Performance Evaluation Of Morphology Based Image Reconstruction Using Different Structuring Elements In The Presence Of Noise

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Abstract-* Noise elimination from the medical images sometime causes losing some information from the original image. Thus, it is important to find a way to eliminate the noise and reconstruct the image. In this paper, a morphology based method for eliminating noise from the image and reconstructing an image using different structuring elements in order to get information without any loss, and check for which type of noise, a particular structuring element in the morphology suits better is proposed. Four types of noises, such as Salt & Pepper, Speckle, Gaussian and Poisson and four types of structuring elements, such as diamond, disk, line and square are used. The evaluation process involves with calculation of the correlation value, peak signal to noise ratio, and mean absolute error co-efficient for different structuring elements and for all the four types of noises and finding for which type of noise the proposed morphology suits better.

I. INTRODUCTION

Edge detection is one of the most commonly used operations in image analysis. An edge is defined by a discontinuity in grey level values. In other words edge is the boundary between an object and the background. The shape of the edges in images depends on many parameters: the geometrical and optical properties of the object, the illumination conditions, and the noise level in the image [1]. Medical image detection is an important work for object recognition of the human organs such as lungs, brain and ribs, and it is an essential pre-processing step in medical image segmentation. The work of the edge detection decides the result of final processed image [2]. In real world applications, acquired medical images contain object boundaries and object shadows and noise. The processing to be applied depends on the content which one desires to extract. Therefore, a frequent problem in low-level vision arises to eliminate and suppress the noise and other unrelated detail from the degraded image, without degrading the regions of interest.

II. REVIEW OF PREVIOUS WORK

In the past two decades several algorithms were developed to extract the contour of homogenous regions within a digital image. Edge detection being a crucial part a lot of interest and attention is focussed on most of the algorithms. L.J.Spreeuwers and F.vander Heijden [3] evaluated the performance of edge detectors using average risk with arbitrary test images which estimates the probabilities on different types of errors. Mike Heath et al. [4]has made comparison of four edge detectors describing a new frame work which allows to make quantitative comparisons using subjective ratings made by people using experimental procedure and statistical methods borrowed from psychology. Tuba Sirin et al. [5] made evaluation of competitive learning algorithms for edge detection enhancement using a two stage edge detection algorithm involving clustering (segmentation) followed by an edge detector and concluded that the performance of two stage algorithm is superior to one stage algorithm. Shin.M.C et al [6] presented an evaluation of edge detector performance using structure from motion task and concluded that canny detector had the best test performance. Mohesen Sharifi et al. [7] introduces a new classification of most important and commonly used edge detection methods namely ISEF, Canny, Marr-Hildreth, Sobel, Kirsch and Lapalcian. Raman Maini and J.S.Sohal [8] evaluated the performance of Prewitt edge detector for noisy images and concluded that Prewitt operator works quite well for images corrupted with Poisson noise.M.Roushdy [9] made a classified and comparative study of edge detection algorithms using morphological filter.

III. IMAGE SEGMENTATION

The first and foremost step in image analysis generally is to segment the image. Segmentation process subdivides an image into its constituent parts or objects. Segmentation should stop when the objects of interest in an application have been isolated [14]. In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels). The goal of segmentation process is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is done in two ways, edge-based and region-based. Edge based segmentation works by detecting discontinuities in the image and uses those discontinuities as the outline of each segment. Region-based segmentation works by grouping similar-valued adjacent pixels in an image.

A. Classification Of Edge Detectors

Edge detectors are classified in to five categories as follows [7]:

Gradient edge detectors: Which contains classical operators and uses first directional derivative operation? It includes algorithms such as : Sobel(1970), Prewitt(1970), Kirsch(1971), Robinson(1977), Frei-Chen(1977), Deatsch and Fram(1978), Nevatia and babu(1980), Konomopoulos(1982), Davies(1986), Kitchen and Malin(1989), Hacock and Kittler(1990), Woodhalland Linquist(1998), and Young-won and Udpa(1999) [1,10,11] **Zero crossing:** Which uses second derivative [12] and includes laplacian operator and second directional derivative.

Laplacian of Gaussian (LOG): This was invented by Marr and Hildreth (1980) who combined Gaussian filtering with the Laplacian. This algorithm is not used frequently in machine vision. Those who continued his way were Berzins (1984), Shoh, sood and Jain (1986), Huertas and Medioni (1986) [12, 11].

Gaussian Edge Detectors: This is symmetric along the edge and reduces the noise by smoothing the image. The significant operators here are canny and ISEF (Shen-Castan) which convolve the image with the derivative of Gaussian for Canny and ISEF for Shen-Castan. [11,12].

Colored Edge Detectors: Which are divided into three categories output Fusion methods, Multi-dimensional gradient methods and vector methods [13].

B. Advantages And Disadvantages Of Edge Detectors [1,8,12,14]

It is always important to choose edge detectors that fit best to the application. In this respect some advantages and disadvantages of algorithms within the context of our classification are.

Advantages

- The operator which uses first derivative such as Sobel and Prewitt are very simple to detect edges and their orientations.
- Lapalcian of Gaussian uses second derivative, finds exact location of edges and tests wider area around the pixel.
- The other Gaussian edge detectors such as Canny, Shen-Casten use probability for finding error rate. They have better detection in the noise conditions as they are symmetric along edges and reduce noise by smoothing the image.
- Colour edge detectors are more accurate in object recognition

Disadvantages

- First derivative operators have inaccurate detection sensitivity in the presence of noise.
- The LOG cannot find edge orientation as it uses Laplacian filter and cannot respond correctly at corners where the intensity function varies.
- Other Gaussian edge detectors include complex computations and are time consuming.

Colour edge detectors are complex to compute.

IV. IMAGE NOISE [15]

Noise represents unwanted information which deteriorates image quality. Noise is defined as a process (*n*) which affects the acquired image (*f*) and is not part of the scene (initial signal – *s*). Using the additive noise model, this process can be written as:

$$f(i,j) = s(i,j) + n(i,j) \quad (1)$$

Digital image noise may come from various sources. The acquisition process for digital images converts optical signals into electrical signals and then into digital signals and is one processes by which the noise is introduced in digital images. Each step in the acquisition process may introduce random changes into the values of pixels in the image. These changes are called noise. Deliberately corrupting an image with noise allows us to test the resistance of an image processing of various noise filters. Noise is generally grouped into two categories – independent noise and image dependent noise.

A. Image Data Independent Noise:

This type of noise can be described by an additive noise model, in this the recorded image i(m, n) is the sum of true image t(m, n) and the noise n(m, n) .The noise is often zero mean and described by its variance. In fact the impact of noise on the image is often described by the signal to noise ratio. In many cases additive noise is evenly distributed over the frequency domain and is dominant for high frequencies and generally referred as **Gaussian noise**.

B. Image Data Dependent Noise:

a. Poisson Noise:

This is due to nonlinear response of the image detectors and recorders. The image data dependency arises because detection and recording processes involve random electron emission having a Poisson distribution with mean response value [16] .Since the mean and variance of a Poisson distribution are equal; the signal dependent term has a standard deviation if it is assumed that the noise has unity variance. it is assumed that the noise has unity variance.

b. Detector Noise:

The detector noise is the type of Gaussian noise that occurs in all recorded images to some extent. This kind of noise is due to the discrete nature of radiation, i.e., due to the fact that each imaging system is recording an image by counting photons. With assumptions this noise can be modelled with an independent, additive model, where the noise has zero-mean Gaussian distribution described by its standard deviation or variance. [17].

c. Speckle Noise:

Another noise is speckle noise is also referred as data drop out noise. In fact it is caused by errors in data transmissions [18]. The corrupted pixels are either set to the maximum intensity, it is something like a snow in image or have single bits flipped over.

d. Salt & Pepper Noise:

This type of noise is also caused by errors in data transmission and is a special case of data drop-out noise when in some cases single pixels are set alternatively to minimum or to the maximum value giving the image a salt and pepper like appearance [19]. This noise is usually quantified by the percentage of pixels which are corrupted.

C. Noise reduction [20]:

Digital images are prone to a variety of types of noise. There are many ways that noise can be introduced into an image; it depends on how the image is generated. For example: If the image is scanned from a photograph made on film, the grains on the film are a source of noise. Noise can also introduced by the scanner or it may result due to the damage to the film. If the image is acquired directly in a digital format, the mechanism for extracting the data (such as a CCD detector) can produce noise. Electronic transmission of image data can introduce noise. Image noise elimination (reduction) is the process of removing noise from the image. In general noise reduction techniques are conceptually very similar regardless of the type of signal being processed, but having the prior knowledge of the characteristics of an expected signal can mean the implementations of these techniques vary greatly depending on the type of signal. In practice a lot of methods are used to eliminate the noise from the image and a lot of filters are used. Table 1 shows a summary of some filters which are used to eliminate the noise and the results after using these filters was compared with the proposed methodology in this work.

Table I: Standard Filters

Value	**Description**
Averaging	Averaging filter
Gaussian	Gaussian low pass filter
Laplacian	Filter approximating the two-dimensional laplacian operator
Sobel	Sobel horizontal edge-emphasizing filter
Prewitt	Prewitt horizontal edge-emphasizing filter
LoG	Laplacian of Gaussian filter
Unsharp	Unsharp contrast enhancement filter

V. PROPOSED APPROACH

The approach is mainly based on the Morphology based image reconstructing from the segmented image obtained from the noise added image of original CT lung image. For the morphological operations different structuring elements are used and the performance of different structuring elements on different noises is examined based on calculating certain parameters. The step-wise procedure of the proposed approach is as follows.

Step 1: Read the CT LUNG image.

Step 2: Noise is added to the original image.

Step 3: Image segmentation - Perform Edge detection on the noise added images by applying Sobel operator.

Step 4: Use the gradient magnitude function as the segmentation function

Step 5: Use different Structuring Elements to probe an image with a small shape or template.

Step 6: Perform Morphological operations like - opening by reconstruction.

Step 7: Perform closing by reconstruction.

Step 8: Compliment the input image (from step 7) and reconstruct image (from step 6).

Step 9: Reconstruction is performed to extract the original image.

Step10: Calculate correlation coefficient, PSNR and MAE between original image and the reconstructed image (from step 9).

The evaluation process includes finding the parameters between the original lung image and subsequently reconstructed image from the noise added image using different structuring elements of the morphology and later reconstructing to extract the original image.

A. Cross Correlation: [20]

A standard means of estimating the degree to which two series are correlated is cross correlation that can be computed using equation (2).

$$r = \frac{\sum_i [(x(i) - m_x * (y(i-d) - m_y)]}{\sqrt{\sum_i (x(i) - m_x)^2}\sqrt{\sum_i (y(i-d) - m_y)^2}}$$

(2)

B. Peak-Signal to Noise Ratio [20]

Objective Fidelity criteria to estimate the quality of the image after denoising is an objective measure for the quality of a denoised image that would be very useful. A common measure for the closeness of two data sets is the *root mean squared error*, or RMSE. When ground truth is available, the two data sets could be the denoised or approximate image f´(x,y) and the original image, f(x,y). The RMSE value can be calculated by.

$$RMSE = \sqrt{\frac{1}{XY}\sum_{y=0}^{Y-1}\sum_{x=0}^{X-1}[f'(x,y) - f(x,y)]^2}$$

(3)

The RMSE is proportional to the difference between two images. In case if two images are equivalent, it is zero. For the case of additive zero-mean Gaussian noise, the RMSE between the noisy and original images will be exactly equal to the noise standard deviation. Another parameter related to RMSE is *peak signal to noise ratio*, or PSNR, derived from the RMSE, and measured in decibels (dB). This logarithmic measure is computed using equation (4) below where Z-1 is the maximum possible pixel intensity.

$$PSNR = 20\log_{10}\left(\frac{Z-1}{RMSE}\right) dB$$

(4)

C. Mean Absolute Error [20]:

The two parameters, RMSE and PSNR use the *square* of the pixel differences resulting in large errors frequently. For example, a single pixel in error by 10 will have the same contribution as 100 pixels in error by 1. A substitute measure, that aims to improve the potential problem, is the *mean absolute error*, or MAE, calculated using equation (5). The MAE overcomes errors by their magnitude, and is less likely, compared to RMSE, to be biased by occasional large errors.

$$MAE = \frac{1}{XY}\sum_{y=0}^{Y-1}\sum_{x=0}^{X-1}|f'(x,y) - f(x,y)|$$

(5)

VI.EXPERIMENT RESULT AND EVALUATION

Initially CT lung image is added with noises considered. Then the edge of the noise image is detected by using sobel operator. It acts as marker. A mask is created by using noise image. Here closing of noise image acts as mask. Morphological techniques probe an image with a small shape or template called a structuring element. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighbourhood of pixels. Image is reconstructed using Mask and Marker with noise reduction. The entire process is repeated for different structuring Elements and image reconstruction is performed using morphology .The performance of reconstruction process on different Noises for different Structuring Elements is evaluated by using parameters such as Correlation Coefficient, Peak signal to noise ration and Mean absolute error and check for which type of noise a particular structuring element suits better for reducing noise effect. The parameters are obtained between the original image and noise added, segmented and subsequently reconstructed images for different structuring elements.

TABLE.I. PARAMETERS OBTAINED FOR STRUCTURING ELEMENT DIAMOND

Noise	Co-efficient	Value
Salt & Pepper Noise	Correlation	**0.9977**
	PSNR	**32.3729**
	MAE	**0.4765**
Speckle	Correlation	0.9933
	PSNR	27.4382
	MAE	2.3347
Gaussian	Correlation	0.9867
	PSNR	24.6892
	MAE	6.1791
Poisson	Correlation	0.9956

	PSNR	29.3803
	MAE	2.1810

TABLE.II. PARAMETERS OBTAINED FOR STRUCTURING ELEMENT LINE

Noise	**Co-efficient**	**Value**
Salt & Pepper Noise	Correlation	**0.9961**
	PSNR	**30.0894**
	MAE	**0.6765**
Speckle	Correlation	0.9912
	PSNR	26.2726
	MAE	2.3700
Gaussian	Correlation	0.9847
	PSNR	24.0985
	MAE	6.1262
Poisson	Correlation	0.9936
	PSNR	27.8098
	MAE	2.2059

TABLE.III. PARAMETERS OBTAINED FOR STRUCTURING ELEMENT DISK

Noise	**Co-efficient**	**Value**
Salt & Pepper Noise	Correlation	**0.9953**
	PSNR	**29.2264**
	MAE	**0.7733**
Speckle	Correlation	0.9920
	PSNR	26.2426
	MAE	2.0461
Gaussian	Correlation	0.9845
	PSNR	23.8710
	MAE	6.2500
Poisson	Correlation	0.9933
	PSNR	27.5018
	MAE	2.1519

TABLE.IV. PARAMETERS OBTAINED FOR STRUCTURING ELEMENT SQUARE

Noise	**Co-efficient**	**Value**
Salt & Pepper Noise	Correlation	**0.9789**
	PSNR	**22.6898**
	MAE	**1.2204**
Speckle	Correlation	0.9755
	PSNR	20.6353
	MAE	1.9031
Gaussian	Correlation	0.9696
	PSNR	20.4958
	MAE	6.6100
Poisson	Correlation	0.9757
	PSNR	21.5939
	MAE	2.1886

VII. CONCLUSIONS AND FUTURE SCOPE

Since edge detection is the initial step in object recognition the reconstruction of the original image with the help of existing edge detection methods alone may not give good result. There are problems of false edge detection, missing true edges, producing thin or thick lines and problems due to noise etc. In this paper the evaluation of different structuring elements is performed on medical image of CT Lung to reconstruct the original image based on morphology from noisy image after segmentation using Sobel operator. Four types of noises Salt & Pepper, Speckle, Gaussian and Poisson are used and added to the original CT lung image to evaluate. From the tabulated results it can be noticed that for Salt & Pepper noise and for diamond structuring element the proposed morphological approach suits better. From the tabulated results, the structuring element diamond has the better performance i.e., Correlation value is nearer to 1, PSNR is high and MAE is very low. The performance of morphological operations exhibit better performance than other direct operators because of filtering operation introduced in it as pre-processing which can be noticed through visual examination of the resultant images particularly for Lung images. The approach can be used to analyze other type of medical images, which can be taken as future work.

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