Improved Automatic and Robust ROI Detection Technique for Medical Image Watermarking Application

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***Abstract*— An image authentication scheme called watermarking is suggested to protect patients' privacy by preventing patient documents from unauthorised access. In watermarking of medical image, in order to retain the quality of a region used for diagnostic purpose, known as Region of Interest (ROI), a prior knowledge about this area is needed. Most current medical watermarking schemes detect the ROI manually by assigned polygons or rectangles. In addition, in current automatic ROI detection algorithms, the robustness of ROI detection process is not being considered and addressed. It means the algorithms cannot tolerate any changes in the content of the medical images via any intentional or un-intentional attacks and the ROI detection algorithm is not efficient. By distributing and sharing the medical images between specialists and hospitals, they will be more vulnerable to different attacks. One of these potential attacks that may corrupt the medical images through transmission in communication channels is salt and pepper noise. In this paper an automatic ROI segmentation method for medical images watermarking application is proposed, which is robust against salt and pepper noise as a possible attack. Experimental results show satisfactory performance of ROI segmentation under different densities of salt and pepper noise.**

***Index Term* — ROI detection; salt and pepper noise; medical images; robustness**

I. INTRODUCTION

The speedy development of computer networks and the popularity of electronic managing of medical records have made it possible for digital medical images to be shared across the world for services such as telemedicine, teleradiology, telediagnosis, and teleconsultation. With growing number of exchanging medical images among specialists of different hospitals via unsecured open network, the need for preserving the security of these images against any act of tampering by any unauthorized person is inevitable. Thus, developing standard solutions for preserving the medical images security is the main concern of the existing electronic medical system [1-3].

Digital watermarking is a solution for tackling the above issue, which is composed of two main parts; embedding and extraction. Through the embedding process, special information called watermark is inserted into medical images. During the extraction procedure, the embedded information is retrieved to check the integrity and authenticity of the medical image [4-7].

One crucial point in embedding process of medical images watermarking, is protecting the ROI quality that is the important part of the medical image. As this area is utilized by doctors for diagnostic purposes and any distortion in this area may cause misdiagnosis [8]. So detecting this region prior to watermarking procedure allows more protection for this area during the embedding process. Most of the current ROI segmentation techniques in the literature are manual-based approaches [9-19]. Moreover, in existing automatic methods the robustness against different attack is not considered [20-24]. Therefore, in these methods the ROI vertices are also need to be stored into the RONI during the embedding process.

In communication between specialists or hospitals through the network, the content of image can be tampered intentionally or unintentionally. After tampering the medical image content, the ROI vertices, hidden inside the medical image during the embedding process, may also be changed and the extracted ROI information shows a different boundary for the ROI. Consequently, the ROI cannot be extracted accurately in the extraction process, which is a drawback of the method.

Instead of embedding the ROI vertices inside the medical image, an automatic and robust ROI detection method can be designed. By this method, even after modification or manipulation on some parts of medical images content, unique ROI vertices results in both embedding and extraction procedure can be generated. The content of medical images may be changed by different kinds of attacks. One of the common noise attacks employed on watermarked images is salt and pepper noise. This noise not only can be used by the invaders to corrupt the embedded watermarks inside the medical images, but also may be occurred due to transmission in noisy channel, faulty memory locations in hardware as well as channel decoder damages [25, 26]. Therefore, in this work, the concentration is on the salt and pepper noise as a potential attack.

In this work, an automatic ROI detection technique that is robust against salt and pepper noise is proposed to separate the ROI from the RONI. The rest of this paper is structured as the following. In Section II, the related works are explained.

In Section III, the suggested ROI detection system is described. Experimental results and discussions are given in Section IV. In this section, the salt and pepper noise with various densities are tested on the medical image to measure the proposed method robustness. Finally, Section V concludes and summarizes the proposed work.

II. Related Works

It can be found through the different works in the past that, before starting the embedding and extraction steps in medical image watermarking; usually the ROI is selected manually by experts such as radiologists, physicians or doctors. For instance, the ROI is assigned manually by drawing a rectangle [9-14] or polygon [15-19] box around it. However, several automatic ROI partitioning methods are also proposed recently [20-24], there are some drawbacks, which are explained in the following part.

A pixel based method was proposed by [20] for automatic ROI detection. This algorithm scans images simply in row major direction. Classifying the pixels as a ROI or RONI is done based on a pre-defined threshold value (ranged from 20 to 40). In [22], the ROI region is recognized after applying a suitable thresholding on the medical image. To find the appropriate thresholding value, the system creates a database contains of numerous test images with several thresholding values. Then the input image is compared to each of the pre-defined test images in the database to find the optimum thresholding value for detecting the ROI. Memon *et.al* proposed the other automatic ROI detection method to separate the ROI in CT images [23]. In the mentioned scheme, the region-growing process and Otsu thresholding method are used to segment the lung parenchyma. All three mentioned methods in [20, 22, 23] are pixel-based methods that can detection ROI automatically. However, they are not robust against any noises and they may not work properly in case of intentional or unintentional tampering on the content of medical image. The suggested method in [21, 24] can detect the ROI automatically even in noisy medical images. However, this technique is merely appropriate for elliptical ROI in medical images. In our previous work [27], the automatic ROI detection method is proposed, which is robust against different attacks such as average, sharpening, Wiener, median, and Gaussian filters. However, the robustness against salt and pepper noise is not considered. One solution to this problem is proposed in this work, which is explained in the following section.

III. ROBUST ROI DETECTION

This work proposed an automatic robust ROI detection against salt and pepper noise. The explanation of automatic ROI segmentation scheme is described in our previous paper [27]. The concentration of this work is highlighting the robustness of the proposed scheme against different densities of salt and pepper noise attack. In following sections, first the weakness of the technique against the salt and pepper noise will be shown. Then it will be explained how the proposed noise filtering method can enhance the performance of the ROI segmentation technique against different densities of salt and pepper noise.

A. Robustness Evaluation Procedure

To assess the resistance of the proposed ROI separation scheme against salt and pepper noise, it needs to measure the ROI vertices distance between the noisy and noise-free images. For this purpose, different densities of noise are applied on the medical images first. Then ROI vertices of the noisy images are obtained and compared to the ROI vertices of the same noise-free images. If the method can generate the same ROI vertices for each image, before and after noise, it means the method is robust against the noise, otherwise is not. In this work, the difference between the ROI vertices of each noisy image with the same noise-free image is called Comparative Accuracy (CA). The explained evaluating process is depicted in Fig. 1.

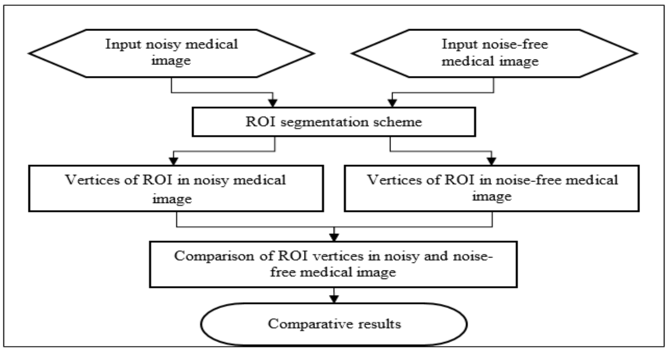


Fig. 1. Robustness evaluation procedure before applying noise-filtering block

B. Noise-Filtering Block

One of the common noise that can alter the original image through the image acquisition, storage and transmission is salt and pepper noise. This noise modifies the image pixel values randomly to either maximum or minimum image gray level. In this work, for increasing the ROI detection robustness against this attack, a noise-filtering block is used prior to starting the detection procedure (Fig. 2).

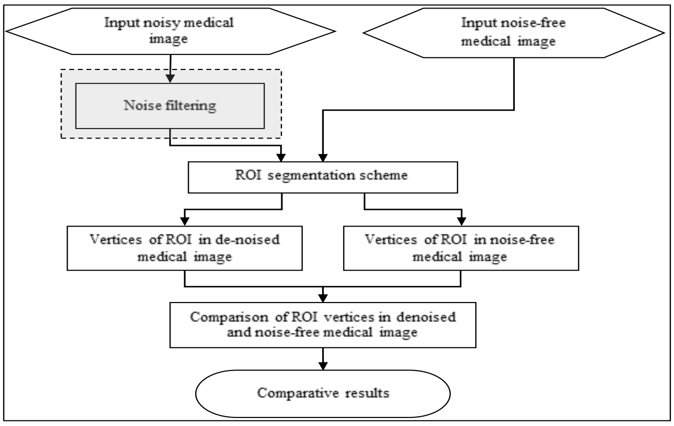


Fig. 2. Robustness evaluation procedure after applying noise-filtering block

In Fig. 3, the proposed noise-filtering method is demonstrated and explained as follow [26]:

1. Catch the second largest pixel value in noisy image as a desired maximum pixel value and named as MAX. Note that the first highest pixel value in noisy image is considered as salt noise.
2. Dividing the input noisy image into 3×3 blocks and sort the pixel values in each block from the lowest value to

the greatest value. The lowest value is considered as pepper noise and the highest value is considered as salt noise, which should be ignored.

3. Calculate the mean of the remaining pixel values (AVG).
4. Lastly, compare the calculated AVG in Step 3 with the obtained MAX in Step1. If the AVG is still bigger than MAX, omit the largest pixel value and return to Step 3. When MAX becomes lower than AVG, the central pixel of the corresponding block can be replaced by this average value.

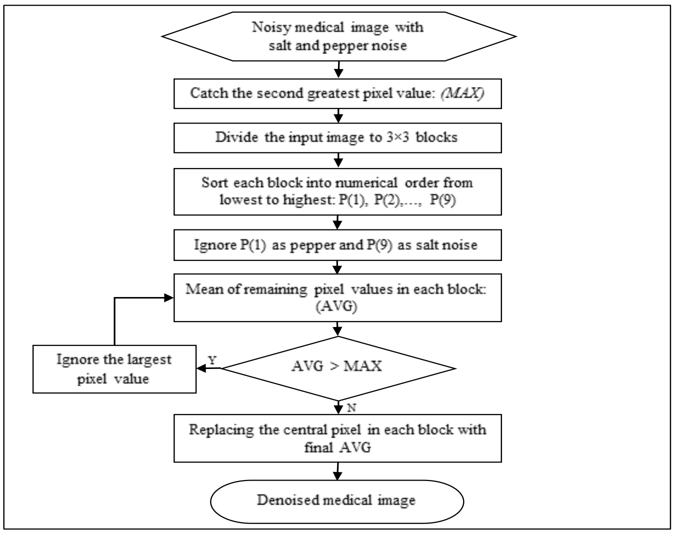


Fig. 3. Noise filtering algorithm [26]

C. *Correction ROI Vertices*

After using the proposed noise filtering method, to increase the ROI detection accuracy, correction block can be used. The explanation of the ROI vertices correction block is also explained in our previous work [27].

IV. Results and Discussion

The proposed method is implemented in MATLAB (version R20014b). Our databases in this work [28] contain 179 MRI medical images (5 databases) which are 16-bit images in DICOM format. In Table I, more information about the datasets is given.

Table I
Database information applied in this work

Databases	Db1	Db2	Db3	Db4	Db5
Modality	MRI	MRI	MRI	MRI	MRI
Images in each database	20	9	97	22	31
Image dimension	256	256	256	512	256

Fig. 4 demonstrated some medical image samples, which are used in this work.

A. *Evaluating the Robustness of ROI Detection Scheme*

To measure the ROI detection robustness against salt and pepper noise, different densities of this noise are applied on the MRI medical images in mentioned databases. This evaluation is performed under three different conditions; before filtering block, after filtering block, and after ROI vertices correction block.

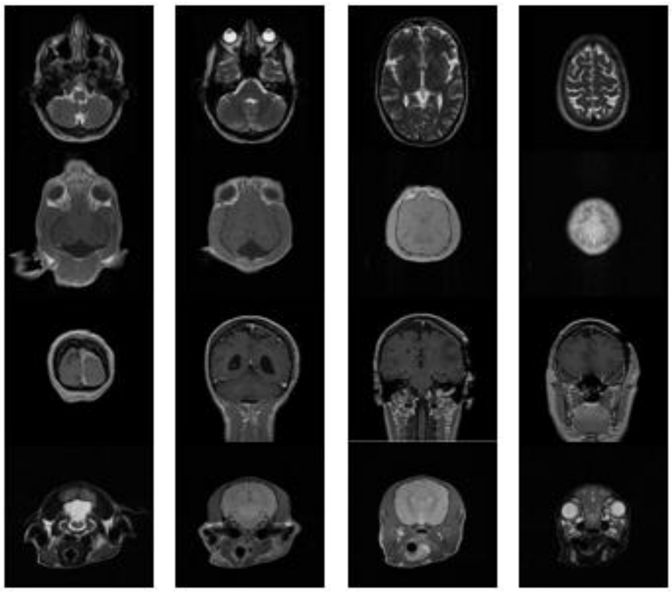
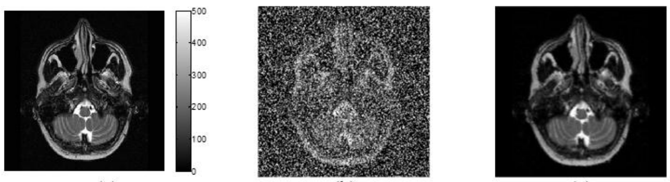


Fig. 4. Samples of medical images in this work [26]

1) Before Noise Filtering: In this part, different densities of salt and pepper noise are applied on the medical images first. Then the ROI vertices of tampered medical images are obtained. Afterwards, these ROI vertices are compared to the detected ROI vertices in the noise-free medical images (as depicted in Fig. 1). CA parameter as explained before is used for this comparison. Table II (columns ‘a’), shows the comparative results of ROI vertices in noisy and noise-free medical images. The result shows that the ROI cannot find the ROI vertices under salt and pepper noise with different densities. Therefore, before starting the ROI detection procedure a noise-filtering block is unavoidable.

2) After Noise-Filtering: The noise filtering algorithms is described in Section III. Fig. 5 shows the proposed noise-filtering result after corrupting the medical image by 50% salt and pepper noise.



(a) (b) (c)

Fig. 5. Proposed noise-filtering scheme: a) original image, b) tampered image by salt and pepper noise (50%), c) denoised image [26]

Table II (Columns ‘b’) shows the comparative results of ROI vertices between noise-free and denoised medical images. It shows that the CA is improved after applying the noise-filtering block.

Fig. 6 presents a better view of the improvement in the CA after using the proposed noise-filtering technique. Weighted mean CA (%) of the ROI detection method is displayed in this figure. Because the number of images in each database is not equal, the weighted mean CA (WMCA) is used and the following equation is used for this purpose:

$$WM(CA)^{\lambda} = \frac{\sum_{i=1}^{5} CA_i^{\lambda} \times Q_i}{\sum_{i=1}^{5} Q_i} \quad (1)$$

where, Q_i is total number of images in each database, i denotes the database number, and λ refers to the density of

Table II
CA (%) of tampered image by salt and pepper noise; (a) before noise filtering, (b) after noise filtering

	CA (%)									
	Db1		Db2		Db3		Db4		Db5	
S&P*	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
10%	0	64.5	0	85.7	0	76.2	0	71.2	0	66.2
20%	0	40.2	0	71.4	0	67.6	0	59.5	0	50.6
30%	0	28.8	0	60.6	0	56.6	0	54.3	0	35.7
40%	0	20.0	0	48.3	0	48.6	0	41.6	0	21.8
50%	0	10.7	0	30.5	0	40.6	0	23.2	0	11.0
60%	0	1.0	0	16.5	0	29.9	0	6.7	0	3.5
70%	0	0	0	9.2	0	12.9	0	0	0	0.4
80%	0	0	0	3.8	0	2.0	0	0	0	0
90%	0	0	0	0.6	0	0.1	0	0	0	0

*S&P: Salt and Pepper Noise

Table III
PSNR of tampered medical image; (a) before noise filtering, (b) after noise filtering

	PSNR (dB)									
	Db1		Db2		Db3		Db4		Db5	
S&P*	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
10%	13.0	37.91	13.0	40.90	13.02	38.90	13.01	45.01	13.05	40.84
20%	10.0	35.39	10.0	38.28	10.01	35.99	10.01	43.05	10.02	37.88
30%	8.25	33.42	8.27	36.42	8.26	33.99	8.25	41.08	8.25	35.90
40%	7.00	31.73	7.00	34.60	7.00	32.30	7.01	39.12	7.01	34.19
50%	6.03	30.04	6.05	32.79	6.03	30.70	6.03	36.87	6.04	32.56
60%	5.24	28.19	5.25	30.82	5.24	29.13	5.24	34.48	5.24	30.83
70%	4.56	26.43	4.59	28.72	4.57	27.48	4.57	31.80	4.57	28.99
80%	3.99	24.32	4.01	26.08	4.00	25.56	3.99	28.87	3.99	26.90
90%	3.47	21.69	3.50	22.58	3.48	23.02	3.48	25.04	3.49	23.96

*S&P: Salt and Pepper Noise

salt and pepper noise. Since there are five databases, i changes from one to five.

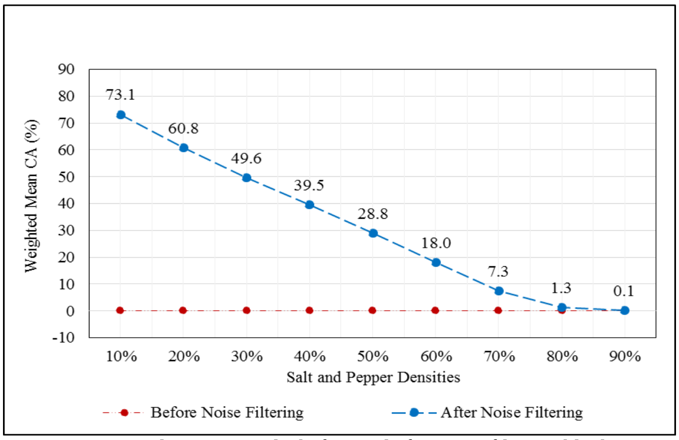


Fig. 6. ROI detection results before and after noise filtering block

As can be seen in Fig. 6, the ROI detection results are improved after noise-filtering block, however, the results need further improvement.

Table III (columns ‘a’), illustrates the PSNR of tampered medical images by salt and pepper noise. Columns ‘b’ show the PSNR improvement after denoising the medical images by proposed noise filtering block.

3) After ROI Vertices Correction: By applying the Vertices Correction (VC) block that mentioned in Section III, the ROI detection accuracy is increased. The completed explanation of method is presented in our previous work [27]. The effect of using VC block is shown in Table IV.

Weighted mean CA is shown in Fig. 7. This figure illustrates a better view of positive effect of VC block on ROI detection results.

As previously explained in related works and here can be seen in Table V, most of previous medical watermarking methods, separate the ROI manually prior to starting the watermarking procedure [9-19]. In addition, in automatic methods [20-24] the robustness is not considered. In this work, by improving our previous automatic method [27] that was robust against different attacks except the salt and pepper noise, the proposed scheme is now robust against different densities of salt and pepper noise.

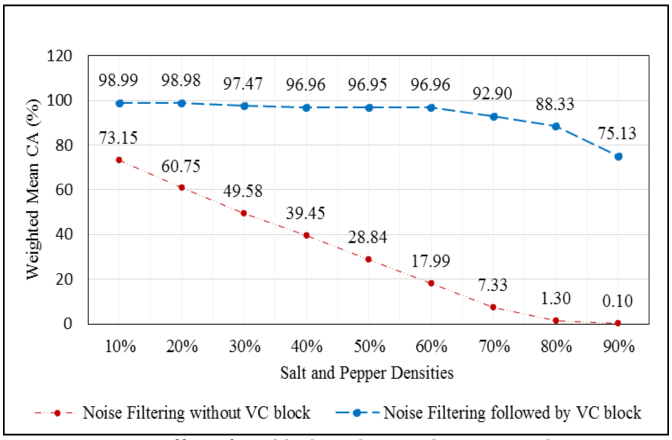


Fig. 7. Effect of VC block on the ROI detection results

V. Conclusion

An automatic and robust ROI detection scheme proposed in this paper. For this experiment, five databases contain 179 medical images were used. It demonstrated that under different densities of salt and pepper noise the proposed ROI detection method could not detect the ROI vertices correctly. Consequently, a noise-filtering block added to the system and the result has improved from 0% to the range of 0.1-73.1%.

Table IV
CA (%) of tampered image; (a) noise-filtering block without VC block, (b) noise-filtering followed by VC block

	CA (%)									
	Db1		Db2		Db3		Db4		Db5	
S&P*	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
10%	64.5	100	85.7	100	76.2	99	71.2	95.5	66.2	100
20%	40.2	95	71.4	100	67.6	99	59.5	100	50.6	100
30%	28.8	90	60.6	100	56.6	98	54.3	95.5	35.7	100
40%	20.0	85	48.3	100	48.6	98	41.6	95.5	21.8	100
50%	10.7	85	30.5	100	40.6	98	23.2	100	11.0	97.5
60%	1.0	75	16.5	100	29.9	100	6.7	95.5	3.5	100
70%	0.0	65	9.2	86.7	12.9	96	0.0	95.5	0.4	100
80%	0.0	55	3.8	80.0	2.0	90	0.0	95.5	0.0	100
90%	0.0	30	0.6	66.7	0.1	84	0.0	59.1	0.0	87.5

*S&P: Salt and Pepper Noise

Table V
Comparison to other methods

	ROI detection Method				
Author	Year	Automatic	Manual	Robustness	Problem
References [9-19]	2002-2012	×	✓	×	Neither automatic, nor robust
Fotopoulos [20]	2008	✓	×	×	Not robust
Memon [21]	2008	✓	×	✓	Only works for elliptical ROI
Badran [22]	2009	✓	×	×	Not robust
Memon [23]	2011	✓	×	×	Not robust
Memon [24]	2011	✓	×	✓	Only works for elliptical ROI
Mousavi [27]	2015	✓	×	✓	Weak against salt and pepper noise
Proposed Scheme	2016	✓	×	✓	Solved

In the last part, a Vertices Correction (VC) block added to the system to guarantee similar ROI vertices before and after different densities of salt and pepper noise. The VC block has improved the detection results from the range of 0.1-73.1% to 75.13-98.99 % under different densities of salt and pepper.

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