Medical Image Denoising using Non-Linear Spatial Mean Filters for Edge Detection

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Abstract—All medical image processing techniques need to extract meaningful information from medical images. However, the noise generated during image acquisition and transmission degrades the human interpretation, or computer-aided analysis of these images. Therefore, denoising should be performed to improve the image quality for more accurate analysis and diagnosis. In this paper we propose a medical image denoising technique using three spatial mean filters and the performance of these filters are evaluated using the Canny edge detector by computing the edge image difference between the original and the denoised image.

Keywords: Spatial Mean Filters, Medical Image Enhancement, Denoising, canny edge Detector, Enhancement.

I. INTRODUCTION

Diagnostic imaging is an invaluable tool in medicine today. Medical image acquisition techniques such as X-rays, Computed tomography (CT), Ultrasound, Magnetic resonance imaging (MRI), Functional magnetic resonance imaging (fMRI), Positron emission tomography (PET), Single photon emission computed tomography (SPECT), Electrical impedance tomography (EIT), Digital mammography, Biomagnetic Imaging, Radiographic Imaging, Autoradiographic Imaging, 2-D and 3-D Microscopy Imaging (Light, Electron, Confocal, Atomic Force) and other imaging modalities provide an effective means for mapping the anatomy of a subject. These technologies have greatly helped to understand the normal and diseased anatomy for medical research and are critical component in diagnosis and treatment planning.

However the noise present in the medical image degrades the performance of the medical image processing techniques.

Image enhancement through noise reduction is a fundamental problem in image processing [1]. Noise filtering has become one of the indispensable components of image processing operation [2]. Noise filters generally attempt to smooth the corrupted image by neighborhood operations. Non-linear filters exhibit better performance than linear filters. The linear filters distribute the noise over the image rather than eliminating it [3], [4].

Non-linear filters control the direction and/or degree of averaging with the local contents of neighborhood because the spatial relations of the gray values of neighborhood pixels can recognize the objects in an image [5],[6].The spatial mean filters are simple sliding window filters that replaces the center value by the calculated mean value.

In this paper, we demonstrate how the non-linear spatial filters, arithmetic mean, geometric mean harmonic mean can be effectively used to eliminate the Gaussian noise in the medical images. The performances of these filters are compared by finding the edge image difference between the original and the denoised images using Canny edge detector.

The remaining part of the paper is organized as follows: In section II, we explain the methods and materials that are used in the proposed approach. In section III, the experimental results and discussion are given. In section IV, the conclusions are given.

II. METHODS AND MATERIALS

A. Image Noise

Image noise is a random variation of brightness or color information in images that are not present in the object imaged, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera.

Image noise is generally of the following types [7]:

- Gaussian noise
- Salt-and-pepper noise
- Short noise
- Uniform noise
- Film grain noise
- Non-isotropic noise

Gaussian noise is evenly distributed over the input image. This means that each pixel in the noisy image is the sum of the true pixel value and a random Gaussian distributed noise value. The Gaussian noise has a Gaussian distribution having a bell shaped probability distribution function given by [8], [9]:

\[
F(g) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(g-\mu)^2 / 2\sigma^2}.
\]

where, \( g \) represent the gray level, \( \mu \) represents the mean of the function and \( \sigma \) the standard deviation of the noise. The chosen medical images are degraded with Gaussian noise for de-noising with the selected spatial filters.
B. Spatial Mean Filters

Spatial mean filters provide a convenient way to remove the random noises from the image intensity profile. In this paper, three non-linear spatial filters, arithmetic mean, geometric mean and harmonic mean filters are used to remove the noise in the medical images.

The arithmetic mean (AM) filter is defined as the average of all pixels within a local region of an image. Pixels that are included in the average operation are specified by a mask. The arithmetic mean filter is given by:

\[
\hat{f}(x, y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} g(s,t) \tag{2}
\]

where, \(\hat{f}\) is the denoised image, \(g\) represents the corrupted image, \(m, n\) is the size of the sliding window and \(S_{xy}\) represents the set of coordinates in a sliding window of size \(m \times n\) centered at point \((x, y)\).

The geometric mean filter is a member of a set of nonlinear filters that are used to remove image noise. It operates by replacing each pixel by the geometric mean of the values in its neighborhood. Geometric mean (GM) filter is given by:

\[
\hat{f}(x, y) = \left[ \prod_{(s,t)\in S_{xy}} g(s,t) \right]^{1/mn} \tag{3}
\]

where, \(\hat{f}\) is the denoised image, \(g\) represents the corrupted image, \(m, n\) is the size of the sliding window and \(S_{xy}\) represents the set of coordinates in a sliding window of size \(m \times n\) centered at point \((x, y)\).

Harmonic mean (HM) filter is a member of a set of nonlinear filters that are used to remove image noise. It operates by replacing each pixel by the geometric mean of the values in its neighborhood. Harmonic mean (HM) filter is given by:

\[
\hat{f}(x, y) = \frac{mn}{\sum_{(s,t)\in S_{xy}} \frac{1}{g(s,t)}} \tag{4}
\]

where, \(\hat{f}\) is the denoised image, \(g\) represents the corrupted image, \(m, n\) is the size of the sliding window and \(S_{xy}\) represents the set of coordinates in a sliding window of size \(m \times n\) centered at point \((x, y)\).

C. Materials

We have used 20 volumes of Magnetic Resonance Image (MRI) brain images obtained from the Internet Brain Segmentation Repository (IBSR) [11] of the Centre for Morphometric Analysis (CMA) at the Massachusetts General Hospital and from the website ‘The Whole Brain Atlas’ (WBA) [12] maintained by the Department of Radiology and Neurology of Brigham and Women’s Hospital, Harvard Medical School, the Library of Medicine, and the American academy of neurology. We have also used 40 CT scan and X-ray images collected from the internet for our experiments.

D. Performance Evaluation

We use edge detection as a measure to evaluate the performance of the selected filters on medical image. For edge detection we use Canny edge detector.

The Canny [13] method finds edges by looking for local maxima of the gradient of the input image. The gradient is calculated using the derivative of a Gaussian filter. This method uses two thresholds, to detect strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges.

III. RESULTS AND DISCUSSION

We carried out experiments by degrading the collected images with Gaussian noise and then we applied the selected spatial filters to enhance the corrupted images. The sample selected images, and the corresponding corrupted and enhanced images are shown in Fig.1. Each row in Fig. 1 represents images numbered from 1 to 8. Images 1 to 3 are MR brain images, Images 4 to 8 are CT scan and X-ray images.

The qualitative performance of these selected filters is evaluated using canny edge detector. The edge image obtained using canny edge detector on the original image, corrupted image and enhanced images of the selected sample images are shown in Fig.2. From Fig.2, we observe that the edges of the harmonic mean and geometric mean filtered images are more similar that of the edges of uncorrupted image. For the quantitative comparison of the selected filters, the differences of edge images are calculated for the images shown in Fig.2 and are given in Table.1.

<table>
<thead>
<tr>
<th>Images Corrupted Image</th>
<th>AM</th>
<th>GM</th>
<th>HM</th>
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<tbody>
<tr>
<td>Image 1 4451 3291 2903 2898</td>
<td></td>
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<tr>
<td>Image 2 4850 2635 2326 2293</td>
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<td>Image 3 3070 3508 3168 2125</td>
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<td>Image 4 2833 2818 2653 1915</td>
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<td>Image 5 3360 2736 2588 2116</td>
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<td>Image 6 3351 3376 3138 3183</td>
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<td>Image 7 4816 2063 1888 1983</td>
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<td>Image 8 7390 7112 954 905</td>
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Table 1: Computed edge difference values for the selected images in figure 2 by the AM, GM and HM mean filters
Fig. 1: Results of Image Denoising: Column 1 Original Image, Column 2 Corrupted Image, Column 3 Denoised Image by AM, Column 4 Denoised by GM and Column 5 Denoised by HM
Fig. 2: Results of Canny Edge Detection: Column 1 Edges in the Original Image, Column 2 Edges in the Corrupted Image, Column 3 Edges by AM Filtered Image, Column 4 Edges by GM and Column 5 Edges Image HM.
IV. CONCLUSION

In this paper, we have demonstrated the performance of three noise filters, AM, GM and HM for denoising medical images. Further the effectiveness of these filters is studied by finding the edges on the denoised images. It is found from the experimental results that HM filter is more effective in removing noise thereby giving more clear edges than with the images denoised by other two noise filters AM and GM.

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