Image Impulse Noise Removal Using a Hybrid System Based on Self Organizing Map Neural Networks And Median filters

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Abstract

Digital image restoration has become important for many image applications. Therefore, Image Noise removal is an essential issue in an image processing fields. In this paper, we presented a hybrid system, based on Self Organizing Maps neural networks (SOM NN) and Median filter (MF), to eliminate Random Impulsive Noises (RIN) from grayscaled digital images. In our system we applied two main processes (features extraction process, detection process): in the features extraction process, feature vectors of two or three features, (central pixel value, standard deviation value) or (pixel value, standard deviation, Mean Difference value) respectively, were extracted. In the detection process, the self-organizing maps (SOM NN) are used as an impulse noise detector. This SOM NN module is trained using competitive learning algorithms. Then the detected corrupted pixel is modified using Median filter (MF) algorithm; otherwise, it is left unchanged. Finally, the results of this study are compared with the previous traditional and state-of-the-art methods results that applied on the same database. Our results are significantly outperforms other traditional methods and were comparable with the state-of-the-art methods results in terms of reconstruction quality and that are comparable to the FL using the MSE and PSNR measurements.

الملخص

أصبحت استعادة الصور الرقمية مهمة للعديد من تطبيقات الصور. لذلك، تعد إزالة ضوضاء الصورة مشكلة أساسية في مجالات معالجة الصور. في هذه الورقة, قدمنا نظام هجين, يعتمد على الشبكات العصبية لخرائط التنظيم الذاتي (SOM NN) ومرشح الوسيط (MF), للتخلص من الضوضاء الاندفاعية العشوائية (RIN) من الصور الرقمية ذات التدرج الرمادي. في نظامنا، قمنا بتطبيق عمليتين رئيسيتين (عملية استخراج الميزات ، عملية الكشف): في عملية استخراج الميزات، تم استخراج متجهات الميزة لميزتين أو ثلاث ميزات ، (قيمة البكسل المركزية ، قيمة الانحراف المعياري) أو (قيمة البكسل ، الانحراف المعياري ، متوسط قيمة الفرق) على التوالي. في عملية الكشف، يتم استخدام خرائط التنظيم الذاتي (SOM NN) ككاشف للضوضاء الدافعة. يتم تدريب هذه**SOM NN** باستخدام خوارزميات التعلم التنافسي. ثم يتم تعديل البكسل التالف المكتشف باستخدام خوارزمية مرشح الوسيط (MF) ؛ خلاف ذلك ، يتم تركه دون تغيير. أخيرا، تمت مقارنة نتائج هذه الدراسة مع نتائج الطرق التقليدية والحديثة السابقة التي طبقت على نفس قاعدة البيانات. تتفوق نتائجنا بشكل كبير على الطرق التقليدية الأخرى وكانت قابلة للمقارنة مع أحدث نتائج الطرق من حيث جودة إعادة الإعمار والتي يمكن مقارنتها ب FL باستخدام قياسات MSE و PSNR.

Keywords— *Random value impulsive noise, Impulse noise, grayscaled digital image, Neural networks (NN), Self Organizing Map (SOM), Hybrid systems.*

I. INTRODUCTION

The field of DIP has become an interest field by researchers since digital image importance in many applications. Nowadays, it is very rare to find an application is devoid of existence of an image due to the fact that the picture is a source of information as well as it is a method of expressing, etc. An image is exposed to many kinds of deterioration which affects and degrades its quality and significance as an important source of information. Impulse Noise can affect the quality of an image and it occurs during the processes of the image such as acquisition, transmission and storage. IN can be classified two classes: Salt & Pepper Noise (SPN) and Random Valued Impulse Noise (RVIN). As shown in Fig. 1.

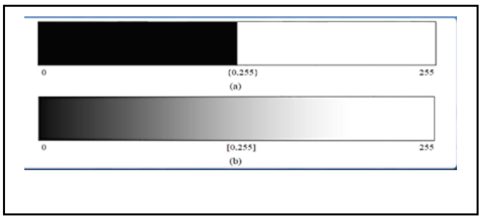

Fig. 1. Representation of Digital Images by 2-D arrays. (a) Salt & Pepper Noise(SPN), (b) Random Valued Impulse (RVIN)

In the SPN, the corrupted pixels were changed to either the minimum or maximum value of the image intensity range. However, the RVIN changes some of the pixels to values in the image dynamic range. Therefore, RVIN restoration is the focus of this paper.

Several studies applied various techniques to contribute in improvement of the image quality. Some of these studies review traditional algorithms for reducing or removing Impulse Noise (IN) such as [2, 3, 4, 5] applied the median filter (MED) that first introduced in [38]. Although some of its modified versions is still popular algorithm to remove the IN due to its low complexity and its efficiency. Where, Median filter algorithm (MED), replaces the value of a pixel by the median of the gray levels in the neighborhood of that pixel [35]. More details for these filters are presented in [6]. However, [1, 2, 3] used a Switching Median Filtering (SMF) Technique to detect whether a pixel is noisy or noise-free. If the pixel is noise-free, the filtering window is moved forward to process the next pixel. On the other hand, if the pixel is a noisy one, then it is replaced by the median pixel value if it is not an impulse; otherwise, the pixel is replaced by the already processed immediate top neighboring pixel in the filtering window [34]. Fuzzy Logic (FL) noise reduction methods are also widely used for image restoration. Such as [6, 12] used a fuzzy filter approach to remove the IN from gray-scaled and colored images. Also, [8] applied a boundary discriminative noise detection algorithm and Fuzzy impulse noise (FIN) Filter images. In [9] proposed a technique to detect the Gaussian and IN from colored images. Also, [10] used a Fuzzy Switching Median (FSM) filter to remove the Salt & Pepper Noise (SPN). Also, Schulte in [11], reduced SPN from a digital images using a fuzzy and an iterative filtering techniques. In addition, [3] used the Switching Median Filtering (SMF) technique to improve the performance of the median filter (MF).

Neural Networks are considered as a powerful and effective tool in detection phase of noisy. Many researchers were interested in the field of digital image restoration, based on neural networks. Deng and etal. In [13], proposed a new noise removal algorithm based on improved neural network to remove the IN. The algorithm is used to detect the noise-pixels and distinguish them from noise-free pixels efficiently in the first stage, then, the noise-pixels are replaced further by the suitable pixel which has the most local similarity in the final stage. Gorjizadeh and etal. In [14, 36], used a Self-Organizing Map (SOM) Neural Networks (NNs) for Noisy Image Segmentation. A hybrid Technique Based on Neural Networks and Switching Filters was used to remove the Impulse Noise from Highly Corrupted Images. Also, in [38-42] a convolutional neural network deep learning neural networks (DNN) are proposed to remove the Impulse Noise from Corrupted Images with high efficacy. However, it should be considered that impulse noise detection is a challenging task and the performance of the detector can affect the reconstruction quality. The aim of this paper is to apply a hybrid system used Self Organizing Maps neural networks (SOM) to detect the impulsive noisy pixels and Median filter (MED) to reconstruction of noisy pixels from grayscaled digital images corrupted by RVIN.

The rest of this paper is organized as follows. In Section II, a brief fundamentals of digital image processing (DIP) will be presented, the Concepts of Artificial Neural Networks (ANNs) an filtering scheme are introduced in section III. Followed by the performance metrics and experimental results of (SOM) network for impulse noise reduction in grayscaled images are discussed in sections IV, V respectively. Future work is suggested in section VI. Finally, the paper is concluded in section VII.

II. Fundamentals of Digital Image Processing (DIP)

The field of DIP has been taken more of an interest by researchers since an image features are considered one of the most distinctive inputs for several applications. An image is exposed to many kinds of deterioration which affects the quality and degrades its significance as an important source of information. Therefore, in image restoration studies methods that recover an original image from degrade one.

Images can be represented in a two-dimensional function O(i, j), where i and j are plane coordinates, and the amplitude of the function O at any point (i, j) is the intensity or gray level of the image at that point [10]. Images are represented as a two-dimensional matrix in the computer. The intersection of any row and column in the matrix 2-D is called a pixel. Pixel represents the degree of intensity of color, or grey value gradient [16, 17]. There are three types of the representation of digital images which are Binary Digital Images, Monochrome (grayscale) Digital Images, and Color Digital Images. A binary image has only two possible values (0 for black pixel and 1 for white pixel [16].

The binary Image is usually stored in memory as a bitmap, a two-dimensional set filled by limited elements of the image [16]. In many cases there is a need to deal with Monochrome (grayscale) digital Images, as it appears in medical images for example. In this type of images is usually the pixel value of grayscale images range from 0 (black) to 255 (white). The digital grayscale images are often represented by a two-dimensional set of image elements with a numeric value between 0 and 255, representing the value of intensity or grayscale value in that position. This type of images will be within the concerns of this paper. In color images each pixel has a particular color and that color which is described by the amount of red, blue, and green in it. Each of these components has a range 0-255.

Digital image processing can refer to the processes of analyses an image using a computer [1, 3, 4]. Several image processing functions can be done on an image such as Filtering, Analysis and Recognition, Transform, and Restoration, acquisition, enhancement, Color Image Processing, segmentation, Data Compression, Representation and description, etc. In this paper, an Image filtering and restoration is used. the digital image restoration is defined as a process of improving an original image, where noise, blurriness and vagueness and are eliminated from the corrupted images [6, 12].

Different types of noises can affect an image. This leads to change the quality of the original information of the image [22]. There are many types of noise such as additive, impulse, Gaussian noise [11]. This paper focused on the impulse noise RVIN which were added, in this work to, the original image using the MATLAB application.

III. Concepts of Artificial Neural Networks (ANNs) Filttering Scheme

Computers can perform many operations considerably faster than a human being. However, faster is not always the point for problem solving. There are many tasks for which the computer falls considerably short of its human counterpart. There are numerous examples of this. For instance, given two pictures, a preschool child can easily tell the difference between a cat and a dog. Yet, this same simple task is extremely difficult for today's computers [23].

ANNs can generalize to others they have not yet encountered. They can recognize handwritten characters, identify words in human speech [25], and detect explosives at airports [24]. Also. The ANNs have a variety of applications in the field of DIP, for example could be used to specify which part of an image corresponds to edges, textures, and smooth regions, etc. It is also possible extract image features from the specified regions as training examples for a properly designed neural network such that the trained network will be capable of classification a previously unseen image into the primitive feature types [26]. Structure of (ANNS), training, testing are in [24, 28, 6].

Supervised training is accomplished by giving the neural network a set of sample data along with the anticipated outputs from each of these samples. Supervised training is the most common form of neural network training. As supervised training proceeds, the neural network is taken through a number of iterations, or epochs, until the output of the neural network matches the anticipated output, with a reasonably small rate of error. Each epoch is one pass through the training samples [23]. However, unsupervised training is similar to supervised training, except that no anticipated outputs are provided. Unsupervised training usually occurs when the neural network is being used to classify inputs into several groups. The training involves many epochs, just as in supervised training. As the training progresses, the classification groups are "discovered" by the neural network. Using a Self-Organizing Map is the most famous example of this training. It is also one of the main concerns of noise detection in this study [23].

A. *Self Organizing Maps (SOM)*

SOM or Self Organizing Feature Map (SOFM) is a kind of artificial neural network and it belongs to the class of unsupervised and competitive learning algorithms (CLA). SOMs are the most well-known neural network approach to clustering [28], the topological properties of the input space. Neural networks engaged in the process of self-organization are therefore a very attractive tool to perform the task of grouping the input data and the creation of classes of similarity among them. [29]

The SOM is a data-analysis method that visualizes similarity relations in a set of data items. For instance, in economy, it has been applied to the comparison of enterprises at different levels of abstraction, to assess their relative financial conditions, and to profile their products and customers. On the other hand, in industry, the monitoring of processes, systems and machineries by the SOM method has been a very important application, and there the purpose is to describe the masses of different input states by ordered clusters of typical states. Generally, in science and technology, there exist unlimited tasks where the research objects must be classified on the basis of their inherent properties, to mention the classification of proteins, genetic sequences and galaxies. etc...[37].

SOM is working with high dimensional data sets is difficult. The SOM reduces information while preserving the most important topological relationships of the data elements on the two-dimensional plane, so that information from different sources can be efficiently fused. Also, the SOMs are trained using unsupervised learning, i.e. no prior knowledge is available and no assumptions are made about the class membership of data. In addition, the SOM algorithm is very efficient in handling large datasets. The SOM algorithm is also robust even when the data set is noisy [28]. However, in the SOM, the number of clusters needs to be specified. Clustering is a two-phase process: determining the number of clusters and clustering the data. Determining the number of clusters is not trivial, since the characteristics of the data set are usually not known a priori. This can be overcome by running the algorithm with varying numbers of clusters and selecting the most appropriate clustering result according to a figure of merit. A user has to either do manual inspection or apply traditional algorithms, like hierarchical, to find the cluster boundaries [28, 31]. In this research we are interested in dividing the pixels into two clusters (noisy and free)

B. *SOM Neural Network for Impulse Noise Reduction*

Self-Organizing Neural Networks are effective in dealing with unexpected and changing conditions. In this section, an explanation of the Competitive Learning Algorithm (CLA), which are based on self-organizing networks. Among the most common species of unsupervised learning is competitive learning. In competitive learning, neurons compete among themselves to be activated. in the competitive learning only a single output neuron is active at any time. The output neuron that wins the 'competition' is called the winner-takes-all neuron. The CLA was introduced in interval (1972-1975) by (Grossberg, von der Malsburg, Fukushima), and it was widely spread in the late 1980s, when Teuvo Kohonen introduced a special class of (ANNS) called self-organizing feature maps (Kohonen, 1989). These maps are based on CLA [24]. Details of the Competitive Learning Algorithm (CLA) are in [6, 12, 19, 26, 24]:

This section provides a description of noise removal from images using SOM neural network. Images noise removal consists of three separated phases: Features Extraction Phase, Detection Phase and Filtering Phase. Feature selection depends on local statistical properties of the images, while detection phase depends on the self-organizing maps neural network which trained using CLA, finally filtering phase performed using the traditional median filter.

a) *Vector Features Extract Phase from digital Image*

To detect IN in a digital image, extraction of important features is needed. Thus, two different experiments were conducted, each experiment dependent on different features. In the first experience a vector of two features were used are (central pixel value, standard deviation value which is calculated from the difference between the central pixel value and the median in the sliding window of size 3x3) these two features are used to distinguish the IN from the signals, as they can effectively reflect the characteristics of the impulse noise. The first feature helps the neural network to train the weight vectors to represent impulses of both directions, and second feature provides accurate information about the likelihood of whether the current pixel is corrupted [20, 33]. In the second experiment a vector of three features were used (pixel value, standard deviation, Mean Difference value).

b) *Detection Phase:*

Detection phase is the most important stage in removing IN of digital image. The noise detection part is performed using neural networks. To effectively detect the impulse noise, the local statistics are used as feature vectors. Neural network impulse detector is used to generate a binary flag image, which gives each pixel a flag indicating whether it is an impulse noisy or not. Then a pixel is modified only when it is considered as an impulse; otherwise, it is left unchanged, as it is shown in Fig. 2. Neural network receives a features vector, which extracted from the image, then trains and adjusts the weights by CLA. By using a single Kohonen layer with competitive learning neurons, this network learns clusters in an unsupervised mode. The input to this network are two or three features and their outputs are two clusters corrupted or not corrupted (noise-free, noise). The Implementation of CLA are detailed in [6, 12]. In addition, the source code of the Self Organizing Map Algorithm module was written using Visual Studio. Net Technology by C# language, and it is made for free to use.

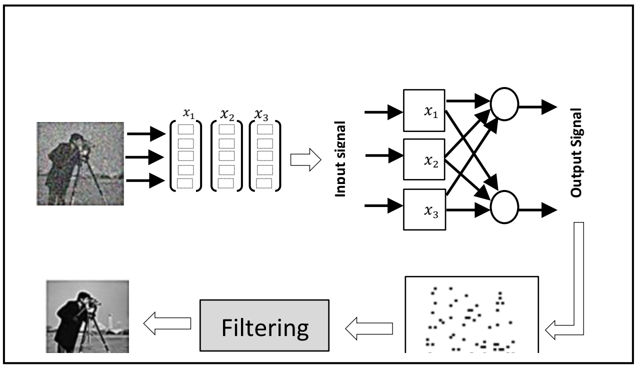

Fig. 2. The structure of system for impulse noise reduction using SOM network.

c) *Filtering Phase:*

To remove noises from the corrupted pixels or that considered as an impulse noisy pixel witch detected by SOM neural network, the Median filter algorithm (MED) are used to replace the value of the corrupted pixel by the median of the gray levels in the neighborhood of that pixel. Fig. 3 shows the filtering scheme that used in this work.

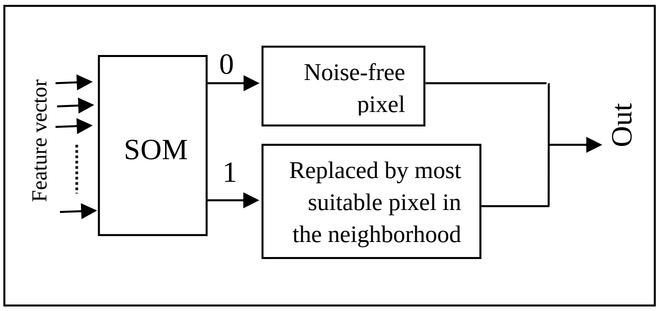

Fig. 3. General filtering scheme

IV. PERFORMANCE *METRICS*

In order to ensure the quality of the proposed techniques an image is examined by various metrics. In this work we applied Mean Squared Error (MSE) and Peak Signal to Noise Ratio (PSNR) measurements.

A. Mean Squared Error (MSE)

MSE is one of the most used quality measures in image processing. This measure expresses the dissimilarity between two images, i.e., the smaller the MSE value between two images the more similar they are. MSE is defined for grayscaled image as:

$$\mathrm{MSE} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[O(i,j)-F(i,j)]^2 \qquad (1)$$

And it is defined for colored image as:

$$\mathrm{MSE} = \frac{1}{MNQ}\sum_{q=1}^{Q}\sum_{i=1}^{M}\sum_{j=1}^{N}[O(i,j)-F(i,j)]^2 \qquad (2)$$

Where Q is the number of color channels (3 for RGB space), M and N are the image width and height, O is gray value of the original reference image and F is gray value of the filtered image, where an 8-bit color channel resolution is assumed.

This classic quality measure is extremely sensitive to the offsets in color or luminance channels. It is possible that, although the visual impression of the image does not change, the (PSNR) value may be much lower [23].

B. Peak Signal to Noise Ratio (PSNR)

PSNR analysis is used to measure an objective difference between two images, and it is one of the most commonly used similarity measures. It estimates the quality of a reconstructed image with respect to an original image. The basic idea is to compute a single number that reflects the quality of the reconstructed image. To judge the reconstructed images it is noticed that the higher value of PSNR, a better quality of an image [2] ,[7].

Given an original image O of size (M × N) pixels and a reconstructed image F with the same size where: *m* with 8-bit, the PSNR (dB) is defined as:

$$\mathrm{PSNR} = 10\log_{10}\frac{(2^m-1)^2}{\mathrm{MSE}(F,O)}\ (\mathrm{dB}) \qquad (3)$$

V. Experimental Results of (SOM) network for Impulse Noise Reduction in grayscaled images

B. *Data Sets*

There are many test images datasets that can used in this study, such as "lena", "Boats", "Peppers", "Cameraman" with different sizes. However, in this paper we selected the "lena" grayscaled images with sizes (512 × 512) for our experiments. The main reason for that is to compare our results that obtained from this paper to the results that obtained on the same dataset that presented in [6, 12].

C. *Adjust and selection parameters of (SOM) network*

Adjusting parameters are important and needed to improve the results that obtained by using SOM network. The parameters where adjusted to restore the corrupted "Lena" (512 × 512) with different Random Valued Impulse Noise (RVIN) are PSNR, and NMSE.

D. *Numerical Results*

In this section, we show the performance SOM network for reducing IN in digital images. Below we display some the numerical results based on several methods to restore corrupted pixels. Table 1. presents the numerical results of the "Lena" image that corrupted with several ratios of RVIN IN.

Table 1. Comparative results in terms of PSNR (dB) of (SOM) network used various distortions of random valued impulse noise (RVIN) with other researchers result for the` (512 × 512) "Lena" image

MSE				
Method % / RVIN noise	**MEDIA[38]**	**PSM–CNN based [41]**	**NEN [45]**	**SVM-MED (this work)**
5%	-	-	-	0.0013
10%	0.0213	0.0029	0.0026	0.0026
30%	0.0324	0.0148	0.0077	0.0073

The SOM–MED results showed higher performance qualities, in terms of MSE for commonly used 512 × 512 grayscaled LENA image, when it's compared with various methods used the same database and the same metric performance.

E. *Visual Results*

By comparing the results of the restoration of corrupted "Lena" image, presented in Fig. 4, it has been found that they are similar to the results displayed in the reference [36].

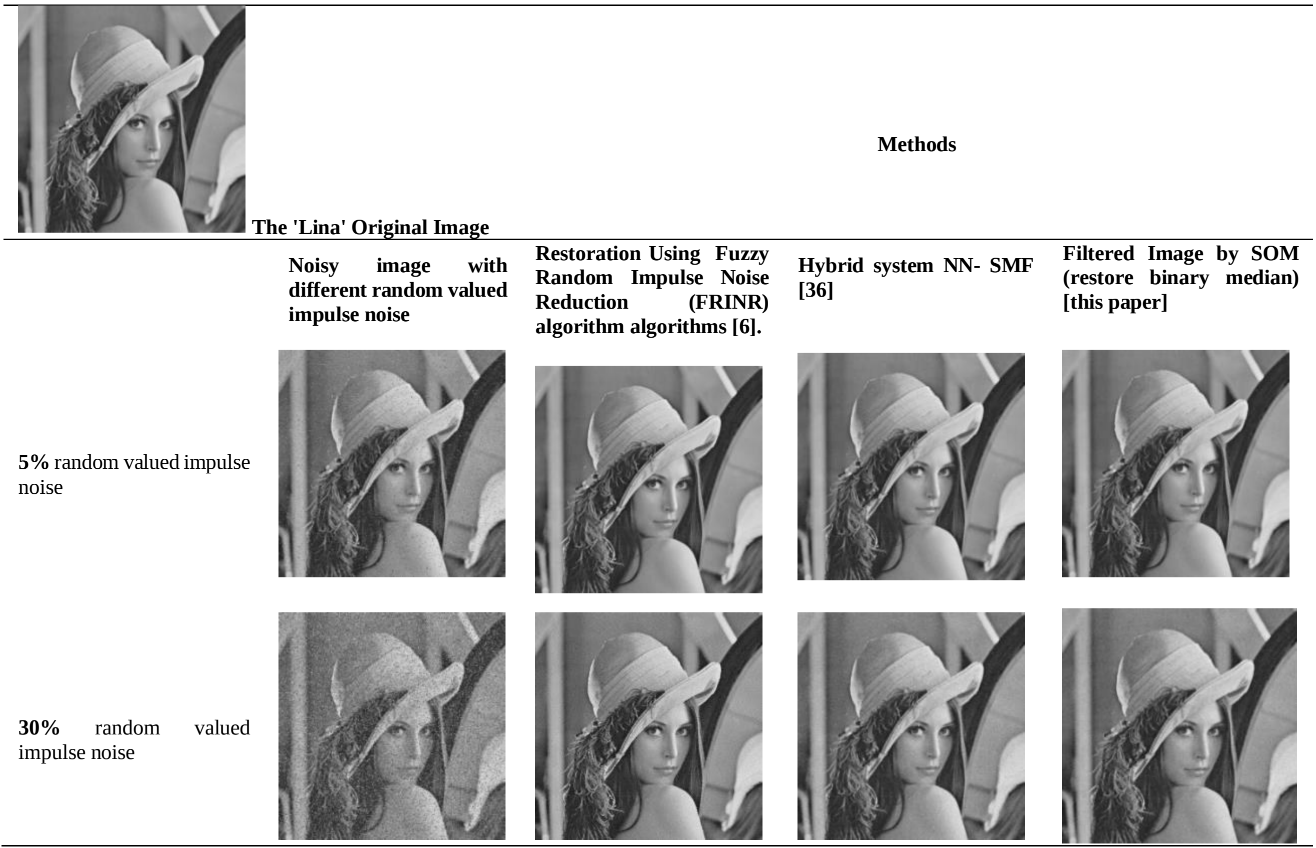

Fig. 4. A Visual comparison restoration results of the corrupted "Lena" image using different *RVIN.*

F. *Performance comparison*

In this section, we compare the performance of SOM_MED hybrid system with other methods results such as traditional filters (MF, MED, SMF, AMF) in [6], fuzzy filter used FRINR [6], CNN (named INRNet) [38], CNN-32 channel [43], CNN-64 channel [43], WESNR [44], Hybrid system NN- SMF [36]. All of these researches have done on the same LENA image corrupted by 30% RVIN. Table 2 presents the reconstruction qualities in terms of PSNR metric for the commonly used 512 × 512 LENA BMP image. the restoration results using the SOM-MED system outperforms other traditional methods result such as MF, MED, SMF, AMF filters. Also, that the performance of the SOM-MED system was comparable with the CNN performance. However, the Fuzzy Logic (FL) method has still had higher performance on the same database. In summary, our network, SOM-MED, is fast and effective in removing RVIN and equivalent to

VI. FUTURE WORK

Usually, post-processing stage is used to further performance enhancement achievement. So the future work will focus on enhance our system performance using post-processing algorithms. Also, the RGB images are also widely used, in many image applications, with added features. Therefore, the SOM will be proposed for the RGB-based images.

VII. CONCLUSION

The object of this paper was to use Self Organizing Maps (SOM) Neural networks module to remove the random value impulsive noises (RVIN) in different rates of noise (5%, 10%, and 30%) form the grayscaled digital images. Thus, we applied two separated stages: the first was features eextraction, where in this stage we extracted features vector of two or

TABLE 2. COMPARATIVE CESULTS IN TERMS OF UIQ OF FRINR AND INRC ALGORITHMS WITH VARIOUS DISTORTIONS FOR IN LENA COLOR IMAGE

Methods	**Filters**	**5% of Noise density (Random-valued Impulse Noise)**
		PSNR(dB) for 5% RVIN
Traditional Filters [6]	**MF**	29.194
	MED	33.675
	SMF	34.253
	AMF	37.099
CNN (named INRNet) [38]		38.20
CNN-32 channel [43]		32.36
CNN-64 channel [43]		32.95
WESNR [44]		33.00
Fuzzy Filter [6]	**FRINR**	40.523
Hybrid system NN- SMF [36]	**SMF**	37.3
Hybrid system SOM-MED (this work)	**MED**	**37.385**

three features. These features are generally used to distinguish the IN from the grayscaled images using the self-organizing maps neural network (SOM) in the second stage. The network is trained using competitive learning algorithm (CLA). Finally, filtering phase performed using the traditional Median filter (MED) algorithm. The “lena” grayscaled images with sizes (512 × 512) are used for our experiments, In order to explore the potential of the IN detection and reduction system using the hybrid SOM-MED system. The MED, AMF, MF, SMF traditional filters and FL filters FL are used as a baseline to this work from our previous work. We can conclude that, the restoration results using the SOM-MED system outperforms other traditional methods result such as MF, MED, SMF, AMF filters. Also, that the performance of the SOM-MED system was comparable with the CNN performance. However, the Fuzzy Logic (FL) method has still had higher performance on the same database. In summary, our network, SOM-MED, is fast and effective in removing RVIN and equivalent to CNN modules that used for image restoration.The Mean Squared Error (MSE) and Signal to Noise Ratio (PSNR) measurements were used in this work.

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