An Application Filter for Filtering Noise from Medical Images using Responsive Ablaze Medical Filter (An application specific image filter)

B. N. Bhargava[a]* and S. Patil Neelakantagouda[b]
[a]*Hewlet and Packard Global Soft, Bangalore, India*
[b]*Torry Harris Business Solutions, Bangalore, India*
*bnbhargavthebest@gmail.com

Abstract

In the field of image processing image filtering plays a dominant role. The main reason for excessive use of image filter is due to noise. We can find thousands of filters, but are generic purpose filters. We thought of medical images (like x-ray, fluoroscopy, CRT, CT scans, MRI etc.) as most of which are gray scale. The noise generally present in these images will be categorized as quantum noise. In this paper we employed a new technique to remove quantum noise thereby providing a robust system that can be exclusively used for the medical instruments and measuring devices and thus serving for social cause.

Keywords - Radiography, Edge detection, Quantum noise, Fuzzy, Standard deviation, RAM filter, Medical images, X-ray beam

Introduction

Image processing (Acharya and Ray, 2006; Burger and Mark, 2007) is a technique in which the data from an image are digitized and various mathematical operations are applied to the data, generally with a digital computer, in order to create an enhanced image that is more useful or pleasing to a human observer, or to perform some of the interpretation and recognition tasks usually performed by humans.

In the field of image processing image filtering plays a dominant role, in which a particular filtering technique will be employed by manipulating the image pixels in order to remove or reduce the irrelevant or unexpected patterns in the image. The main reason for excessive use of image filter is due to noise. The Image noise is random (not present in the object imaged) variation of brightness or color information in images, and is usually an aspect of electronic noise. So it is highly desirable to develop an effective filter which can remove 100% noise, although it is quite impossible.

The need of image filtering is more intense in the field of medical science than any other field. Since medical imaging instruments itself produce some amount of noise due to hardware and circuit limitations (such as capacitors, registers, display unit etc.) the analysis by physician may become imperfect. The noise generally present in these images will be categorized as quantum noise which is unavoidable.

We organized all the above thoughts and developed a new well advanced image filter and thereby providing a robust system called reponsive ablaze medical (RAM) filter that can be exclusively used for the medical instruments and measuring devices and thus serving for social cause.

Overview

Image quality is the overall characteristic of a medical image that determines which objects and structures in an image are visible. The general objective of most imaging procedures is to visualize the various anatomical structures and any signs of pathology if they are present. Image quality can be measured by five specific image characteristics such as contrast sensitivity, blurring, visual noise, artifacts and spatial characteristics.

Among the five above mentioned image characteristics, we are interested in removal of noise in the medical images. Medical images were a bit different and the noise present in them is categorized as quantum noise. In all medical imaging procedures using x-ray or radiography (Ritchey and Orban, 1953) most of the image noise is produced by the random manner in which the photons are distributed within the image. This is generally designated as quantum noise.

In almost all medical imaging techniques (radiography, CT scan, MRI, fluoroscopy etc.,) a light beam (photons) will be projected towards the patient and collected back using a receptor plane. The amount of quantum noise in images will be dependent on number of photons collected at the receptor plane. When large amount of photons are projected towards patient, the noise will be reduced but patient will be highly exposed to the radiation. In contrast if less radiation is used the photon fluctuation in the image will be increased this photon fluctuation is what actually called quantum noise. So as a tradeoff between noise and the patient's exposure to radiation is to be handled by projecting optimal radiation.

This trade off ensures us that complete removal of noise in processing stages is not practically possible, so there is a need of post processing technique which can filter the quantum noise. To remove the uneven random fluctuation of photons in an image (quantum noise), we have developed a new image filter called RAM filter. Through our repetitive testing we found it is highly efficient and according to domain experts it preserves all the necessary objects and also preserves edges of the actual image objects.

The new filter irrespective of its simplicity, highly specific for quantum noise and got high scope in field of medical science such as X-ray, radiography, CT, magnetic resonance imaging etc., where noise cannot be removed by hardware refinement and being no filter efficient as proposed one.

Working Principle

The base of the RAM filter is mainly standing on the three core techniques and which are also the advantages of our filter and they are elaborated in each as mentioned below.

Raster scans the input image

A raster image is a way to represent digital images. The raster image takes a wide variety of formats, including the familiar .gif, .jpg, .png, .pgm and .bmp. A raster image represents an image in a series of bits of information which translate into pixels on the screen. These pixels form points of intensity which create an overall finished image.

When a raster image is created, the image on the screen is converted into pixels. Each pixel is assigned a specific value which determines its color. So after raster scanning the input image the pixels are extracted with their pixel values and they are used for the overall processing of filtering process

Preserving the boundary pixels of an image

In any image processing procedures boundary pixels of images are more subjected to risk and they may be lost, since few of their neighboring pixels will contain no information and hold value of null. To preserve these border values even after subjecting image to lots of iteration, we have employed a simple technique to replace any null value (value of neighbor pixel to current pixel) by the current pixel value. This technique is quite simple but fetches a specific solution to deal with any image processing techniques.

Edge detection and object preservation.

Especially in medical images each and every minute object plays significant role, so domain experts expect such a work. In order to preserve every object in the filtered image it is necessary to sustain every pixels corresponding to edges of that object. Thus before starting to filter the noise it is necessary to have a technique that can effectively retain the edges.

When we are dealing with a particular pixel we have to distinguish that whether the given pixel is noise or part of an edge and alter that pixel only if it is noisy.

Calculating simple derivative

(a) simple derivative at the central pixel position (x,y) in direction D(D € dir={NW,W,SW,S, SE, E,NE, N}) is defined as the difference between the pixel at and its neighbor in the direction.

Figure 1 represents kernel of size 3X3, where (x, y) is the current pixel along with its neighboring pixels are shown. We calculate simple derivative for each of the pixel on which four lines are drawn in the fig 1.

(b) Based on these eight simple derivative values, we will make an assumption whether the pixel (x, y) belongs to any edges in four directions (the four lines are drawn in four directions in Figure 2) or not.

NW	*N*	*NE*
W	*(x,y)*	*E*
SW	*S*	*SE*

Figure 1: Neighborhood of a central pixel (x; y).

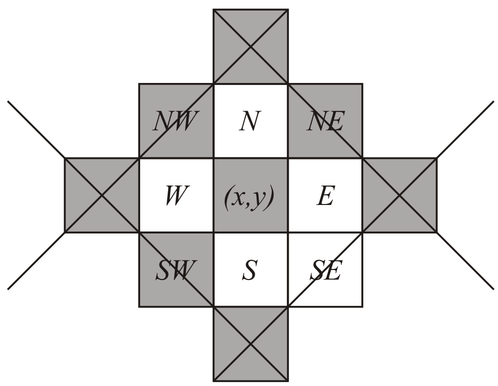


Figure 2: Calculation of "simple derivative" for pixel on which four lines passes.

Here we employed very simple technique of using simple derivatives in all possible directions instead of calculating complex operations such as fuzzy derivatives (Novak *et al.,* 1999).

Assumption of edge

In Fig 2 each line passes on three pixels, which represents a direction of probabilistic edge. For every direction if any two simple derivatives are greater than current pixel value, then we assume that the current pixel value is contributing itself as a part of edge passing in that direction.

Calculate composition value

For every pixel consider its neighboring pixels as 3x3 kernel. Calculate mean and median for each pixel (x_i, y_i), where mean is the average of the corresponding kernel and median is the median value of the kernel. Now composition value which is denoted by **Ω**.

$$\Omega = (\alpha+\beta+\gamma)/3 \quad \text{... (1)}$$

In equation (1) α represents mean of corresponding kernel, β represents median of corresponding kernel and γ represents current pixel. Now if the pixel is found to be a part of any edge, **Ω** is calculated as in equation (2).

$$\Omega = (\alpha+\gamma)/2 \quad \text{... (2)}$$

The overall jest of the working of our filter lies where we considered the composite value. As we observed composition value is composed of the mean and median filters and they are best in few cases individually and as they are combined we get the combined effect. Meanwhile this trick or logic well matches with the medical images (quantum) noise, this is because of the reason that the difference in the pixel value in the medical images will be maximum in most of the cases compared to the photographic images. We have also considered the current pixel values to avoid the large variations that can happen during filtering.

With this working, we are clear about our objective i.e., to make the medical images look noise free and also retain the intension of the image and their by highlighting the interested aspect of the image, which is the most critical aspect of the images of this kind.

Algorithm

The overall process of the RAM filter is conveyed through algorithm as below

```
//Input: Medical image (m rows and n columns) and number of iterations (I)
//Output: Filtered image
Step 1: Read Input Image(Img(mxn))
Step 2: i←0 and t←n
Step 3: for t←0 to m*n
            for  r←0 to m for c←0 to n
                k[i]←getpixel(r,c)
                k[i+1] ←getpixel(r,c,NW)
                k[i+2] ←getpixel(r,c,W)
                k[i+3] ←getpixel(r,c,SW)
                k[i+4] ←getpixel(r,c,S)
                k[i+5] ←getpixel(r,c,SE)
                k[i+6] ←getpixel(r,c,E)
                k[i+7] ←getpixel(r,c,NE)
                k[i+8] ←getpixel(r,c,N)
            end for
        end for
     if(k[i]==NULL) ∀ i =0 to 9
            k[i]= γ
     end if
Calculate α, β and γ
Calculate Ω
Check for edge (if it is edge, Ω changes to average of α and γ)
end for
```

Step 4: stop

RAM filter is an iterative medical image filter, which takes an medical image and number of iterations(n) as input, and the image will be filtered n times. Starting from the left corner of the images (raster scan), algorithm extracts one pixels at a time with its neighboring pixels, which forms 3X3 kernel. Then for each kernel, mean median and composition value as shown below (refer Fig 1).

$$\alpha = \{NW+W+SW+S+SE+E+NE+N+\gamma\}/9 \quad ... (3)$$

$$\text{if} (\gamma \in \text{edge}) \ \text{then}\ \Omega=(\alpha+\beta+\gamma) / 3 \quad ... (4)$$

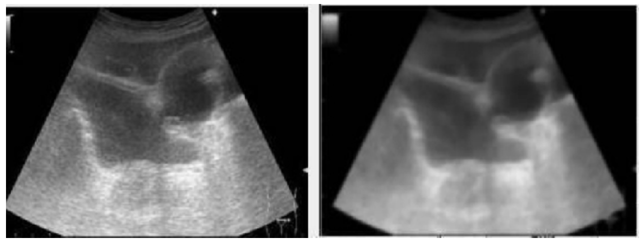
$$\text{else}\ \Omega=(\alpha+\gamma) / 2 \quad ... (5)$$

Find weather the current pixel contributes to any of the edges or not as explained in section 2. If the current pixel is contributing to any of its edges than consider equation (5) to calculate composition value, otherwise consider equation (4) to calculate composition value. Similarly composition value will be calculated for each pixel of an input image and each pixel will be replaced by its composition value. Here γ is used as correction factor to avoid large variation in the intensity that removes the intension of the image.

Results

Our main basis for the analysis of the system is based on the standard deviation (Gauss and Friedrich, 1816; Walker and Helen, 1931). As the quantum noise present in the medical images can be measured using standard deviation. Quantum noise is the amount of fluctuation of photons in an image. In all imaging procedures using x-ray or gamma photons, most of the image noise is produced by the random manner in which the photons are distributed within the image. This is generally designated as quantum noise. Recall that each individual photon is a quantum (specific quantity) of energy. It is the quantum structure of an x-ray beam that creates quantum noise.

Let us use the illustration below to refresh our concept of the quantum nature of radiation to see how it produces image noise. Consider the part of an x-ray beam that forms the exposure to one small area within an image. Remember that an x-ray beam is a shower of individual photons. Because the photons are independent, they are randomly distributed within an image area somewhat like the first few drops of rain falling on the ground. At some points there might be clusters of several photons (drops) and, also, areas where only a few photons are collected. This uneven distribution of photons shows up in the image as noise. The amount of noise is determined by the variation in photon concentration from point to point within a small image area. The standard deviation is a quantity often used in statistical analysis to express the amount of spread, or variation, among quantities. The value of the standard deviation is somewhat like the "average" amount of deviation, or variation, among the small areas. One of the characteristics of photon distribution is that the amount of fluctuation (standard deviation value) is related to the average photon concentration, or exposure level. The square root of the average number of photons per area provides a close estimate for the value of the standard deviation. In this example the standard deviation has a value of ten photons per area. Since this is 10% of the average value, the quantum noise (photon fluctuation) at this exposure has a value of 10%.



(a) (b)

Figure 3: Illustration of experimental result.

Above figure represents a scanned image of fetus. In Fig. 3(a), there is much noise (photon fluctuation reveling as deviation of thousands of dots) content which can be easily visualized. This noise content is adverse effect for domain experts who analyses small patterns in it. Fig. 3(b) shows the output from RAM filter in which quantum noise of 90% is successfully reduced. According to the domain experts the fig 3 (b) is more use full for analysis of minute patterns.

The above image Fig. 3 depicts visually how the RAM filter is serving the need but coming to statistical analysis, as we mentioned earlier standard deviation is the parameter that can capture the noise content in an image. Accordingly the following tabular value in table 1 depicts the behavior of new RAM filter with respect to the input number of iterations.

Table 1: Behavior of RAM with change of iterations.

No. of Iterations	Standard Deviation
2	10.44
4	10.29
6	9.84
8	9.76
10	9.38
12	9.32
14	9.32
16	9.30
18	9.00
20	8.66

Fig. 4 depicts the behavior of RAM filter for variation in number of iterations and it reflects the values of tabular column of Table 1. According to the graph of fig 4 we can easily see that standard deviation decreases as the filter is applied iteratively. Decrease in standard deviation, as explained earlier shows the decrease in quantum noise level in the input image.

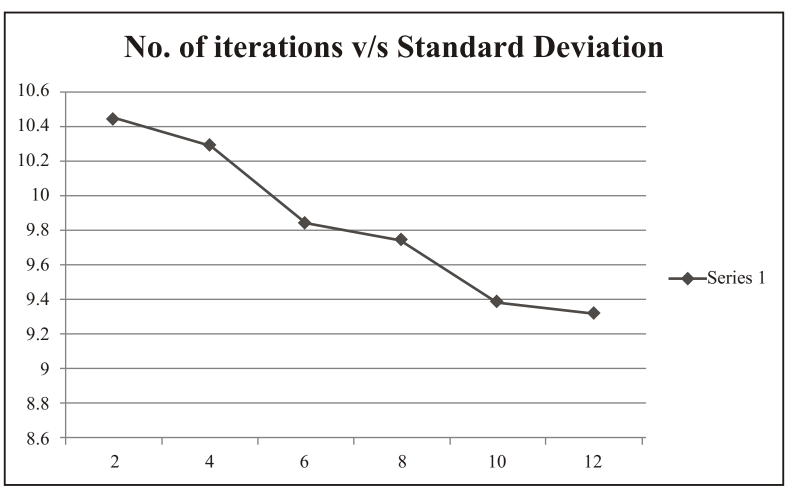


Figure 4: Number of iterations v/s standard deviation.

Scope

On successful implementation and deployment of this project to the work environment, it will have the direct impact on the medical field. Because of the drawbacks that, practically measuring instruments in medical field cannot provide 100% noise free images, there is a desperate need of medical image filters. Our newly designed image filter is exclusively for the field of medicine and can ease the medical diagnosis process. It can have a major hand by playing a role of post processing module in the operations of measuring devices and can help the field of medical science thereby serving a social cause.

Advantages

Few advantageous features of RAM filter are unique than any other medical image filters and are listed below

1. Simple image filter
2. Effective noise reduction
3. Less time consuming
4. Effective edge detection
5. Effective object preservation
6. Preserves boundary of an image

Future work

As discussed in the abstract of this paper there are many existing image filters but most of them are not specific to any particular domain and even there are few image filters which are exclusively designed to operate on medical images. Among which many are not capable to operate on quantum noise. Through this proposed filter we have how shown how to deal with the quantum noise in simple.

Conclusion

In almost all medical imaging techniques (radiography, CT scan, MRI, fluoroscopy etc.,) a light beam (photons) will be projected towards the patient and collected back using a receptor plane. The amount of quantum noise in images will be dependent on number of photons collected at the receptor plane. When large amount of photons are projected towards patient, the noise will be reduced but patient will be highly exposed to the radiation. In contrast if less radiation is used the photon fluctuation in the image will be increased this photon fluctuation is what actually called quantum noise. So as a tradeoff between noise and the patient's exposure to radiation is to be handled by projecting optimal radiation.

This trade off ensures us that complete removal of noise in processing stages is not practically possible, so there is a hectic need of post processing technique which can filter the noise. As listed in section VII of this paper, in contrast with any other image filters, RAM stands unique and interesting because of its simplicity and best edge preserving strategy and also its boundary preservation technique. Above all these features and advantages we have got the supporting result for various images taken from medical instruments in different fields such as X-ray, ultraviolet, radiography, CT, magnetic resonance imaging etc.

References

Acharya, T., Ray, A. K. 2006. *Image Processing - Principles and Applications*. Wiley Inter Science.

Bean, 1963. Fine particles, thin films and exchange anisotropy. In *Magnetism,* Eds., G. T. Rado and H. Suhl, New York: Academic, 271-350.

Burger, W., Burge, M.J. 2007. *Digital Image Processing: An Algorithmic Approach Using Java*. Springer.

Gauss, Friedrich, C. 1816. Bestimmung der Genauigkeit der Beobachtungen. *Zeitschrift für Astronomie und verwandt Wissenschaften,* 187-197.

Hajek, Petr, 2006. Fuzzy Logic. *The Stanford Encyclopedia of Philosophy, Eds.* Edward N. Zalta.

Novak, V., Perfilieva, I., Mockor, J. 1999. *Mathematical principles of fuzzy logic.* Dodrecht: Kluwer Academic.

Ritchey, B., Orban, B. 1953. The Crests of the Interdental Alveolar Septa. *Journal of Periodontology,* 75-87.

Sprawls, P. Image noise. *In The physical principles of medical imaging,* Medical Physics Publisher.

Sprawls, P. Receptor Sensitivity. *In The physical principles of medical imaging,* Medical Physics Publisher.

Ville, D.V., Nachtegael, M., Weken, D.V., Kerre, E.E., Philips, W., Lemahieu, I. 2003. Noise Reduction by Fuzzy Image Filtering. *IEEE Transactions on Fuzzy Systems,* 429-436.

Walker, Helen. 1931. *Studies in the History of the Statistical Method*. Baltimore, MD: Williams & Wilkins Co., 24-25.