

## HIT NOISE REDUCTION IN SOME X-RAY IMAGES

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### Abstract

The imaging system we have investigating suffer from the appearance of scattered bright points. A usual solution to reduce this noise can be achieved by an increase in exposure but it is very difficult to prevent the hits. In present study, we have investigating algorithms to reduce noise with out an increase in exposure by adopting four digital filters for noise reduction and comparing between efficiency of each filter to determine an efficient method. The resulting images and fidelity criteria showed that the median filter smoothes hit noise while maintaining edge information, but the mean filter image is a blurred version of the noisy image.

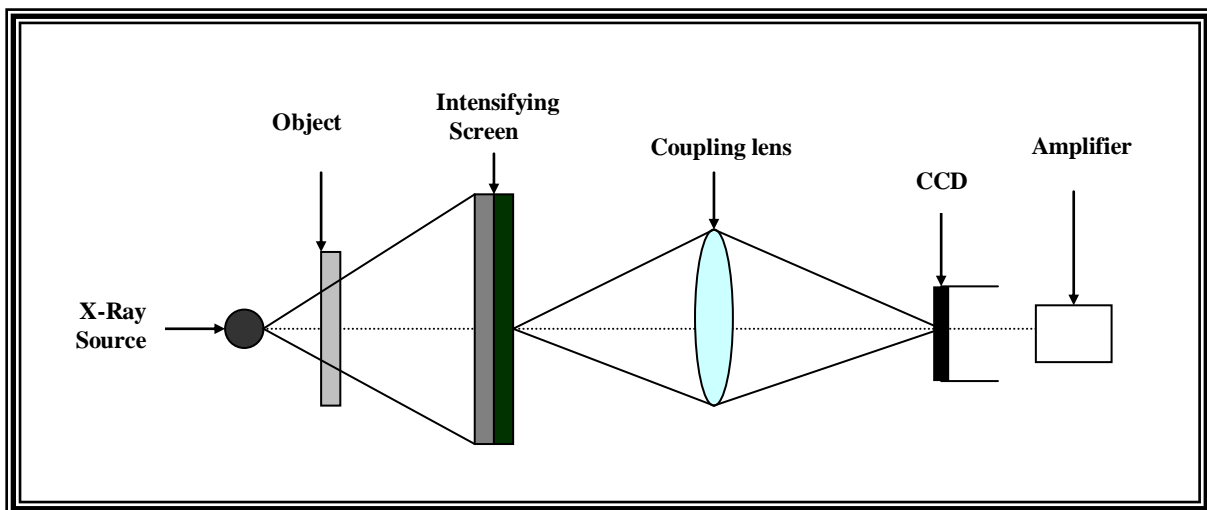
### Introduction

In the medical imaging and other similar applications including industrial x-ray inspection, X-ray imaging detectors (such as a charge coupled device (CCD) may produce variation in both intensity and position, this will causes displaying random manner spots that degraded the images. A number of advancements for X-ray inspection systems have recently been implemented in the image presented to the operator [1]. One of the identified problems of retrieval is that a large part of the images does not contain any important information for retrieval but rather noise [2]. Motion correction of coronary X-ray images can help sharpen image results. For example, to minimize the effects of breathing and heart pumping (cardiac-respiratory cycle) during imaging [3].

The originality of the hit noise is that some x-ray photons penetrate through or get around the converting screen (i.e. dose not converted all the x-ray photons to the visible light). Then this penetrated x-ray photos strike the light sensitive array, where this portion of the x-ray photons when strike the light sensing array will create a signal in the array, which will be much larger than that of a visible light photon due to the much higher energy of the x-ray photons [4]. The result is a bright (white) spots in some locations on the resulted image, which look like a salt has been shaken onto a photograph. So that the generic name for this type of noise is (salt noise).

In those detectors (i.e. CCD) where white spots are a problem, many means are usually used to reduce the likelihood of the unwanted

x-rays striking the detectors. One such means is to add shielding in the form of lead or other high-atomic number material to block scattered radiation from striking the detector while allowing the visible light to strike the detector. These means typically add cost and complexity to the overall detectors system. After the image has been captured, image processing is applied to remove the offending spots. It is remarkable comment on the advance of technology. For our purpose, this study discuss the steps require to reducing noise, where the image enhancement operations are perform after the basic image has been formed.



*Fig. (1): CCD x-ray detector.*

### Digital Image Smoothing Filters

There are many filters, which could directly apply to enhance the noisy images as, follow:

#### a) Minimum filter

The minimum-filter selects the smallest value within the ordered of smoothing window of pixel values [5].

#### b) Mean filter

The mean filter technique operates by reducing the statistical fluctuations in each pixel by averaging the pixel with its closest neighbors. Mean-filter can be implemented directly to replace the image pixel values  $I(i,j)$  by their mean values  $\bar{I}(i,j)$ , over sliding window [5,6].

#### c) Median filter

This filter replaces the gray level of each pixel by the median of the gray levels in a neighborhood of that pixel. Recall that the median  $M$  of a set of values is such that half of the values in the set are less than  $M$  and half are greater than  $M$ . In order to perform median filtering in a neighborhood of a pixel must be sort the values of the pixel and its neighbors, then determine the median, and assign this value to the pixel. For example, in a  $3 \times 3$  neighborhood the median is the 5th largest value [5,7]:

$$\begin{bmatrix} 20 & 40 & 15 \\ 25 & 70 & 10 \\ 90 & 55 & 85 \end{bmatrix}$$

First sort the values in order set as follow:

$$10, 15, 20, 25, \underline{40}, 55, 70, 85, 90$$

Here the median value is (40).

#### d) Mode filter:

Mode-filter is another example of the smoothing filters in which the window's central pixel value is replaced by the point's value of the greatest repeated in the sliding mask. The mode filter is defined in the same way as the median filter, but instead of taking the median of the pixels in a neighborhood, that take the value of highest repetition in the sliding mask. A definite disadvantage of the mode filter is that it need not be unique, as is illustrated by the following data [8]:

$$1 \ 2 \ 3 \ 6 \ 3 \ 4 \ 9 \ 8 \ 5 \ 8$$

Here 3 and 8 both occur with the highest frequency (The fact that there is more than one mode is sometimes an indication that the data are not homogenous, that is, they constitute a combination of several sets of data). Another disadvantage of the mode filter is that if on two values are alike, the mode does not exist [8].

### Fidelity Criteria

To measure the quality of the results images that has been obtained by applying enhancement techniques the following measurements can be adopted.

**a) mean and variance**

The mean ( $\mu$ ) of a set of values is its statistical average, such that, if I represents a set of N values the mean can be written as:

$$\mu = \frac{1}{N} \sum_{i=1}^N I_i \dots\dots\dots(1)$$

The mean of a set of values locates only the average value [9]. It is helpful to know how much the data varies from its mean. The variance  $V^2$  of a random variable I with expected value  $\mu$  is given by:

$$V^2 = \frac{\sum_{i=1}^N (I_i - \mu)^2}{N - 1} \dots\dots\dots(2)$$

The smallest value of  $V^2$  can be assumed is zero, and that would occur if all the I-samples take the same value. When the variation between the samples increase, the variance will be increased.

Since the variance is expressed in square units, more useful value is the square root of the variance, which is expressed in units, and can be related back to the original values [9]. The standard deviation (STD) of a random variable I is the square root of the variance as follows:

$$STD = \sqrt{\frac{\sum_{i=1}^N (I_i - \mu)^2}{N - 1}} \dots\dots\dots(3)$$

**b) Signal to Noise Ratio (SNR)**

Signal-to-noise (SNR) measures are estimates of the quality of a reconstructed image compared with an original image. The basic idea is to compute a single number that reflects the quality of reconstructed image [10]. The amount of useful image information (signal) compared to non-useful information (noise). In digital x-ray systems, as noise decreases, or SNR increases, object detectability increases very rapidly [11]. Calculation of the Signal-to-Noise Ratio (SNR) defined as the mean over the standard deviation [9];

$$SNR = \frac{\mu}{STD} \dots\dots\dots(4)$$

**c) Normalize Root mean square error (RMSE)**

The comparison between a source image that contains (N×M) pixels and the processed

or noisy image gives one measure of quality, however, the error between the two images is easier to compute by using the parameter (NRMSE).

First we compute the normalized mean squared error (NMSE) of the processed or noisy image that has (N×M) pixels as follows [10,12]:

$$NMSE_1 = \frac{1}{N \times M} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \frac{(\hat{I}_{(i,j)} - I_{(i,j)})^2}{255} \dots\dots(5)$$

$\hat{I}$ = the original image

I= the processed image

In this work a new criteria has been suggested, this measure compute NMSE between pdf of histogram region in original image and processed image this given by :

$$NMSE_2 = \frac{1}{256} \sum_{i=0}^{256} [pdf_1(i) - pdf_2(i)]^2 \dots\dots\dots(6)$$

Where pdf = is the probability density function of the image.

The summation is over all pixels. The normalized root mean squared error (NRMSE) is the square root of NMSE:

$$NRMSE = \sqrt{NMSE} \dots\dots\dots(7)$$

Typically the NRMSE values range between (0) and (1).

**Results**

As it has been mentioned previously, Four smoothing filters have been adoptive to reduce the hit noise in the x-ray Image. It should be noted that all these mentioned filters have been perform by utilizing a smoothing window of size (5×5).

One image have been adopt to demonstrate the smoothing effects, this is:

**x-ray Chest image:** have size (256×256) and grays ranged between 0 (dark) to 256 (bright). The generation noise of this image produced two images with noise ratio 0.01 and 0.02, respectively.

The results obtained by perform each of smoothing filters are demonstrated as follows:

Fig.(1) represent, chest x-ray images (i.e. the original, noisy, and the smoothed images) smoothed by window of size (5×5).

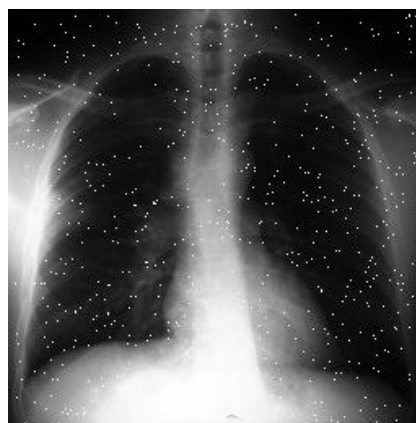
The histograms of the original and smoothed x-ray chest image are shown in Fig.(2). The histograms results are for original and filtered images that have noise (0.01).

Threeomogenous regions have been selected to compute the mean ( $\mu$ ) and signal-to-noise ratio (SNR), for each image region within all original, noisy (0.01), and filtered images. These values have been used to judge

the performance of the adopted filters, by comparing the results of the noisy and filtered images with that of the original image. An optimum filter is pronounced which give highest SNR values, and preserved  $\mu$  values constant. Another quality test has been carried on the selected regions of all noisy and filtered images to demonstrate the performance of the adopted filters; i.e. the normalized of root mean-square-error (NRMSE<sup>1</sup>- NRMSE<sup>2</sup>). The results of the above mentioned tests are tabulated in Tables (1).



*Original image*



*Noisy image (0.01)*



*Minimum filter*



*Mean filter*

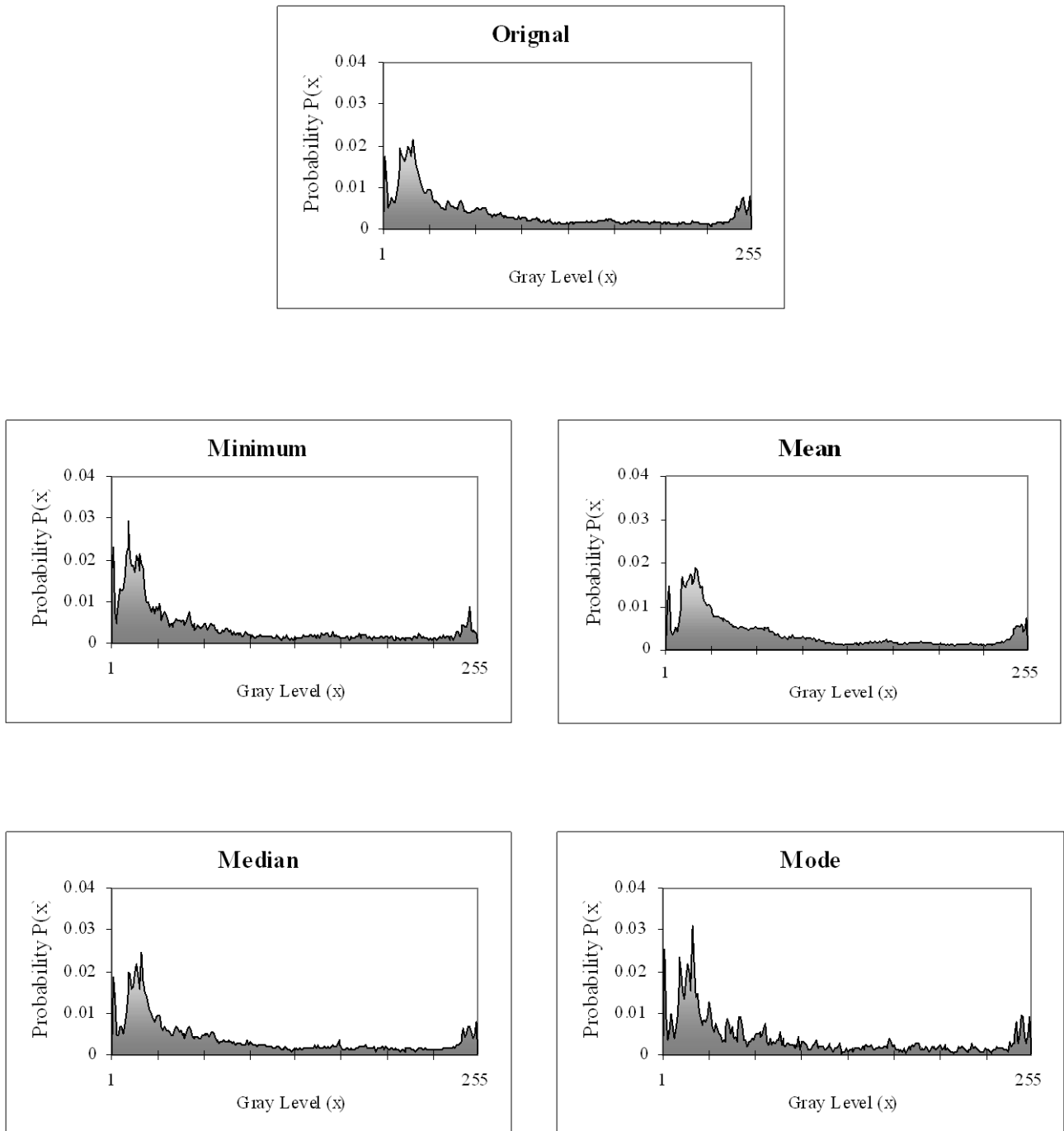


*Median filter*



*Mode filter*

**Fig. (1) :Original, Noisy (0.01) and smoothing images for chest image.**



*Fig. (2) : Histograms of original chest image and their smoothed Images.*

*Table (1)*  
*Mean, SNR, NRMSE1 and NRMSE2 obtained for chest image with noise ratio (0.01), by different smoothing filters, using window of (5 ×5).*

Original image		
Region	$\mu$	SNR
DARK	12.06	4.36
GRAY	151	5.9
BRIGHT	251	108

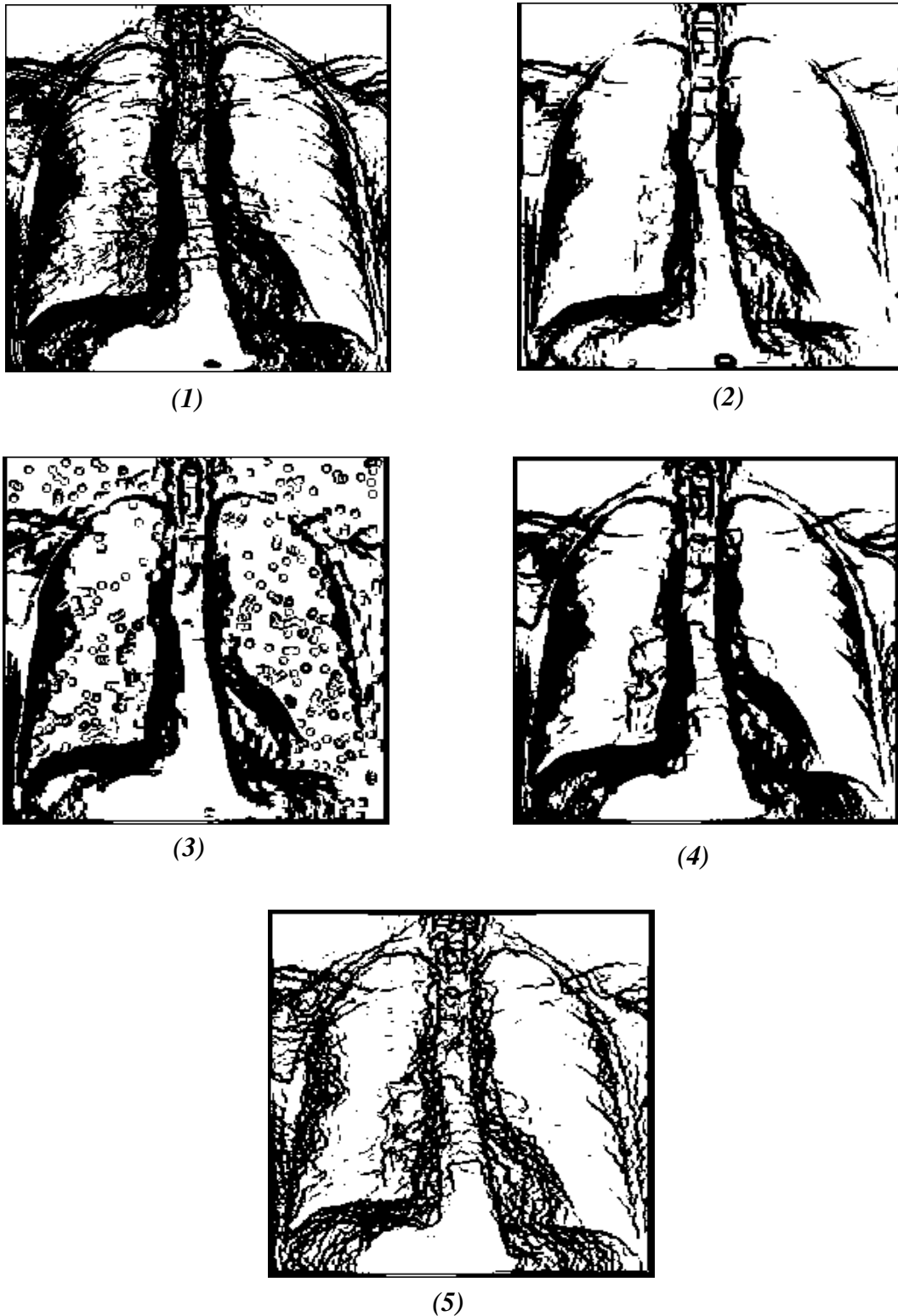
Minimum filter				
Region	$\mu$	SNR	NRMSE <sub>1</sub>	NRMSE <sub>2</sub>
DARK	9	4	0.01447	0.0168
GRAY	137.5	5.26	0.0584	0.00415
BRIGHT	247	93.35	0.0084	0.01483

Mean(box) filter				
Region	$\mu$	SNR	NRMSE <sub>1</sub>	NRMSE <sub>2</sub>
DARK	15	2.78	0.2257	0.00826
GRAY	152	6	0.0152	0.00328
BRIGHT	251	114.6	0.00336	0.00567

Median filter				
Region	$\mu$	SNR	NRMSE <sub>1</sub>	NRMSE <sub>2</sub>
DARK	12	4.4	0.0075	0.00658
GRAY	151	5.9	0.013	0.00168
BRIGHT	251	108	0.00388	0.0026

Mode filter				
Region	$\mu$	SNR	NRMSE <sub>1</sub>	NRMSE <sub>2</sub>
DARK	12	4.2	0.0072	0.0068
GRAY	150	5.28	0.0244	0.0042
BRIGHT	250	106	0.0035	0.0022

Fig.(3) demonstrate the edges case after applying of depended filters, where the edges detected by sobel operator.



*Fig. (3) : Results of edge detection (sobel operator) for :  
(1) original image. (2) result of minimum filter .  
(3) result of mean filter. (4) result of median filter. (5) result of mod filter.*

## Discussion

### a) Tables Conclusion

According to the quantitative measures given in Table (1), in which the mean, the signal-to-noise ratio, and the normalized root mean square error of the homogenous regions were examined, the adopted filters can be discussed as follows;

- **Minimum filter:** This filter gave smaller signal-to-noise ratio, and smaller mean values for all homogenous regions than that of the original and author smoothed images. However, this filter produces a high normalized root mean square error (NRMSE<sub>1</sub> and NRMSE<sub>2</sub>).
- **Box (mean) filter:** This filter gave a high signal-to-noise ratio but less than that of the original image. Whereas the mean values was not preserved, it's few higher than that of the original image. This filter produce a high NRMSE<sub>1</sub> and NRMSE<sub>2</sub> than that of all smoothed images.
- **Median filter:** This filter gave highest signal-to-noise ratio for all homogenous regions with conserved mean values, approaches to those obtained in the original image. Also, this filter produced small NRMSE<sub>1</sub> and NRMSE<sub>2</sub> in all regions compare with that of the author smoothed images.
- **Mode filter:** This filter gave mean values, and signal-to-noise ratio approaches to that of median filter or may be slightly smaller. But the results of NRMSE<sub>1</sub> and NRMSE<sub>2</sub> are higher than that of median filter.

### b) Histograms Conclusion

From the image histograms shown in Fig.(2), for the original, noisy, and soothed images, respectively, we can conclude the following:

The chest image histograms have continuous range of gray-level values also we can see that the main peak in the original chest image in the dark region.

Comparing the image histograms of smoothed images with that of the original image, it can be seen that;

- **Minimum filter:** The produced image histogram by this filter, shows that the main peak is slightly deviated toward the dark side, and the probability of the tails value of this filter is higher than that of original image.
- **Box (mean) filter:** When we perform this filter on the noisy image, we have seen that the main peak is slightly deviated toward the bright side. Moreover, the probability of the tail values is decreased to smaller value compare with that of the original and author smoothed images.
- **Median filter:** The image histogram of this filter is very similar to that of the original image, so that we can see a better smoothing performance is achieved when this filter is implemented on the nosy image.
- **Mode filter:** The image histogram of this filter will create a secondary and sharp peaks along histogram range, and the main peak of this filter is higher than that of the original image.

## Conclusion

The methods used for noise removal that apply on the x-ray image are simple and represent effective filtering techniques.

The median filter smoothes hit noise, while maintaining edge information, but the mean filter image is a blurred version of the noisy image .All methods of smoothing x-ray noisy image sacrifice some resolution in the process of smoothing the image.

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### الخلاصة

في نظام التصوير لدينا مشاكل من ظهور نقاط الإضاءة المستطارة. عادة يكون الحل لتقليل هذه الضوضاء ممكن أن يكون عن طريق زيادة التعرض، لكن هذا صعب جدا لمنع هذه الضربات. في هذا البحث لدينا خوارزميات لتقليل الضوضاء بدون زيادة التعرض من خلال أربعة مرشحات رقمية لتقليل الضوضاء والمقارنة بي ن هذه المرشحات لتحديد كفاءة كل مرشح. من خلال الصور الناتجة وجدنا إن مرشح الوسيط هو الأفضل حيث ينعم الضوضاء مع الحفاظ على معلومات الحافة، اما صورة مرشح المعدل تكون مشوشة.