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A Restoration Strategy to Extract a Definite Image from Noisy Image in Medical Image Processing System

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ABSTRACT: In the past two decades' image processing technology is playing vital role in the current area of research, this image processing technique is not only implemented in the field of computer technology but also in the field of business statistics, Defence Research and Development, Forensic labs, Medical image processing, etc. The imaging technology in medicine made the doctor to see the interior portion of the body for easy diagnosis, image processing techniques developed for analyzing remote sensing data may be modified to analyze the output of medical imaging systems to get best advantage to analyze symptoms of the patients with ease. This paper is mainly concentrating on commonly encountered problem that is image restoration for medical imaging application. Image restoration is a pre-processing method that suppresses a known degradation. The restoration technique can be defined as the estimation of the original image or ideal image from the observed one by the effective inversion of degradation phenomena through which the scene was imaged". This restoration of image technique will be implemented on the noisy image which is generated in medical images like X-ray, CT, MRI, PET and SPECT have minute information about heart, brain, nerves, etc. These images are corrupted during transmission; Removal of noise is an essential and challengeable operation in image processing, before performing any process, image must be first restored. The main purpose of restoration is to reduce noise which is present in image, this can be done by introducing a new method such as; Medical image smoothing based on Minimum Wiener (mean square error) filtering, Nearest neighbour method. The main purpose of implementing this filtering technique is to get clear image from the noisy image/blurred image.

KEYWORDS: Degradation, Expectation, Fourier Transformation, Image Processing, Image Smoothing, Minimum Wiener Filtering, Nearest neighbourhood method, Reconstruction, Restoration.

I. INTRODUCTION

The removal of noise is an essential and challengeable operation in image processing. Before performing any process, images must be first restored. Images may be corrupted by noise during image acquisition and transmission. Noise and blurring effects always corrupts any recorded image. Impulse noise reduction is an active area of research in image processing. With low computational complexity, a good noise filter is required to satisfy two criteria namely, suppressing the noise and preventing the useful information in the signal. It is more effective in terms of eliminating impulse noise and preserving edges and fine details of digital image. Hence the first and foremost step before the image processing procedure is the restoration of the image by removal of noises in the images. The noise removal is to suppress the noise. The filter can be applied effectively to reduce heavy noise. In order to preserve the details as much as possible, the noise is removed step by step procedure. In any image denoising algorithm, it is very important that the denoising process has no blurring effect on the image and makes no changes or relocation to image edges. There are various methods for image denoising using simple filters, such as; average filter, median filter and Gaussian filters, are some of the common techniques employed for image denoising. These filters reduce noise at the cost of smoothing the image and hence softening the edges. This paper is mainly focusing on two different restoration techniques; Wiener Filter and Nearest Neighbour Filter. This paper represents two new approaches that address two problems that are common in image restoration context for medical image processing.

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1. The problem of regularized image restoration when no prior information about the original image and the noise available. To overcome this type of issues a new paradigm is adopted according to which the required information is extracted from the available data at the previous iteration step. i.e. the partially restored image at each step.
2. Consider the problem of not knowing exactly the point spread function of degradation system. The theory of constraint totals least squares and maximum a posterior estimation is used to derive town on linear filters that address this problem.

II. IMAGE RESTORATION

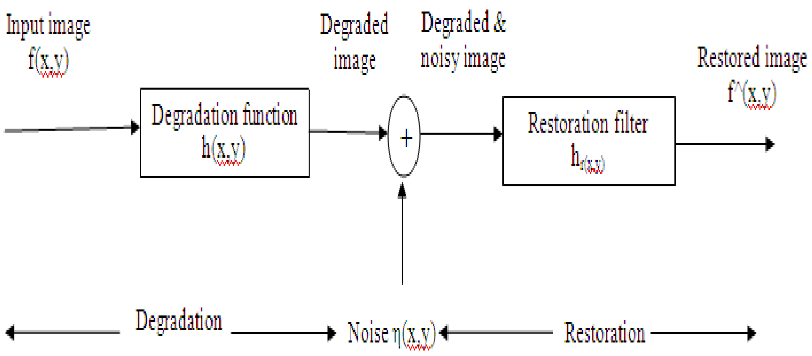
The resolution of an image can be further improved by image restoration, which aims on recovering the original scene from the degraded image observation. By these means, image restoration estimates an inverse filter to compensate for image degradations, including random noise and blurring. Since this process is an ill posed problem, there is no unique solution and a small amount of noise can result in large reconstruction errors. Therefore, restoration methods aim at the modelling the degradation by using a priori knowledge of original scene and Point Spread Function (PSF) as well as noise. The factors the limits the resolution of medical equipment is the fact that they spread the energy of a perfect point source. This blurring phenomenon is captured by point spread function which characterizes each imaging device. Another limiting factor is sensor or photon limited noise that appears in most imaging modalities. Image degradation process can be adequately modelled by a linear space invariant blur and random additive noise. Then the degradation model is described by this mathematical equation which represents degraded and noisy image.

$$G = Hf + \eta$$

Or

$$G(x,y) = h(x,y) * f(x,y) + \eta(x,y)$$

F(x,y) : Original image; g(x,y): degraded and noisy image; h(x,y): degradation function; $\eta(x,y)$: additive noise.



The Degradation and Restoration model

This degraded image can be restored by using following mathematical equation; for this process, inverse filtering techniques are used to extract reconstructed image

$F^\wedge (x, y) = h_R(x,y) * g(x,y)$

$F^\wedge (x, y)$: Restored image; g (x, y): degraded and noisy image; h_R (x, y): inverse filter

Mathematically, image restoration is an inverse problem in which 'f' has to be found from the knowledge of 'g' and 'H'. Image restoration is an ill-posed inverse problem because in most real-life application 'H' has many very small Eigen values. Thus, when the inverse of 'H' is taken to find 'f', these Eigen values result in the amplification of the high frequency noise in 'g' and consequently every noise estimates the obtained image. Regularization is a mathematical approach which has been used in image restoration to ameliorate the effects of the ill-conditioned nature of 'H'. According to this approach, a prior knowledge about the image 'f' and the noise is used in addition to the

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available data. The trade-off between fidelity to the data and satisfaction of the prior constraints is controlled by the regularization parameters.

III. II.1NEED OF IMAGE RESTORATION

In most of the application, denoising the image is fundamental to subsequent image processing operations, various techniques of image processing such as edge enhancement, edge detection, object recognition, image segmentation, object tracking etc., do not perform well in noisy environment. Therefore, image restoration is applied as pre-processing steps. The purpose of various image restoration methods is to smooth out the noisy pixels while maintaining edge features so that there is no adverse effect of noise removal technique on image.

IV. METHODS OF RESTORATION

Image restoration is usually the first step of the entire image processing process; it increases the quality of the image by getting rid of noisy pixels. The restoration of an actually degraded image can be done by writing algorithm, which go on for identifying noisy pixel in the entire image. This paper is mainly focusing the two different methods through mathematical implementation.

V. IMAGE RESTORATION USING NEAREST NEIGHBOURHOOD METHOD

Image restoration using nearest neighbour method need to find out the mean value of all neighbours which come in a mask/window/filter of matrix size 3x3, 5x5, 7x7 and 21x21, by using this mask/window/filter calculated pixel value will be generated which represents the probability of occurrence of each pixel value. The resultant output image is better reconstructed image than the degraded/noisy image. During restoration, the high frequency information of given degraded image is estimated from its low frequency information based on artificial noise. For the restoration problem, a number of techniques are designed corresponding to various versions of the blurring function. The main problem of this technique is, if we want to apply this filter/mask/window to edge pixel values, then we need to add some extra pixels to the image matrix by using padding techniques. This technique will make your image matrix is fully covered with zero value in all the sides of the image matrix and then mask/filter/window will be travelled along each pixel value and we can generate the resultant pixel to the particular position/pixel value that particular pixel value which need to be reconstructed is called “Hot Spot”. The mathematical representation using mask of M x N size matrix for reconstruction of the pixel f(x,y) of m x n size image matrix can be written as,

$$g(x,y) = \sum_{(i,j)\in RH}^{\infty} \left(f(x+i, y+j) w(i,j) \right)$$

0 <= x <= m-1 & 0 <= y <= n-1

R_H denotes the set of pixel/coordinate values converted by mask. The process of performing this restoration by using nearest neighbour filtering, the following steps need to be implemented.

1. Position the mask over the current pixel such that hotspot f (x, y) coincide with mask pixel values.
2. Form all products of filter elements with the corresponding elements in the neighbourhood.
3. Add up the products and store it at current position in the output image.

These steps must be repeated for every pixel in the image. To handle image borders, there is a problem in applying a filter at the edge of the image where the mask partly falls outside the image. This problem can be overcome by using ***padding technique and mirroring technique***, where these two techniques will introduce the extra pixels at the border of the image and another technique is ***ignoring edges***.

Padding:

The input image matrix padded with zero values at the border. This increases the size of input image before applying mask. This gives us all the values for mask overlapping and returns an output image of the same size as the original, but this may cause introducing unwanted artificial values around edges. Consider the hotspot pixel position as f(1,1) with value 4 and apply mask to hotspot which is the border value of image, hence we are applying padding

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technique and the resultant value is generated, then replace original image value with the generated/reconstructed pixel values in the output matrix values.

$$\begin{pmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & \underline{\mathbf{4}} & 7 & 5 & 0 \\ 0 & 6 & 20 & 6 & 0 \\ 0 & 1 & 2 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} * 1/9 \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} = \begin{pmatrix} \underline{\mathbf{5}} & 7 & 5 \\ 6 & 20 & 6 \\ 1 & 2 & 4 \end{pmatrix}$$

Mirroring: A mirror image of the known image is created with the border as mirroring axis, copy the first and last rows and columns so that the mask is overlapped fully to the input image, here in this method the output image size is as same as input image size. Consider the example input image with mirror values of first and last rows and columns values are entered with mirror technique, consider the hotspot pixel position f(1,1) with value 4 and apply mask to the hotspot position which is the border value of image, hence we are applying mirroring technique and the resultant value is generated, then replace original image value with the generated/reconstructed pixel values in the output matrix values.

$$\begin{pmatrix} 4 & 4 & 7 & 5 & 5 \\ 4 & \underline{\mathbf{4}} & 7 & 5 & 5 \\ 6 & 6 & 20 & 6 & 6 \\ 1 & 1 & 2 & 4 & 4 \\ 1 & 1 & 2 & 4 & 4 \end{pmatrix} * 1/9 \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} = \begin{pmatrix} \underline{\mathbf{7}} & 7 & 5 \\ 6 & 20 & 6 \\ 1 & 2 & 4 \end{pmatrix}$$

Ignoring edges: Applying the mask to only that pixel in the image for which the mask lies fully within the image. That means mask is applied to all pixels in the image except for edges which results in an output image that is smaller than that of input image. It may lead to loops of significant amount of information. Consider the hotspot pixel f(2,2) with value 20 which need to reconstructed by using mask and this technique is only applicable for this centre position of the matrix and remaining edge pixel will be neglected, hence those values will remain same without any mask implementation.

$$\begin{pmatrix} \underline{4} & 7 & 5 \\ 6 & \underline{\mathbf{20}} & 6 \\ 1 & 2 & 4 \end{pmatrix} * 1/9 \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} = \begin{pmatrix} \underline{4} & 7 & 5 \\ 6 & \underline{\mathbf{7}} & 6 \\ 1 & 2 & 4 \end{pmatrix}$$

Image Reconstruction Algorithm by using Nearest Neighbourhood Technique.

Step 1: Read an input image by using imread () function in MATLAB environment.

Step 2: Display the Original image which has been read.

Step 3: Consider a pixel say f(x,y) as a hotspot and identify its nearest neighbours by implementing 8-neighbours for chess_board distance and neighbour for city_block distance.

Step 4: If the input image has a large matrix element then extract relevant values based on 8/4 neighbour method which has holds the hotspot position/values. i.e. f(x,y)

Step 5: Then calculate the mean value of all the neighbours of sub-matrix by applying suitable mask/filter.

Step 6: The approximate mean value will be generated with the help in step 5, that resultant value is g(x,y).

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Step 7: Replace the pixel at f(x,y) with the value obtained in step 6. i.e. g(x,y).

Step 8: Finally display the reconstructed image.

Wiener filter:

Wiener filter restores the image in the presence of blur as well as noise. Consider above derived CLSF equation, if x is zero then CLST fitter is same as wiener fitter. The recovered image is represented as,

$$f^\wedge(x,y)=h_R(x,y)*g(x,y)$$

f^(x,y)-inverse filter.

g(x,y)-degraded & noise image.

multiplying g(x,y) on both the side for above equation

$$f^\wedge(x,y)\ g(x,y)=h_R(x,y)*g(x,y)\ g(x,y)$$

taking equation on both sides.

$$E[f^\wedge(x,y)\ g(x,y)]=E(h_R(x,y)*g(x,y)\ g(x,y)]$$
$$E[f^\wedge(x,y)\ g(x,y)]=h_R(x,y)*E[g(x,y)\ g(x,y)]$$

(since h is not statistical function as fixed expectation)

We know that

$$E[(f^\wedge(x,y)\ g(x,y)]=r_{fg}(x,y)\ \text{(cross correlation)}$$
$$E[g(x,y)\ g(x,y)]=r_{gg}(x,y)\ \text{(auto correlation)}$$

Substitute these values in the previous eqution.

$$r_{fg}(x,y) = h_R(x,y) * r_{gg}(x,y)$$

Apply Fourier transform for above equation.

$$F[r_{fg}(x,y)]=F[h_R(x,y)*r_{gg}(x,y)].$$
$$F[h_R(x,y)]\ .\ F[r_{gg}(x,y)]$$

Where $F[r_{fg}(x,y)]=S_{fg}(u,v)$ =>power spectral density.

$$F(h_R(x,y)]=h_R(u,v)$$
$$F(r_{gg}(x,y)]=S_{gg}(u,v)=PSD$$

Substitute these values to the FT function

$$S_{f^\wedge g}(u,v) = H_R(u,v)\ S_{gg}(u,v)$$
$$H_R(u,v) = \frac{S_{f^\wedge g}(u,v)}{S_{gg}(u,v)}$$

if f^= f,

$$\mathbf{H_R(u.v) = \frac{S_{fg}(u,v)}{S_{gg}(u,v)}} \rightarrow \mathbf{1}$$

The presence of noise, degradation model is

$$g(x,y)=f(x,y)*h(x,y)+n(x,y)$$

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multiply f(x,y)

$$g(x,y)*f(x,y) = f(x,y)*h(x,y)*f(x,y)+n(x,y)*f(x,y)$$

Taking expectation on both side

$$E[g(x,y)*f(x,y)] = E[f(x,y)\ f(x,y)]*h(x,y)+E[n(x,y)\ f(x,y)]$$

$$E[n(x,y)\ f(x,y)]=0 \text{ (noise is not correlated to input)}$$

$$E[f(x,y)\ g(x,y)]=r_{fg}(x,y)=\text{cross correlation}$$

$$E[f(x,y)\ f(x,y)]=r_{ff}(x,y)=\text{auto correlation}$$

$$r_{fg}(x,y)=r_{ff}(x,y)*h(x,y) + 0.$$

Taking Fourier transform on both sides

$$F[r_{fg}(x,y)]=Fr_{ff}(x,y)*h(x,y)]$$

$$= F[r_{ff}(x,y)]*F[h(x,y)]$$

H(u,v) changes H*(u,v) to adjust FT

$$\underline{\mathbf{S_{fg}(u,v)=S_{ff}(u,v)\ H^*(u,v)}} \quad \rightarrow \mathbf{2}$$

Consider the degraded function

$$g(x,y)=f(x,y)*h(x,y)+n(x,y)$$

Multiply g(x,y) on both side

$$g(x,y)\ g(x,y)=g(x,y)\ [f(x,y)*h(x,y)+n(x,y)]$$

$$= [f(x,y)*h(x,y)+n(x,y)]\ [f(x,y)*h(x,y)+n(x,y)]$$

$$= f(x,y)\ f(x,y)*h(x,y)\ h(x,y)+ n(x,y)$$

$$n(x,y)+2[f(x,y)*h(x,y)+n(x,y)]$$

Taking expectation on both side

$$E[g(x,y)\ g(x,y)]=E[f(x,y)\ f(x,y)*h(x,y)\ h(x,y)]+E[n(x,y)\ n(x,y)]+2E[f(x,y)*h(x,y)+n(x,y)+n(x,y)]$$

$$r_{gg}(x,y) = r_{ff}(x,y)*h^2(x,y)+r_{nn}(x,y)+0$$

$$\rightarrow 2E[f(x,y)*h(x,y)+n(x,y)]=0$$

→By implementing FT

$$\underline{\mathbf{S_{gg}(x,y)=S_{ff}(u,v)*|H(u,v)|^2 +S_{nn}(u,v)}} \rightarrow \mathbf{3}$$

Substitute the value of equation 2 and 3 in equation 1

$$\mathbf{H_R(u,v) = \frac{S_{fg}(u,v)}{S_{fg}(u,v)} = \frac{H^*(u,v)\ S_{ff}(u,v)}{|H(u,v)|^2\ S_{ff}(u,v)+S_{nn}(u,v)}}$$

The derived equation for Wiener filter

VI. CONCLUSIONS

This algorithm provides one of the good way of image restoration from noisy image; it gives the smooth image by the technique of Wiener filter nearest neighbour method.

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BIOGRAPHY

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