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Research Article

A SUGENO AND TSUKAMOTO FUZZY INFERENCE SYSTEM FOR DENOISING MEDICAL IMAGES

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ABSTRACT

All digital images contain some degree of noise due to the corruption in its acquisition and transmission by various effects. Particularly, medical image are likely disturbed by a complex type of addition noise depending on the devices which are used to capture or store them. The presence of noise in the medical image reduces the visual quality that complicates diagnosis and treatment. In this paper Tsukamoto type fuzzy inference system for noise filtering in medical images is proposed. The proposed system consist of two fuzzy filters and a post processor The proposed method is suitable for various types of noisy images and it is highly preferred by the medical expert: The proposed method performance is evaluated in terms of MSE (Mean Squared Error) and PSNR (Peak Signal to Noise Ratio). The results demonstrate its usefulness for noise reduction in medical imaging. Thus the proposed method clearly outperforms the previous approaches of medical image denoising in terms of quantitative performance measures as well as in terms of visual quality of the images.

INTRODUCTION

In medical images, noise filtering is a specially an important and complicated task. A balance between noise decreasing and the maintenance of actual image features has to be made in a way that enhances the diagnostically relevant image content. A medical image is often degraded by noise during transmission. The ambition of de-noising is to eliminate the noise such that the important features are not affected. Conventionally, this is achieved by linear processing such as Wiener filtering. The medical image investigation process can be broken into three primary stages which are pre-processing, data reduction, and features analysis. Removal of noise from an image is the one of the important tasks in image processing. Based on nature of the noise, such as additive or multiplicative noise, there are several approaches for removal of noise from an medical images. Medical images acquired from MRI, CT and X-Ray is the most common tool for diagnosis in Medical field. These images are often influenced by random noise arising in the image acquisition process. The existence of noise not only produces unpleasant image quality but also poorer the visibility of small contrast objects. Noise removal is vital in medical imaging appliances in order to increase and improve fine elements that may be concealed in the information.

Image improvement is employed to improve the eminence of images. The major appliances of image improvement are Aerial imaging, Satellite imaging, Medical imaging, Digital camera application and in remote sensing. Image improvement techniques used in regions such as forensics, Astrophotography and in Fingerprint matching, etc. Color contrast enhancement, sharpening and brightening are some of the helpful techniques utilized to make the images clear. Medical imaging utilizes this for lowering noise and sharpening features to progress the visual representation of the image. This makes image improvement a necessary aiding tool for reviewing atomic region in MRI, ultrasound. Images that are attained from fingerprint recognition, security videos examination and crime scene explorations are improved to assist in detection of culprits and safety of victims.

Problem Description

A medical image is represented as a two dimensional function f(x, y), where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the

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intensity or grey level of the image at that point. Data sets collected by image sensor are generally contains large amount of noise. The particular part of an the image can be degraded by the impact of imperfect instrument, the problem, consequently the original image may not be suitable for applying image processing techniques and analysis. A resourceful filtering method is essential for eliminating noise in the medical images. The noise elimination in the medical image is still a tough problem for researcher because noise removal introduces artifacts and causes blurring of the medical image.

Related Work

Peng, Z., *et al.* projected a multi-scales nonlinear enhancement technique of THz photo. The THz photograph has lower assessment and bigger noise due to the fact the THz radiant energy is small, for the cause of enhancing the picture definition. The detail coefficients are taken to de-noise and histogram equalization that allows you to decorate this is of image side and image detail. The approximation coefficients are taken to nonlinear transform as a way to suppress the historical past noise and enhance target facts. The proposed technique ought to accelerate the possible statistics of THz image and get rid of the noise of THz photograph at the same time.

Selvi, M., *et al.* have provided a technique for reinforcing the fingerprint pictures. The first and essential step in fingerprint recognition is enhancement. Fingerprint popularity is used for authentication cause. The most important goal is to provide a noise unfastened photo. First of all, the portion of the photo tormented by noise is analyzed and then the enhancement is carried out on that portion the usage of fuzzy primarily based filtering approach and adaptive thresholding.

Satheesh, S., and Prasad, K. V. S. V. R. proposed a general approach for image denoising is to renovate the noisy image into a transform domain such as the wavelet and contourlet domain, and then compare the transform coefficients with a unchanging threshold. The propose contourlet algorithm which defines a new threshold value to remove the ruined pixels.

Bahendwar, Y., *et al.* presented predominantly, medical image are likely disturbed by a complex type of adding noise depending on the devices which are utilized to arrest or accumulate them. No medical imaging devices are noise free. Additive random noise can easily be detached using easy threshold methods. This paper proposes a medical image denoising algorithm using Discrete Wavelet Transform (DWT) The transform of a signal is just another form of representing the signal. It does not modify the information content present in the signal. The Wavelet Transform provides a time-frequency representation of the signal. It was developed to conquer the shortcoming of the Short Time Fourier Transform.

Luo, E., *et al.* proposed to denoising images using targeted external image databases. The existing denoising methods require large targets in the databases. But the planned algorithm requires only a few targeted images in the database. Moreover, the proposed algorithm offers two new insights into the denoising problem. The first step is designing a linear denoising filter. Second is estimating the spectral components of the denoising filter, a localized prior can be utilized and the denoising quality is improved by minimizing the associated Bayesian mean squared error.

Bhattacharya, S., *et al.* proposed a fast method called singular value decomposition (SVD) to improve the contrast of an image locally. The image enhancement is used to increase the visual information of an image using various steps such as contrast enhancement, deblurring, denoising etc. Contrast Enhancement is the most vital part of image enhancement because human eye is more sensitive to luminance than the chromatic information of an image. Mostly, the contrast enhancement techniques focus on the global enhancement of images but such global methods lead to loss of information in images. Thus, a technique is necessary to carry out localized image enhancement.

Wang, Y., *et al.* presented the noise problem in medical images because they could mask and blur important but subtle features in the images To achieve the best possible diagnoses it is important that medical images be sharp, clear, and free of noise and artifacts. The existing approaches are the wavelet hard thresholding and the wavelet soft thresholding. This approach reduces the Gibbs oscillation, but does not eliminate noise effectively. A wavelet TV (total variation) denoising scheme the wavelet coefficients are selected and modified subjecting to minimizing the TV norm of the reconstructed images. The advantage of the method is it performs better than the previous approaches; the drawback of the system is the performance of the method should be evaluated against the performance metrics such as PSNR.

Zhang, L., *et al.* proposed two-stage image denoising LPG-PCA algorithm has two stages. The first stage yields an initial estimation of the image by removing most of the noise and the second stage will further refine the output of the first stage. The two stages have the same procedures except for the parameter of noise level. Since the noise is significantly reduced in the first stage, the LPG accuracy will be much improved in the second stage so that the final denoising result is visually much better. Compared with WT that uses a fixed basis function to decompose the image, the proposed LPG-PCA method is a spatially adaptive image representation so that it can better characterize the image local structures.

Zuo, W., *et al.* proposed texture enhanced image denoising using gradient histogram preservation. The novel image denoising framework, i.e., TEID, is proposed, which preserves the gradient distribution of the original image. The existing image priors can be easily incorporated into the proposed framework to improve the quality of denoised image. A histogram specification operator is developed to ensure the gradient histogram of denoised image being close to the reference histogram, resulting in a simple yet effective GHP based TEID algorithm. The advantages are better preserving of texture regions and effective removal of random. The disadvantages are Image deblurring, super resolution and other image reconstruction tasks are still under improvement and Image preserving is not satisfactory.

Singh, S., and Wadhwani, S. presented the medical images are corrupted by noises during its transmission and acquisition process. Noise reduction has been a traditional problem in image and signal processing. Medical images generally contains minute information about heart, brain, nerves etc therefore wrong diagnosis might not rescue the patient from harmful effects. In this paper we proposed an approach for image denoising based on wavelet 2D transform using adaptive thresholding technique. The proposed technique estimates the threshold value and decomposition level for an image. In this an additive white Gaussian noise is added to image and forward wavelet transform is applied on noisy image. After this wavelet coefficients are threshold and inverse wavelet transformation is performed to restore the original image. The proposed method reduces the noise from image more effectively.

Tamilselvan, K. S., *et al.* proposed the new hybrid technique for the removal of Gaussian, Uniform and Speckle noises from Medical Images, new technique followed was based on the combination of Curvelet and Wavelet Transform. We also utilize the Histogram equalization to smoothen the noisy image. It is found to be more suitable and more efficient than the existing methods of image denoising particularly for the removal of above mentioned three types of noises. Various results were obtained and analyzed by comparing with each other techniques in terms of Signal to Noise Ratio, Standard Deviation, Mean and Median for MRI image.

Sugeno Fuzzy Based Medical Image Denoising

The fuzzy filter adopts fuzzy logic for improving the images degraded by noise. Artificial neural network can be trained efficiently by using examples Thus neuro fuzzy formed by combining the neural and the fuzzy theories can be used as a potent tool for noise filtering.

The fuzzy filter is formed by joining two neuro-fuzzy filters with a postprocessor, which produces the final yield. Each neuro-fuzzy filter is a first order Sugeno type fuzzy inference system with 4-inputsand1- output. The first order Sugeno type fuzzy model:

The input membership functions are generalized as follows:

$$M_{ij}(x_i) = \frac{1}{1+\left|\frac{x_i-c_{ij}}{a_{ij}}\right|^{2b_{ij}}} \qquad (1)$$

Where, x_i is the ith input, a_{ij}, b_{ij} and c_{ij}, are the antecedent parameters.

The output Y of each NF filter is the weighted average of the individual rule outputs Y_K. The weighting factor wk of each rule is the multiplication off our input membership values.

$$Y = \frac{\sum_{K=1}^{81} W_K Y_K}{\sum_{K=1}^{81} W_K} = \sum_{K=1}^{81} \overline{W}_K Y_K\ ) \qquad (2)$$

Where, $\overline{W}_K$ *is* the normalized weighting factor of the k^{th} rule.

Tsukamoto Fuzzy Based Medical Image Denoising

Tsukamoto fuzzy model represented using fuzzy sets with monotonically membership functions. The fuzzy rule is defined as a crisp value induced by the rule's firing strength. The output of the fuzzy model is obtained with weighted area method of defuzzification and taking the weighted average of each rule's output. Defuzzification process in this model is executed by the weighted average method and avoids time-consuming defuzzification methods.

For example, there are two input variables-variable 1 (x) and variable 2 (y)-and one output variable-variable 3 (z). The variable 1 is divided into two sets, namely A1 and A2. The variable 2 is divided into two sets, namely B1 and B2. The variable 3 is divided into two sets, namely C1 and C2 (C1 and C2 must be monotonous). Two rules are used as follows:

[R1] IF (x is A1) AND (y is B2) THEN (z is C1)
[R2] IF (x is A2) AND (y is B2) THEN (z is C2)

First, membership functions of each fuzzy set of each rule is the set A1, B2 and C1 from the fuzzy rules [R1]; and the set A2, B1 and C2 from the fuzzy rules [R2].

The Tsukamoto method, the used set operation is a conjunction (AND), the membership value of antecedents from the fuzzy rule [R1] is a portion of the membership value A1 from Var-1 with the membership value B1 from Var-2. the value of antecedent memberships from the conjunction operation (AND) of the fuzzy rules [R1] is the minimum value between the membership value A1 from Var-1 and the membership value B1 from Var-2. Likewise, the membership values of antecedents from the fuzzy rules [R2] are the minimum value between the membership values A2 from Var-1and the membership value B1 from Var-2.

Subsequently, the membership values of antecedents from the fuzzy rules [R1] and [R2], called α1 and α2. Then, the value α1 and α2 are substituted into the set of membership functions C1 and C2 in line with the fuzzy rules [R1] and [R2] to obtain the value z1 and z2, which are the values z (approximate values) for the fuzzy rules [R1] and [R2]. To obtain crisp output values/ the fixed value Z requires changing the input (fuzzy sets), which is obtained from the composition of the fuzzy rules into a number in the domain of the fuzzy sets. This method is called the defuzzification method (affirmation). The defuzzification methods used in Tsukamoto method is Centre Average Defuzzyfier.

The Tsukamoto type impulse noise filter consists of two operations, namely, training and testing (filtering). In the training process first order sugeno type NF filters are trained according to inputted training image to produces different input-output patterns. In testing process the noisy in the input image is completely removed in order to produce noisy free image.

Training procedure

The following are the steps to be followed while training an input image.

Step1: For every pixel of the input image corresponding four inputs of the NF filter x_1, x_2, x_3, x_4 are calculated based on the way of selecting the data block. There are two ways horizontal and vertical selection of data blocks.

Step2: The target pixels are obtained for the corresponding input pixels resulting in formation of target image.

Step3: The process is repeated until all the pixels of the input training image get processed. Thus according to the training images various input-output patterns are obtained.

Testing procedure

The internal parameters of the filters are fixed after the completion of the training process. The proposed filter is formed by combining the two neuro filter to a post processor which restores the original image.

Step1: For every pixel of the input image corresponding four inputs of the NF filter $x_{1,}$ $x_{2,}$ $x_{3,}$ x_4 are calculated based on the way of selecting the data block. There are two ways horizontal and vertical selection of data blocks.

Step2: With respect to the current operating pixel, the two neuro filter produces the output values. The output pixels produced by these two filters are connected to the post processor to produce final output pixel which is restored value that corresponds to the current input pixel.

Step3: The filtering process is continued until all the input pixels of the noisy image is restored. Thus finally a noisy free image is produced as output.

Advantages of Tsukamoto Fuzzy Model

1. It is computationally efficient.
2. It works well with linear techniques (e.g., PID control).
3. It works well with optimization and adaptive techniques.
4. It has guaranteed continuity of the output surface.
5. It's well-suited to mathematical analysis.

Experimental Analysis

The dataset used for image denoising process are medical images One image represent the brain of the human being and the other represent the lungs of the human being.

Performance Metrics

The performance of the proposed filter is evaluated against two parameters mean squared error and peak signal to noise ratio.

$$\text{MSE}=\frac{1}{M\ N}\sum_{i=1}^{M}\sum_{j=1}^{N}(O(i,j)\quad R(i,j))^2$$

$$PSNR = 20\log_{10}\left(\frac{255}{MSE}\right)$$

Where, $O(i,j)$ and $R(i,j)$ represent the original and the restored version of the corrupted test image with size M*N.

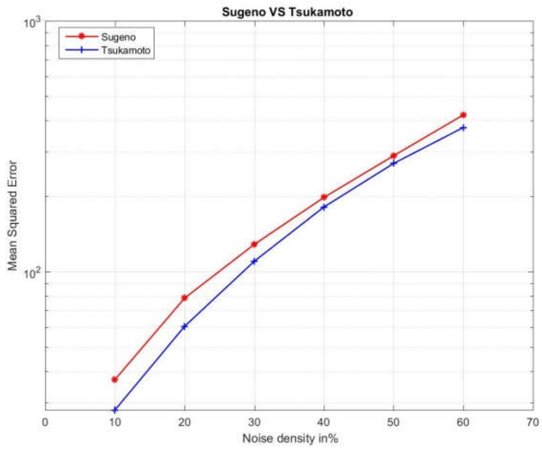

Figure 1 Mean Squared Error Values

Figure 1 takes the noisy range in x-axis and the MSE value in y-axis Sugeno and Tsukamoto models are taken. The mean square error changes with respect to the noisy values, the higher the noise value then higher the mean squared error. The Tsukamoto model based filtering has less mean squared error when compared to the Sugeno model.

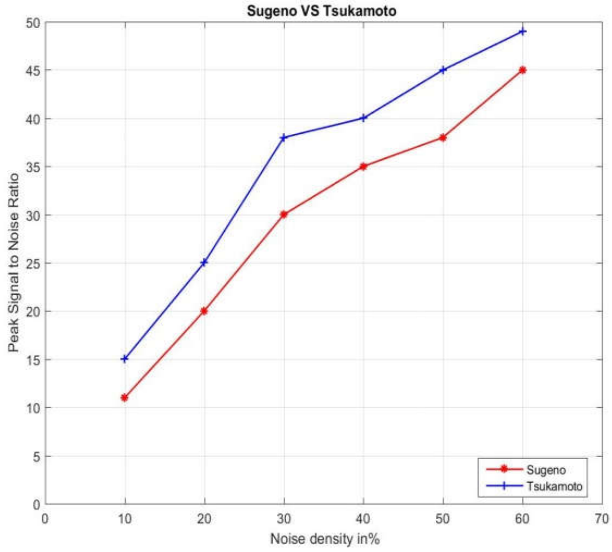

Figure 2 Peak Signal to Noise Ratio

Figure 2 takes the noisy range in x-axis and the PSNR value in y-axis for the neuro fuzzy filter. The PSNR changes with respect to the noisy values. The good denoising algorithm has higher PSNR value.

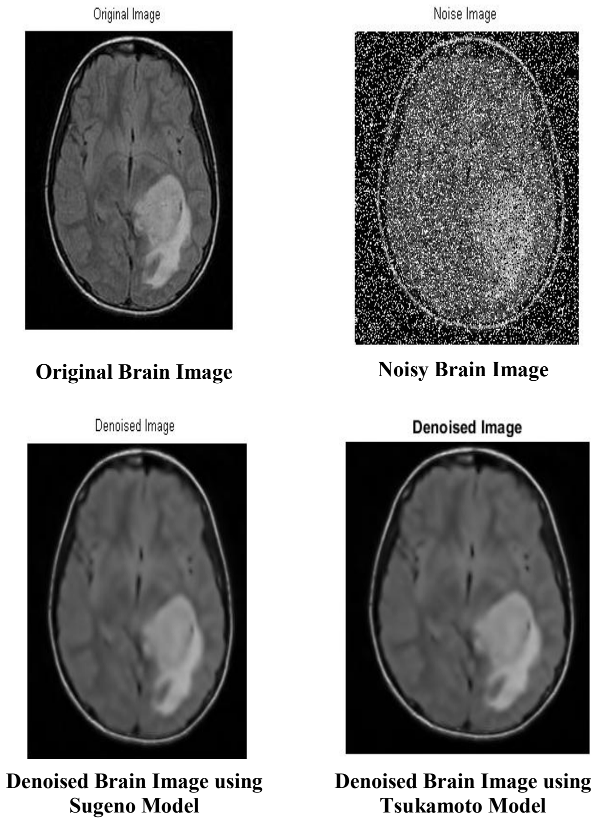

Figure 3 Original, Noisy and Denoised Brian Images

The above Figure 3 and Figure 4 represent the original, noisy and denoised images of brain and lung images respectively.

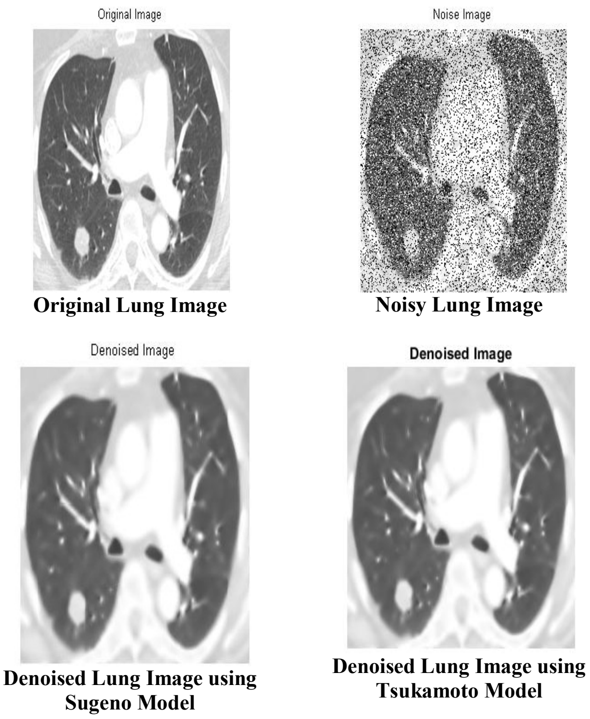

Figure 4 Original, Noisy and Denoised Lung Images

CONCLUSION

The Tsukamoto Model based filter is proposed for efficient removal of impulse noise from the medical images. The proposed system involves two first orders Tsukamoto type fuzzy filters and a post processor. The efficiency of the noise filtering depends on the accurate membership value of the inputs of the pixel. In order to produce an efficient filtering output the accuracy of the Tsukamoto Model is utilized. The experimental results also proved that the proposed filter successfully removes the impulse noise from the medical images. It is flexible, efficient and accurate and it has a great scope for better real time applications.

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