Simulation of Filtering Schemes Applied for Images Enhancement

Khadija I. Garamanli[1], Mostafa B. Abuitbel[2]*, Musbah M. Alahrash[1]

[1] College of Electronic Technology, University of Tripoli , Tripoli, Libya

[2] College of Electronic, University of Azzaytuna, Tarhuna, Libya

*Corresponding author email: mabuitbel64@gmail.com

ABSTRACT

In signal processing, filters generally play a pivotal role in removing unwanted parts of the signal, such as random noise, or extracting useful parts of the signal, such as the components lying within a certain frequency range to enhance the performance and denoising scenario. This paper presents the implementation of linear and non-linear filtering schemes for noise reduction and image enhancement. This is achieved by performing the convolution of a grey-scale image with a mask filter of multiple sizes using MATLAB software. The average and median filters are implemented on the same image of an injected salt and pepper noise. In accordance with the findings, the nonlinear filters show more promising performance with a better peak-signal-noise ratio (PSNR) compared to the linear filters.

محاكاة مخططات التصفية المطبقة لتحسين الصور الفوتوغرافية

خديجة إبراهيم قرمنلي[1]، مصطفى بن عروس أبوطبيل[2]، مصباح محمد الأحرش[1]

[1] كلية التقنية الإلكترونية – طرابلس

[2] قسم الهندسة الكهربائية والالكترونية، كلية الهندسة، جامعة الزيتونة، ترهونة، ليبيا

ملخــــــص البحـــــث

تلعب المرشحات دورا أساسيا في معالجة الإشارات من حيث التخلص من وتقليل الضوضاء واختيار أي جزء مهم من الإشارة. في هذه الورقة بالخصوص تم المقارنة بين نوعين من المرشحات لتحسين الصور الرقمية. تم ذلك باستخدام طريقة رياضية معتمدة على عملية Convolution من خلال خوارزميات MATLAB بعدما تم إضافة نوع معين من الضوضاء للصور تحت الدراسة. أظهرت النتائج ان المرشحات الغير خطية كان أدائها أفضل من المرشحات الأخرى.

1. Introduction

Convolution is a computational mechanism widely used in various applications in the areas of science and engineering disciplines. The convolution as a powerful operation is being applied on signals, such as in the fields of digital signal processing, electrical engineering, audio processing, probability theory, and artificial intelligence [1][2]. It is a fundamental concept that involves combing two signals together to produce a third one in order to apply some enhancements as noise reduction and extracting features. In fact, convolutional filtering plays an important role in many applications such as in the image processing discipline [2].

2. Image Enhancement

Sometimes when pictures are captured from various resources then the quality of images is not very good due to obstacles [3]. Image processing is a field consists of various stages for processing an image. One of the most important stages of image processing is image enhancement which effects the pictorial view of an image [4]. Image enhancement is the procedure of improving the quality and the information content of the required image. Image filtering is also an interesting application of image processing. Suitable image filtering type can be implemented to alter the pixels of the image to transform it into a desired form using software means. It removes noise and brighten images, making it easier to identify key features. In fact, image filtering techniques can be accomplished in either frequency domain or spatial domain. In frequency domain, the images are analyzed in terms of their frequency components with the aid of the Fourier Transform tool [5]. On the contrary, image enhancement in spatial domain deals directly with the manipulation of pixels of the image [6][7].

3. Filtering techniques

In image enhancement, noise removal is very important and for this purpose image filters are used. Filters offer the possibility to restore the detail of original image as much as possible. As a results reduction in noise amount and hence improving the visual quality of the image. These filters are basically linear and nonlinear ones. Nonlinear filters have quite different behavior compared to linear filters. Since they don't obey particularly scaling and shift invariance characteristics. Both filters' types are described below:

3.1 Linear Filters

In image enhancement, noise removal is very important and for this image filters are used. Wide range of filters are there for noise removal. One of the linear filters implemented for image filtering is known as average filter. Its working principal is based on creating a 3x3 mask that each has value of 1. This mask is placed on the image for performing convolution. Figure (1) illustrates the convolution operation using image kernel for a 3x3 mask [6]. The average is then computed after convolution and it is placed on the targeted pixel. The process is kept repeating for the entire image pixels [8].
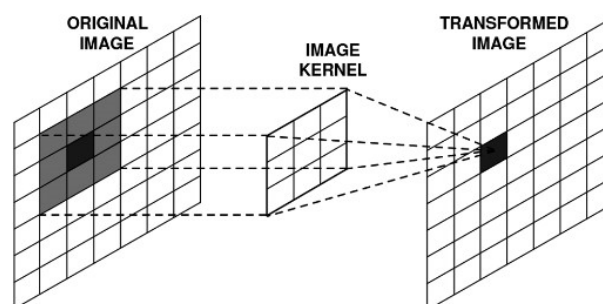

Fig. 1. Convolution operation using image kernel for a 3x3 mask [5].

3.2 Non-linear Filters

In the nonlinear approach, the median filter is used to implement the image filtering. Its mechanism is based on arranging a 3x3 empty mask to place it on the image for convolution. Its values of pixel intensity are ordered in either ascending or descending order. Moreover, the median value is selected and placed at the targeted pixel. This process is repeated in the same fashion for the remained pixels [8].

4. Methodology

The criterion of the noise removal problem depends on the noise type by which the image is corrupting. There have been several denoising algorithms published in this regard and each approach has its assumptions, advantages and limitations [9]. Gaussian, impulse, speckle and mixed noise are common types of noises can impact the image processing. Image processing is commonly used to improve raw images which are received from various resources. One of the most important stages of image processing is image enhancement. In the current work, the image enhancement is applied on a gray-scale image that is injected with some impulse noise called also salt and pepper noise (randomly occurring white and black spots in an image), in order to observe the effect of the applied filters. The percentage of the added noise to the original image is varied from 5% to 30% for both the average and median filters. In addition, the filter process is performed for different masks' sizes (3x3, 5x5, 7x7, 9x9, ….) to notice any effect of this factor on improving the image quality.

5. Simulation Results

Image processing use mathematical procedures for processing of images. Currently, various masks sizes are applied for reducing the salt and pepper noise as can be seen in Figures (2&3) which show the performance of the average and median filters respectively on same gray-scale noisy image with 30% noise injected. Figure (4) on the other hand, illustrates 5x5 mask applied on the same noisy image (15% noise added) for the average and median filters.
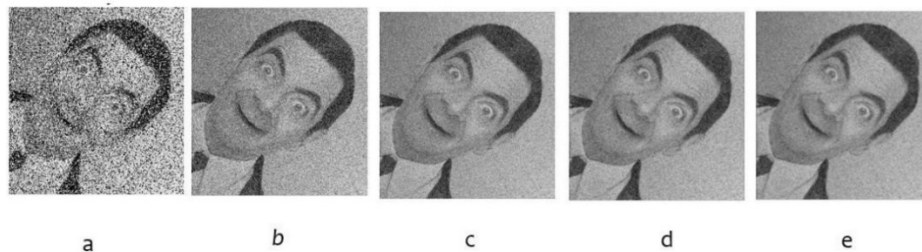

Fig. 2. Average Filter technique with 30% noise injection for different masks' sizes. (a) Noisy Image. (b) 3x3 mask. (c) 5x5 mask. (d) 7x7 mask. (e) 9x9 mask.
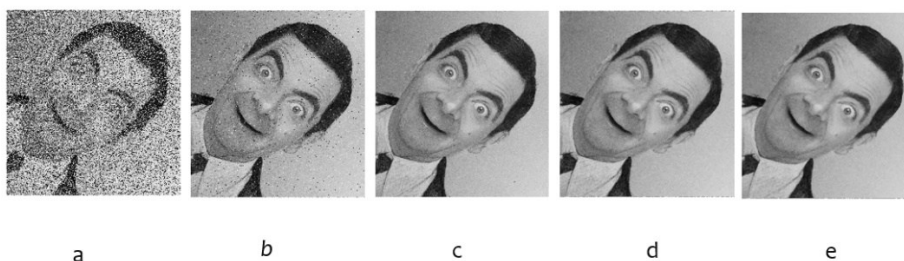

Fig. 3. Median Filter technique with 30% noise injection for different masks' sizes. (a) Noisy Image. (b) 3x3 mask. (c) 5x5 mask. (d) 7x7 mask. (e) 9x9 mask.
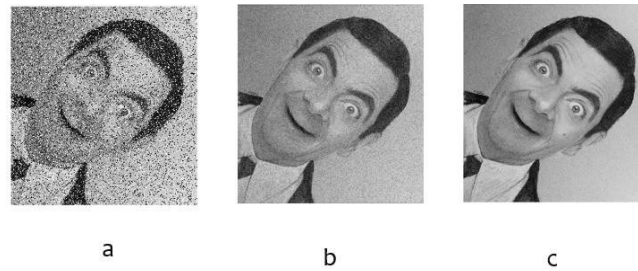
a   b   c

Fig. 4. Average Filter vs. Median Filter with a fixed noise added (15%). (a) Noisy Image. (b) 5x5 mask average filter. (c) 5x5 mask median filter.

6. Discussion & Analysis

There are two main factors that are measured as a figure of merit to evaluate the performance of the linear and non-linear filters, namely; the visual evaluation and the Peak Signal to noise ratio.

6.1 Visual Evaluation

As can be seen from Figure (2) the effectiveness of average filter on a 30% salt and pepper noise added to the original image. It is noticed a clear improvement in the filtered image after applying linear filters with different masks sizes. Furthermore, the reconstructed image for the median filters in Figure (4) have better image appearance and noise reduction relative to the average filter.

6.2 Peak Signal to Noise Ratio

In order to make a better judgment and comparison on the effect of the linear and non-linear filters, the Peak Signal to Noise Ratio (PSNR) is measured. The PSNR is computed between two images at a time, the reconstructed/filtered image and the denoised image. Thus, the greater the figure resulted, the better the output image after passing through the filtering process. Then the PSNR is computed as well for every mask size to observe how much improvement is resulted. Figure (5) shows the relationship between the PSNR and the mask size for different percentages of noise added to the original image. It can be observed that the image with 30% noise has the lowest PSNR as expected. Moreover, it is noticed that there is a dramatic increase in PSNR for the small kernels (3x3, 5x5, 7x7,..) and the more the kernel size becomes larger, the effect of the filtered image does not improve further.

Furthermore, the same relationship is also plotted for the median filter performance in Figure (6). It shows similar performance with greater denoising effect on the image.
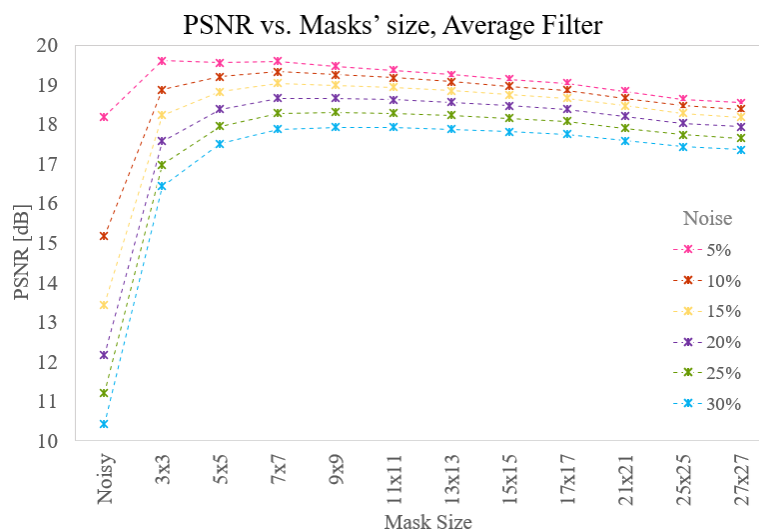

Fig. 5. The relationship between the PSNR and the mask sizes for Average filter
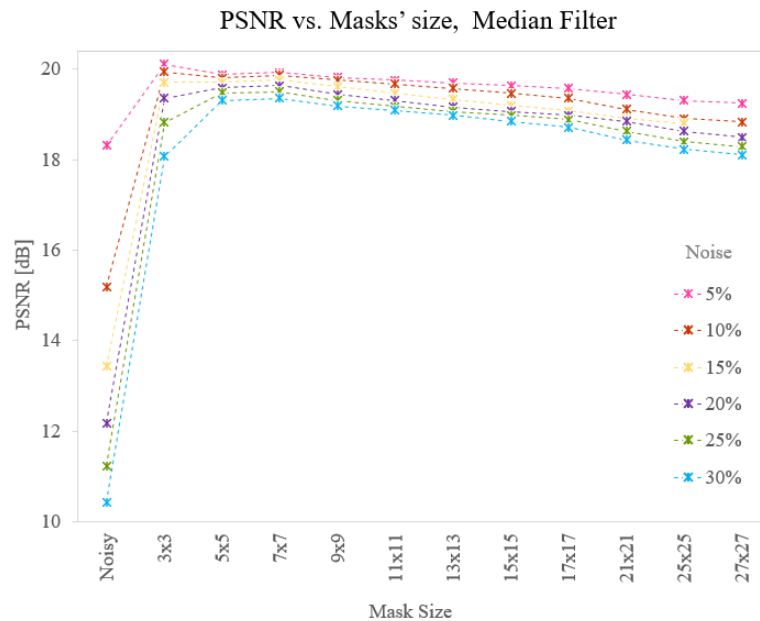
PSNR vs. Masks' size, Median Filter

Fig. 6. The relationship between the PSNR and the mask sizes forMedian filter.

As far as Figure (7) is concerned, it demonstrates that median filters have better salt and pepper noise filter than average filters. As both filters are applied on an image with 30% noise added, and it is performed on different sizes of masks. It is obvious that median filters for the all-masks' sizes are denoising much better than the average filters, and as a consequence have the significant PSNR figures.
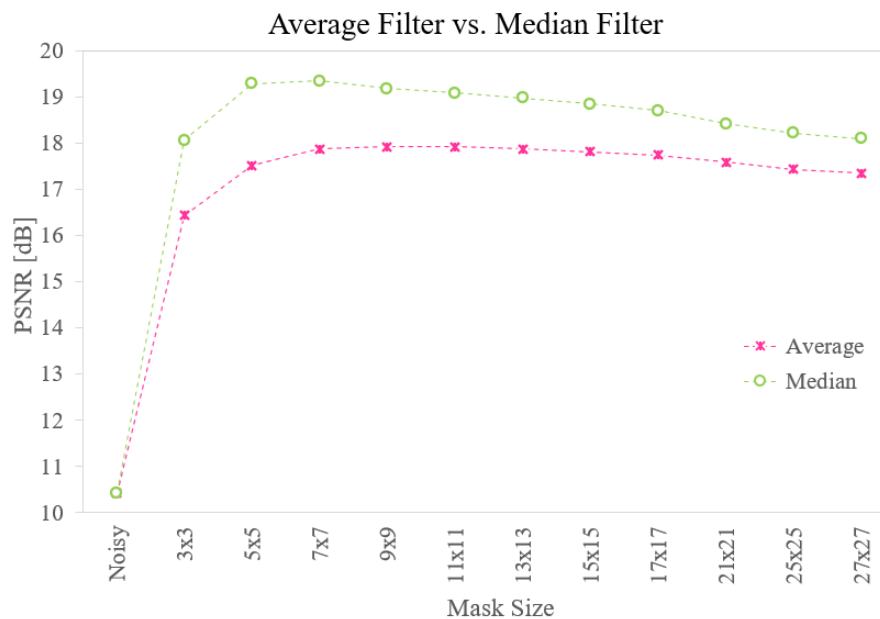
Average Filter vs. Median Filter

Fig. 7. The relationship between the PSNR and the mask sizes forAverage and Median filter with a fixed noise added

7. Conclusions

Noise can deteriorate images quality and may result in loss of important information hidden in images for certain applications. Suitable filtering is therefore a crucial element in a wide range of image processing applications. This paper discussed how convolution concept is implemented in image processing and noise filtering to avoid poor quality images. It is inevitable to state that filtering scheme is considered to be among the diagnostic tools to monitor the systems performance and for denoising

applications such as enhancing the quality of images pixels. MATLAB developed codes have been implemented to analyse the performance and simulate the results. Simulation results claimed that median filters which are classified as non-linear ones have achieved better results in terms of noise filtering and improving the images quality in comparison to average filters. This is observed through visual evaluation of the reconstructed images as well as via computing the corresponding PSNR values.

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