_w < T_w, \\ B(i,j) - \omega \times \nu, \text{ if } awg_w \ge T_w, \end{cases} \quad (4)$$

where ω denotes bit of the watermark and υ is the coefficient of inserting the bit (highest value of υ mean more visible watermark).

Step 7: Different values of parameters d_1 and d_2 are calculated for each block:

$$\begin{aligned} d_1 &= \sum_{B'(i,j)\in S_1} B'(i,j) - \sum_{B'(i,j)\in S_2} B'(i,j) - x, \\ d_1 &= \sum_{B'(i,j)\in S_1} B'(i,j) - \sum_{B'(i,j)\in S_2} B'(i,j) - y, \end{aligned} \quad (5)$$

where S_1, S_2, x and y are parameters from Table 1.

Step 8: Modification of the pixel x into the pixel x' and y into the y' was done:

$$x' = 2 \times d_1 + \omega + \left\lfloor \frac{\sum_{B'(i,j)\in\{S_1 \cup S_2\}} B'(i,j)}{2 \times \left\lfloor \frac{k^2-1}{2} \right\rfloor - 1} \right\rfloor,$$

$$y' = \begin{cases} 2 \times d_2 + 0 + \left\lfloor \frac{\sum_{B'(i,j)\in\{S_1 \cup S_2\}} B'(i,j)}{2 \times \left\lfloor \frac{k^2-1}{2} \right\rfloor - 1} \right\rfloor, \text{ if } avg_B < T_w, \\ 2 \times d_2 + 1 + \left\lfloor \frac{\sum_{B'(i,j)\in\{S_1 \cup S_2\}} B'(i,j)}{2 \times \left\lfloor \frac{k^2-1}{2} \right\rfloor - 1} \right\rfloor, \text{ if } avg_B \ge T_w. \end{cases} \quad (6)$$

After implementing the steps above visible watermarked image I_w is obtained.

The VWM algorithm procedure for recovering image is realized through following steps:

Step 1: The watermarked image I_w is divided into nonoverlaped $k \times k$ blocks in the same manner with the embedding procedure, and parameters S'_1, S'_2, x' and y' can also be obtained as in embedding procedure.

Step 2: Using the obtained values for parameters S'_1, S'_2, x' and y', differences d'_1 and d'_2 can be calculated for each $k \times k$ watermarked block B':

$$\begin{aligned} d'_1 &= x' - \left\lfloor \frac{\sum_{B'(i,j)\in\{S_1 \cup S_2\}} B'(i,j)}{2 \times \left\lfloor \frac{k^2-1}{2} \right\rfloor - 1} \right\rfloor, \\ d'_2 &= y' - \left\lfloor \frac{\sum_{B'(i,j)\in\{S_1 \cup S_2\}} B'(i,j)}{2 \times \left\lfloor \frac{k^2-1}{2} \right\rfloor - 1} \right\rfloor. \end{aligned} \quad (7)$$

Step 3: Extracted binary watermark ω' from each block can be obtained using:

$$\omega' = \mathrm{mod}(d'_1, 2). \quad (8)$$

Step 4: Differences d_1 and d_2 can be obtained using:

$$\begin{aligned} d_1 &= \left\lfloor \frac{d_1'}{2} \right\rfloor, \\ d_2 &= \left\lfloor \frac{d_2'}{2} \right\rfloor. \end{aligned} \quad (9)$$

Step 5: Pixels x'' and y'' can be recalculated according with following equations:

$$\begin{aligned} x'' &= \sum_{B'(i,j)\in S_1} B'(i,j) - \sum_{B'(i,j)\in S_2} B'(i,j) - d_1, \\ y'' &= \sum_{B'(i,j)\in S_1} B'(i,j) - \sum_{B'(i,j)\in S_2} B'(i,j) - d_2, \text{ if } \omega'=1. \end{aligned} \quad (10)$$

Step 6: Recovered blocks B'' can be obtained according to the parameter υ, pixels x'' and y'' according to following equation:

$$B''(i,j) = \begin{cases} B'(i,j) - \omega' \times \nu, \text{ if } \omega_1 = 0, \\ B'(i,j) + \omega \times \nu, \text{ if } \omega_1 = 1, \end{cases} \quad (11)$$

where $\omega_1 = \mathrm{mod}(d'_2, 2)$.

Step 7: Recovered image I_r is obtained.

TABLE I
COEFFICIENT MODE OBTAINING FOR EACH BLOCK

k	$k \times k$ block B	S_1	S_2	x	y
2	$b_{1,1}$ $b_{1,2}$ $b_{2,1}$ $b_{2,2}$	$b_{1,1}$	0	$b_{2,2}$	$b_{1,2}$
3	$b_{1,1}$ $b_{1,2}$ $b_{1,3}$ $b_{2,1}$ $b_{2,2}$ $b_{2,3}$ $b_{3,1}$ $b_{3,2}$ $b_{3,3}$	$b_{1,2}$, $b_{2,1}$, $b_{3,2}$, $b_{2,3}$	$b_{1,3}$, $b_{2,2}$, $b_{3,1}$	$b_{1,1}$	$b_{3,3}$
4	$b_{1,1}$ $b_{1,2}$ $b_{1,3}$ $b_{1,4}$ $b_{2,1}$ $b_{2,2}$ $b_{2,3}$ $b_{2,4}$ $b_{3,1}$ $b_{3,2}$ $b_{3,3}$ $b_{3,4}$ $b_{4,1}$ $b_{4,2}$ $b_{4,3}$ $b_{4,4}$	$b_{1,2}$, $b_{2,1}$, $b_{1,4}$, $b_{2,3}$, $b_{4,1}$, $b_{3,4}$, $b_{4,3}$	$b_{1,1}$, $b_{1,3}$, $b_{2,2}$, $b_{2,4}$, $b_{4,2}$, $b_{4,4}$	$b_{3,3}$	$b_{3,2}$

B. MDB denoising algorithm

The MDB denoising algorithm is performed as it is explained in paper the [8].

Denoising procedure was don in following steps:

Step 1: Watermarked image is superimposed with the noise $p = \{1, 5, 10, 20, 30, 40, 50, 60, 70\}$. I_{wn} image with added noise is obtained.

Step 2: Above the image I_{wn} MDB denoising algorithm is applied and filtered I_{wf} image is obtained.

III. Experimental results and analysis

A. Experiment

Experiment is performed according following steps:

Step 1: Applying the VWM algorithm on the original image I_0 watermarked image I_w is obtained.

Step 2: Image I_w is superimposed with different value of impulse noise $p = \{1, 5, 10, 20, 30, 40, 50, 60, 70\}$. I_{wn} image with added noise is obtained.

Step 3: Recovered image I_{nr} is obtained from the watermarked image with the added impulse noise I_{wn}, applying the VWM algorithm.

Step 4: Above the watermarked image with noise I_n, the MDB denoising algorithm was applied. Filtered watermarked image I_{wf} is obtained.

Step 5: From I_{wf} image recovered image I_{fr} is obtained, applying the VWM algorithm.

Image is watermarked with the inverse binary watermark image.

In order to compare the results, recovering the image is performed from the image with superimposed noise and from the filtered image.

Energy of inserting the bit is set on the value $\upsilon = 40$.

As a measure of the quality of the reconstructed image was used Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR):

$$MSE = \frac{\sum_{ij}\left(x_{ij} - y_{ij}\right)^2}{M \times N}, \tag{12}$$

$$PSNR = 10\log 10\frac{(2^n - 1)^2}{MSE}, \tag{13}$$

where: $i = 1....M$, $j = 1...N$, $x_{i,j}$ - i,j- pixel of the original image, $y_{i,j}$ - i,j - pixel of the recovered image, $M \times N$ – size of image.

B. Base of experiment and results

For the purposes of experiment, the base of standard images: a) Lena, b) Girl and c) Boat was used and d) binary watermark Fig. 1..

Fig. 2. shows look of the image Lena after inserting the watermark with $k = 2$: a) after superimposed noise $p = 10$ %, b) after filtering, c) after recovering the image with noise, and d) after recovering the filtered image.

Fig. 3. shows look of the image Lena after inserting the watermark with $k = 4$: a) after superimposed noise $p = 10$ %, b) after filtering, c) after recovering image with noise, and d) after recovering filtered image.

Fig. 4. and Fig. 5. shows graphs of MSE and PSNR for recovered images, for different value of parameter $k = \{2, 3, 4\}$, after superimposing the noise and after applying the MDB algorithm for filtering.

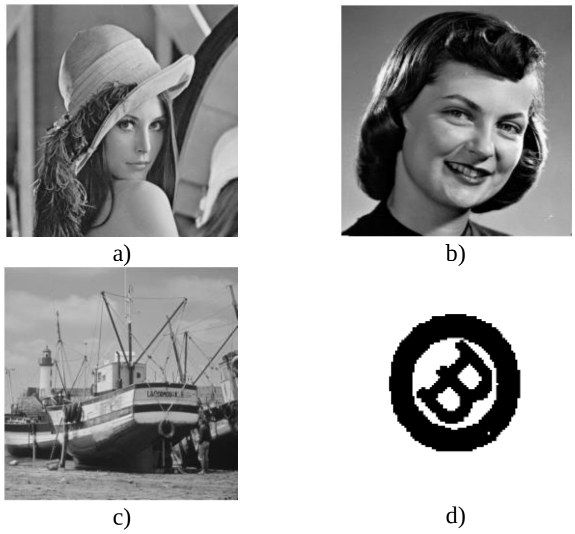

Fig. 1. Base of images: a) Lena, b) Girl, c) Baboon and d) Watermark

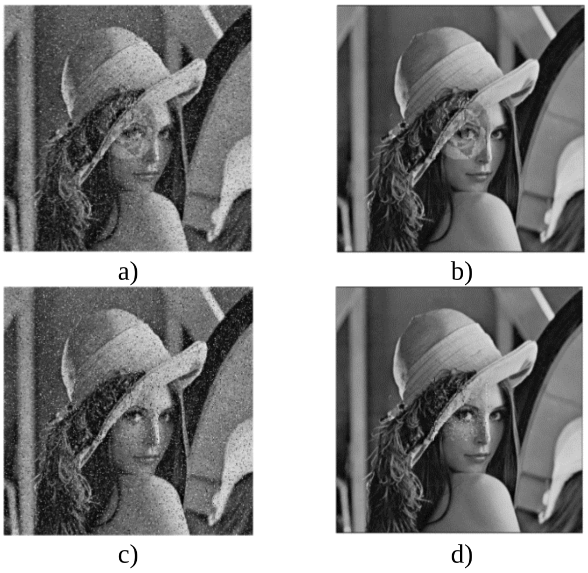

Fig. 2. Watermarked image Lena with $k = 2$ and $p = 10$: a) noised, b) filtered, c) recovered from noised image, d) recovered from filtered image.

a) b)

c) d)

Fig. 3. Watermarked image Lena with $k = 4$ and $p = 10$: a) noised, b) filtered, c) recovered from noised image, d) recovered from filtered image.

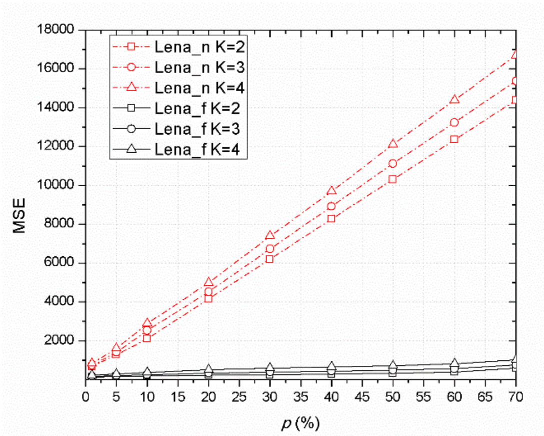

Fig. 4. Quality measure MSE for different value of $k = \{2, 3, 4\}$: Lena_n - Image Lena with noise, and Lena_f - filtered image Lena

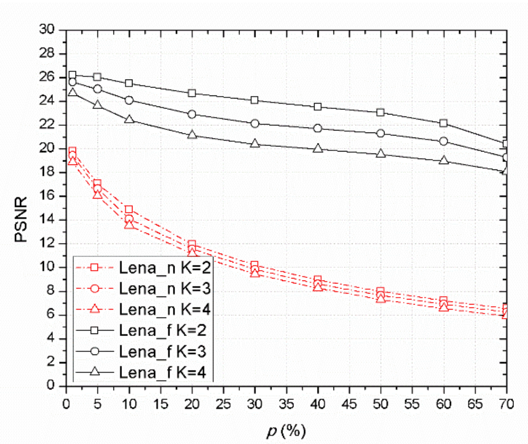

Fig. 5. Quality measure PSNR for different value of $k = \{2, 3, 4\}$: Lena_n - Image Lena with noise, and Lena_f - filtered image Lena

C. Analysis

Based on the results shown in Fig. 2. and Fig. 3. it can be concluded that the MDB algorithm is effective in removing noise and the image is visually better. Recovering image after filtering with MDB algorithm is good in regard to recovered image without filtering. Area of image with watermark after recovering is still with damage. Comparing the quality of images with the watermark inserted in blocks size $k = 2$ and $k = 4$ can be concluded that the recovered images with $k = 2$ have better visible quality comparing to visible quality of images with $k = 4$.

Based on graph shown in Fig. 4. can be concluded that MDB algorithm for filtering impulsive noise is very effective for deonising visible watermarked image. For noise level $p = 10$ %, and block size of inserting watermark bit $k = 2$, MSE for recovered image with noise is exciding value 1000, on the other side after applying MDB denoising algorithm MSE is near the value 100. This shows, that using the MDB algorithm MSE has been decreased 10 times. Based on Fig. 5. for $p = 10$ % and $k = 2$, PSNR for image with noise is decreasing from value 30.66 to 14.99, on other size after applying MDB algorithm PSNR is decrease on value 25.50.

IV. Conclusion

In this paper we has analyzed VWM algorithm for inserting visible watermark, and MDB algorithm for filtering image. For the purpose of experimental analysis of the efficiency of VWM algorithm for recovering image, the image of the inverse binary watermark was used. The watermark is inserted with the coefficient of insertion $\upsilon = 40$, in blocks size $k = \{2, 3, 4\}$. Noise is varied in the range $p = \{1, 5, 10, 20, 30, 40, 50, 60, 70\}$. After comparing the visual appearance of the recovered image with superimposed noise and recovered image from filtered image, it is concluded that the recovered image from the filtered image, is a better quality. Also, the quality measures of MSE and PSNR shows that the recovered image, after application of the MDB algorithm is much better quality.

On the basis of the obtained results, it is concluded that the MDB algorithm successfully eliminates noise from the visible watermarked image.

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