



International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS)

www.iasir.net

Noise Removal Methods of Chili Pepper Images for Detecting Toxin Using Neural Networks

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Abstract: Mycotoxins are toxic substances produced mostly as secondary metabolites by fungi that grow on seeds and feed in the field, or in storage. The food-borne Mycotoxins likely to be of greatest significance for human health are Aflatoxin and Fumonisin. Chili pepper is also affected by Aflatoxin contamination during harvesting, production and storage periods. X-ray is a very popular non-destructive testing method. In this proposed work, X-ray images of chilli pepper samples were collected and processed using image processing methods. This research paper gives a review of existing approaches of pre-processing methods compared with the proposed 4-connected median filter. Based on the performance measure analysis the best pre-processing method is selected, to remove the noise presence in chili pepper X-ray images.

Keywords: Aflatoxin, Chili pepper, image enhancement, performance measures of X-ray images, threshold

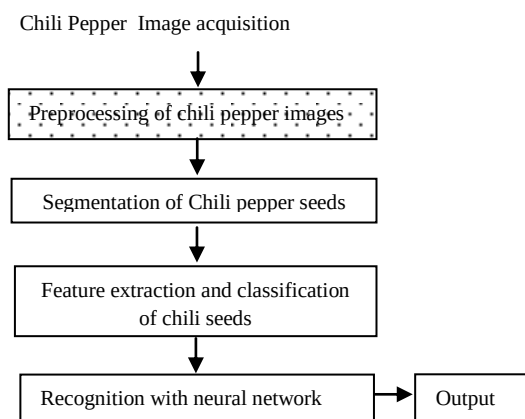
I. Introduction

Accessing high quality and safe food is one of the most important things to the public anxiety in recent decades. Food safety implies that the food includes safe levels of the substances, which does not include toxins and contaminants cause injurious to human health. Food quality includes characteristics such as nutritional value and texture for the food to be preferred by the consumers. Many countries impose strict control on the standards of food contents which directly affect the health and quality. It is essential to all the countries to assure the safety and quality of the imported food to protect their domestic consumers. In addition to the domestic consumers more attention should be given to the safety and quality of export food in the global market [7].

A. Non-destructive methods

Non-destructive methods are a part of quality control function and complementary to other established methods to maintain better quality of the products. Non-destructive testing is the testing of materials in the surface or internal faults or to find purifying and alloying metals condition, without interfering in any way with the reliability of the material or its suitability for service. This method is suitable for testing the sample units individually or the entire production units for the quality control centre. Due to development of high technology and evolution of equipments, huge quality control applications in the lead-time of production sectors. To facilitate production the application of this method requires certain degree of skills to obtain more information about the manufactured product. To improve the product requires consequent feedback from the quality control centre [7]. After the detailed study of the previous researches, the proposed system is as follows in fig1.

Fig. 1. Proposed system



B. Pre-processing

The objective of pre-processing is to improve the quality of the image and make it ready for further processing by removing the irrelevant noise and unwanted parts in the background of the X-ray image. In an input image, the neighbours of a pixel are used to get a new brightness value in the output image. The majority of pre-processing operators work in square windows among 3*3, 5*5, 7*7 or 9*9 are most common [19].

The window size and shape may vary depend upon the researcher and nature of the research problem. To provide better results, most homogeneous neighborhood of each pixel is to be detected. But this is not common for all, because of computational demands and lack of a unique approach. A recent approach to image pre-processing introduces the concept of an adaptive neighborhood determined for each pixel in the given image. The selection of window size and shape are depending upon the noise presence in the image. Neighbors of each pixel have the ability to tune it based on their contextual details in the image [18].

C. Data set

For the proposed research work, 25 chilies were collected from the village near Salem district, Tamilnadu. The collected chilies were kept in a plastic container to maintain the humidity level up to 60 days. After 40 days, some fungus was formed on the surface of most of the chilies. The surface, color and thickness of these chilies are also affected. But remaining chilies are not affected by the fungus.

In the proposed research work the vidisco digital X-ray system was used to take the x-ray images of chili pepper. The type used is HDR/1 with the frequency of 433.920 MHz and maximum power is less than 10mW. By using this system, 25 images of chili pepper were taken for noise removal purpose. The fungus formed chilies x-ray images were looked like very noisy, while, other chili images were good and less noisy.

II. Methodology

In the proposed work, the background of the image is removed by applying thresholding method. After that several pre-processing methods are applied, namely Average filter, Median filter, Adaptive filter, Gamma intensity correction, Contrast-limited adaptive histogram equalization (CLAHE) and the proposed 4-connected median filter. Performance measures of all these methods are evaluated at the end.

A. Image thresholding

Image thresholding divides the pixels into two classes i.e., to which the measure from the image falls below a threshold, and those at which the measure equals or exceeds a threshold value.

In fixed thresholding, a single threshold value is kept constant throughout the image. It assumes that, to determine a single threshold value which treats each pixel independently from its neighborhood [23]. Fixed thresholding is of the form:

$$g(x, y) = \begin{cases} 0 & f(x, y) < T \\ 1 & f(x, y) \geq T \end{cases}$$

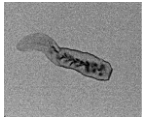
This technique works based on the gray level lies within a certain range belong to one class, while remaining into another class. This method neglects all of the spatial information of the image. This method is not suitable when the image has more noise or blur. For X-ray images, thresholding usually involves selecting a single gray level value from an analysis of the grey-level histogram, for segmenting the histogram into background and chili pepper image. All the pixels with grey level value less than the threshold are marked as background and the rest as chili pepper image. After segregation there are overlapping found in between the chili pepper image and the background [5].

In the proposed work, background of the x-ray image is removed using image thresholding method. After applying this, image enhancement has to be performed.

Few samples an image on which thresholding is applied are:

Table 1. Images after thresholding

S.no	Original Image	Thresholded Image
1		

2		
3		
4		

B. Image enhancement

Sometimes images obtained from conventional digital cameras lack in contrast and brightness because of the illumination conditions while capturing image. Each image may have different types of noise. To remove this kind of noise, image enhancement is adopted. Image enhancement is a technique which processes the original image and produces the result image such that the result is much more suitable for a specific application. It upgrade the pixels of an image into better level. Several enhancement techniques are there to improve the pixels of an image. Image enhancement technique is used for extracting feature, analyzing the image and displaying an image. Image enhancement process does not increase the information content but improves certain specific image characteristics. Image enhancement algorithms are interactive and specific to a particular application [10].

(1).Average filtering

Average filtering is the default filter type, used to remove the noise in an image. The output pixel value is calculated by simply taking the average of the cells in the filter window. Average filter allows few of the higher frequency features with changes, and allows low frequency features to be unchanged. The averages of the cells are calculated by using the following formula.

$$h[i,j] = \frac{1}{M} \sum_{(k,l) \in N} f(k,l) \quad \text{----- (1)}$$

where M is the total number of pixels in the neighborhood N [16].

Smoothing performed by this filter is useful or not is depend upon the nature of the input image. If the noise level rises, then the overall image quality may decrease or else the image quality may acceptable. While performing the smoothing operation, edges of an image, information and contrast were reduced up to some extent [24].

(2). Median Filtering

Some images contain brighter or darker cell values, which is represented as noise and they removed by further processing. Noise reduction process introduces several approaches to removing noise in an image. The median filter orders input pixel values from the current filter window and assigns the middle value to the output pixel value [11]. Median value is not affected by the original value of the noise cells, the Median filter is particularly good at removing isolated random noise and it is calculated by using this formula [6].

$$f(x,y) = \text{median}_{(s,t) \in S(x,y)} \{g(s,t)\} \quad \text{----- (2)}$$

Median filtering produces better results than the average filter by preserving edges and other features. Median filtering is therefore better able to remove this outlier without reducing the sharpness of the image [4]. Here, Salt and pepper noise inputted to improve the performance.

(3).Adaptive Filtering

The adaptive filter is more selective than the other linear filters by preserving edges and other high frequency parts of an image. In addition, there are no design tasks for filtering, the wiener filter performs all preliminary calculations, and implements the filter for an input thresholding image. Wiener filter works best when the noise is constant-power additive noise, such as Gaussian noise [3].

The goal of the Wiener filter is to filter out noise that has corrupted the original image. Wiener filter work is based on a statistical approach. Distinctive filters are designed for a desired frequency response. Wiener filters are characterized by the following assumption that the signal and (additive) noise are stationary linear random processes with known spectral characteristics. Where the variance is large, Wiener performs little smoothing. Where the variance is small, Wiener performs more smoothing [13]. Estimate the local mean and variance in the neighborhood around each pixel by using the following formulas.

$$\mu = \frac{1}{M} \sum f(x, y)$$

$$\sigma^2 = \frac{1}{MN} \sum [f(x, y) - \mu]^2$$

Wiener filters formulation, without blur is as follows:

$$w(x, y) = \mu + \frac{\sigma^2 - n_v^2}{\sigma^2} [f(x, y) - \mu] \text{ ----- (3)}$$

Where M is the total number of pixels in the neighborhood N and n_v is the standard deviation for noise [22].

(4).Gamma intensity correction

Gamma intensity correction produces accurate image display on a computer screen. Gamma correction method corrects the overall brightness of a given noisy image. Noisy images which are not properly corrected by gamma intensity correction can look like bleached out, or too dark. To reproduce colors accurately, it requires knowledge of gamma correction. While changing the value of gamma correction, it affects not only the brightness of an image, but also the ratios of red to green to blue [21]. Gamma intensity correction procedure modifies the pixels value based on the equation:

$$I_{\square} = c I^{\gamma} \text{ ----- (4)}$$

Where I and $I_{\square}$ are the original and enhanced images and c is a scaling factor. Gamma values lesser than 1 improves light areas and values greater than 1 improves dark areas of the original image after the conversion is performed [1].

(5).Contrast-limited adaptive histogram equalization (CLAHE)

CLAHE works on a small part in the image called partitions, instead of the whole image. Each partitions contrast is increased, so that the histogram levels of the output region approximately matches the histogram level specified by the distribution parameter. The neighboring partitions are then combined using bilinear interpolation to avoid artificially caused boundaries. In homogeneous areas, the contrast is limited to avoid amplifying any noise that might be present in the image [20].

CLAHE was originally developed for medical imaging and has proven to be successful for enhancement of low-contrast images such as x-ray images and portal films. The CLAHE algorithm partitions the images into contextual regions and applies the histogram equalization to each one. This will evenly spread out the distribution of used grey values and thus makes hidden features of the image more visible. Contrast Limited Adaptive Histogram Equalization, CLAHE, is an improved version of Adaptive Histogram Equalization (AHE). Both overcome the limitations of standard histogram equalization. CLAHE pixel value calculated by using the following formula.

$$g = g_{min} + (2 \times (\alpha^2) \times \log \frac{1}{1-p(f)})^{0.5} \text{ ---- (5)}$$

Where g_{min} is the minimum pixel value, P(f) is the Cumulative Probability distribution Function (CDF) [14].

(6).4-connected median filter

In this four connected median filter the basic approach is taken from the median filter. In a set of values, class has taken by the set of values less than m, half (m) and greater than m. Here the m is taken as mid pixel.

Median filter for the whole image taken by calculating the mid value of the square windows like 3x3, 5x5, and 7x7 was taken for preprocessing. In this proposed research four connected values are taken in the square windows instead of full set of values.

In four connected median filter mid pixel value found by horizontal, vertical neighbours of pixel p i.e., N_4P and Diagonal neighbours of pixel of p i.e., N_DP and original value of that pixel.

N_4P has four horizontal and vertical neighbors, whose coordinates are given by,

(x-1, y), (x, y-1), (x, y+1), (x+1, y) and it is illustrated in fig 2.

Fig 2.4-neighbors of pixel p i.e., $N_4(p)$

	1	
1	1	1
	1	

The four diagonal neighbors of p i.e. $N_D(p)$ have coordinates (x-1, y-1), (x-1, y+1), (x+1, y-1), (x+1, y+1) and it is illustrated in fig 3.

Fig 3. 4-diagonal neighbors of pixel p i.e., $N_D(p)$

1		1
	1	
1		1

The greater value of three numbers viz. the median of $N_4(p)$, $N_D(p)$, and original value of that point p has taken to replace the pixel value of that point p.

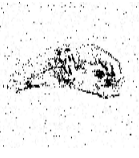
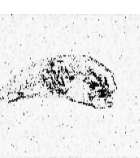
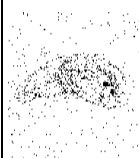
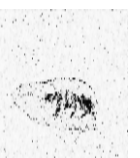
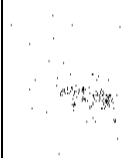
$$\text{Pixel } p = \max \begin{cases} \text{median of } N_4(p)(p) \\ \text{median of } N_D(p) \\ \text{original pixel value of } p \end{cases} \quad \text{---- (6)}$$

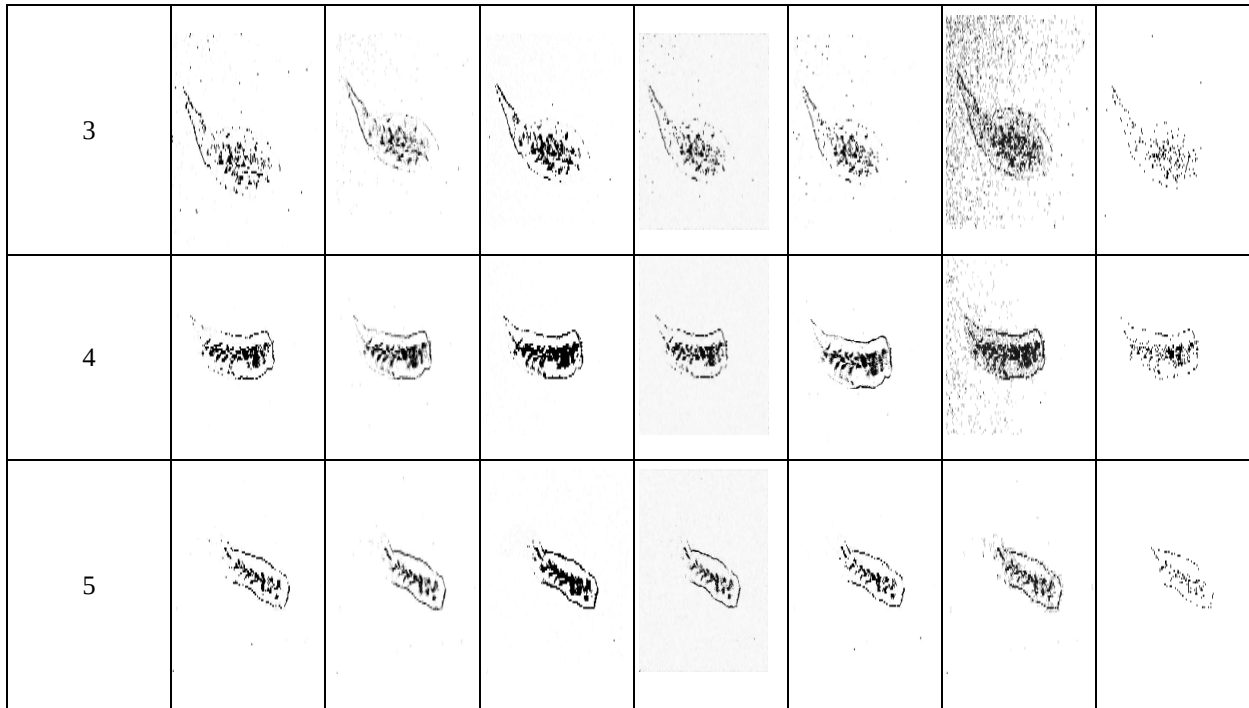
By using the equation (6), the improved median filter was carried over by calculating new pixel value for each pixel. The process was repeated for each and every pixel in the chili x-ray image. Finally the resultant image is evaluated under the performance measures, and proven to be good.

III.Experimental Results and Discussion

Some of the sample images, which are processed using noise removal methods, are shown in the below table 2. After thresholding, the images were less noisy compared with the original image. Threshold images are processed using noise removal methods stated earlier. After that, the background of the images is clear and the inner regions of chili were good. Even though, some of the chili's images are still containing noisy background. To evaluate the best method, apart from prior noise removal method the proposed work carries performance evaluation as follows.

Table 2. Results of noise removal methods on chili images

S.no	Original Image	Average Filter	Median Filter	Adaptive Filter	Gamma Correction	CLAHE	4 - connected Median filter
1							
2							



Peak-signal-to-noise-ratio (PSNR)

Peak Signal-to-Noise Ratio is the ratio between the thresholding image and the filtered image, given in decibels. The higher the PSNR, the closer the filtered image is to the thresholding image. If higher the PSNR it indicates that it is a higher quality image, but tests have shown that this is not true for all images. However, PSNR is a popular quality metric because it is easy and fast to calculate while still giving okay results [15].

$$\text{PSNR} = 10 \log 10 \left\{ \frac{\max(r(x,y))^2}{\frac{1}{n_x n_y} \sum_0^{n_x-1} \sum_0^{n_y-1} [r(x,y) - t(x,y)]^2} \right\} \quad \text{----- (7)}$$

where $r(x, y)$ represents the original (reference) image and $t(x,y)$ represents the distorted (modified) image and x and y are the pixel position of the $n_x \times n_y$ image. Of all the objective quality measures, PSNR which is the most commonly used quality measure which reflects the quality of images approximately. The PSNR of the image lies between 20 dB and 40 dB which indicate that the images are of 'good' acceptable quality [12].

Signal-to-noise-ratio (SNR)

The SNR measures the roughness or granularity of image, and this is independent of the relation between the original signal and background.

$$\text{SNR} = 10 \log 10 \left\{ \frac{\sum_0^{n_x-1} \sum_0^{n_y-1} [r(x,y)]^2}{\sum_0^{n_x-1} \sum_0^{n_y-1} [r(x,y) - t(x,y)]^2} \right\} \quad \text{----- (8)}$$

where $r(x, y)$ represents the original (reference) image and $t(x, y)$ represents the distorted (modified) image and x and y are the pixel position of the $n_x \times n_y$ image.

Root Mean Squared Error (RMSE)

Mean Squared Error is the average squared difference between the thresholding image and the filtered image. It is calculated pixel-by-pixel by adding up the squared differences of all the pixels and dividing by the total pixel count [15]. The mean-squared-error (MSE) is the simplest, and the most widely used, full-reference image quality measurement. This metric is frequently used in signal processing and is defined as follows.

$$\text{RMSE} = \sqrt{\frac{1}{n_x n_y} \sum_0^{n_x-1} \sum_0^{n_y-1} [r(x,y) - t(x,y)]^2} \quad \text{----- (9)}$$

where $r(x, y)$ represents the original (reference) image and $t(x, y)$ represents the distorted modified) image and x and y are the pixel position of the $n_x \times n_y$ image. MSE is zero when $r(x,y)=t(x, y)$ [4].

Mean Absolute Error (MAE)

Mean Absolute Error between two $n_x \times n_y$ digital images 'r' and 't' measures the absolute closeness of these images to each other [17]. It is a linear score which means that all the individual differences are weighted equally in the average and it is calculated by using the following formula as:

$$MAE = \frac{1}{n_x n_y} \sum_{x=0}^{n_x-1} \sum_{y=0}^{n_y-1} |r(x,y) - t(x,y)| \quad \text{----- (10)}$$

Where $r(x, y)$ represents the original (reference) image and $t(x, y)$ represents the distorted modified image and x and y are the pixel position of the $n_x \times n_y$ image.

Table 3. Comparison of quality assessment parameters

Method/Measure	PSNR(db)	SNR	RMSE	MAE
Average Filter	34.8356	13.9795	32.9891	12.7962
Median filter	43.9660	13.9739	36.2320	8.3651
Adaptive filter	29.2060	15.6619	19.0979	13.2794
Gamma intensity correction	Inf	25.4216	0.9165	0.2749
CLAHE	34.0028	14.6569	21.2523	21.2523
4-connected Median Filter	22.4904	22.3001	22.9464	3.6708

Discussion

In this proposed work, different X-ray images of chili pepper were taken for reducing noises. This research work compares various techniques such as Median filtering, Adaptive filtering, Average filtering, Gamma intensity correction, and CLAHE with the proposed 4-connected Median filter. To evaluate the result, performance measures such as Peak signal to noise ratio (PSNR), Signal to noise ratio (SNR), Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE) were calculated using the equations from 7 to 10 between original image and the result of filtering. From the above, 4-connected median filter is producing better results than the other methods. The MAE error value in 4-connected median filter is comparatively lower than the other techniques i.e., value is lesser than 4. Above stated PSNR and SNR value is greater than 20, then the output image is good and suitable, as proved by the previous researches. It is conclude that 4- connected Median filter is suitable for removing noise in chili pepper images.

IV. Conclusion

Through this work, the choice for de-noising the X-ray images of chili pepper depends on the type of noise and type of filtering technique, which are used. Among the preprocessing methods stated above, the results of Gamma intensity correction and 4-connected median filter is considered best in this research. Images obtain in the processing of gamma intensity correction method was found low clarity. At the same time, high image clarity is obtained in the 4-connected median filter. Proposed approach removes the noise in x-ray images. This experimental analysis will also improve the accuracy of x-ray images. This research work concludes that 4-connected Median filter will yield better results than the other methods. The results are more useful and they prove to be helpful for next level proceedings.

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