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Denoising of Computer Tomography Images using Wavelet based Multiple Thresholds Switching (WMTS) Filter

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Abstract

Computer Topography images are often corrupted by salt and pepper noise during image acquisition and/or transmission, reconstruction due to a number of non-idealities encountered in image sensors and communication channels. Noise is considered to be the number one limiting factor of CT image quality. A novel decision-based filter, called the wavelet based multiple thresholds switching (WMTS) filter, is used to restore images corrupted by salt-pepper impulse noise. The filter is based on a detection-estimation strategy. The salt and pepper noise detection algorithm is used before the filtering process, and therefore only the noise-corrupted pixels are replaced with the estimated central noise-free ordered mean value in the current filter window. The new impulse detector, which uses multiple thresholds with multiple neighborhood information of the signal in the filter window, is very precise, while avoiding an undue increase in computational complexity. For salt and pepper noise suppression without smearing fine details and edges in the image, extensive experimental results demonstrate that WMTS filter performs significantly better than many existing, well-accepted decision-based methods.

Keywords*: Computer tomography, wavelet, multiple thresholds switching (MTS) filter, MSE, PSNR*

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INTRODUCTION

Many different filtering methods have been proposed for the removal of salt and pepper noise from Computer tomography images. The standard median filter [1] attempts to remove impulse noise by replacing the center pixel of the filtering window with the median of the pixels in the window. Although this approach provides a reasonable noise removal performance, it removes thin lines, distorts edges and blurs image details even at low noise densities. The weighted median filter [2] and the center-weighted median filter [3] are modified median filters giving more weight to the selected pixels of the filtering window and are proposed to avoid the inherent drawbacks of the standard median filter. These filters demonstrate better edge and detail preservation performance than the median filter at the cost of reduced noise removal performance The standard and the weighted median filters are spatially invariant operators that are incapable of making distinction between the corrupted and the uncorrupted pixels of the noisy input image. Hence, these filters distort the uncorrupted regions of the image while restoring the corrupted regions, causing undesirable blurring effects in the output image. In response to this problem, the switching median filter

[4], in which an impulse detector is employed to classify the center pixel of the filtering window, is proposed.

If the center pixel is classified as corrupted, the window is filtered by the standard median filter (i.e., the center pixel is replaced with the median of the pixels within the window). Otherwise, the window is not filtered (i.e., the center pixel is left unchanged). Although this approach provides considerable improvement over the standard median filter, its performance naturally depends on the performance of the impulse detector. The tri-state median filter [5] and the multi state median filter [6] are further improved switching median filters that are constructed by including an appropriate number of center-weighted median filters into the basic switching median filter structure. These filters exhibit better performance than the standard and the switching median filters at the expense of increased computational complexity. The progressive switching median filter [7] is also a different type of switching median filter that iteratively accomplishes the detection and removal of impulse noise in two separate stages. Although this filter provides improved filtering performance than many other median-based filters, it has a high computational complexity due to its iterative nature.

SALT AND PEPPER NOISE IN CT IMAGES

If Computed Tomography (CT) is polluted by noise, doctors may do the wrong diagnosis. Generally CT images are polluted by the salt and pepper noise [8]. The defining characteristic of salt and pepper noise is that the color of a noisy pixel bears no relation to the color of surrounding pixels. Because the system output is bipolar, hence the image must be pre-processed. Many authors describe noise as a salt and pepper pattern on the CT image [9]. The result of projecting the pixels onto plans produces what is called "salt and pepper" noise. This occurs as artifacts produced discreteness of pixels in the 3D space. Since, when projected, they do not precisely fall upon specific X-Z coordinates [10, 11].

WAVELET TRANSFORM

One of the most important features of wavelet transforms is their multi-resolution representation. The Discrete Wavelet Transform (DWT) of image signals produces a non-redundant image representation, which provides better spatial and spectral localization of image formation, compared with other multi scale representations such as Gaussian and Laplacian pyramid. Recently, discrete wavelet transform has attracted more and more interest in image de-noising [12–14].

SALT AND PEPPER IMPULSE DETECTOR

The proposed MTS filter uses multiple thresholds to classify the signal as either noise-free or noise-corrupted so that only noisy signals are filtered while good signals are preserved.

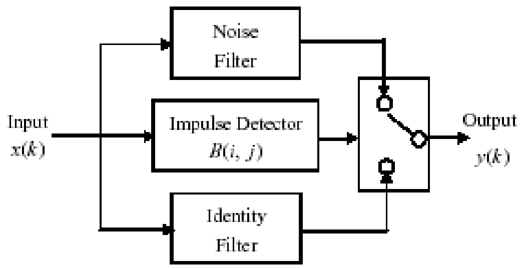

Fig. 1: *MTS Filter.*

To identify corrupted pixels, input pixels can be separated into two classes, A and B. Pixels in class A are supposedly much more likely to be impulse than those in class B. To make sure that this happens, first, we check x(k) to see whether it is a maximum or minimum in the filter window. If x(k) is a maximum or minimum, it will be classified into class A, otherwise it will be classified into class B. When x(k) is classified into class A, the pixels of the 3×3 filter window (excluding x(k)) are sorted in ascending order. The sorted vector can be defined as s(k). The differences between the input pixel x(k) and each of the elements of s(k) provide an efficient measurement to identify noisy pixels. The noise flag map B(i, j) can record the location of the impulse noise in the noisy image.

THRESHOLD DETERMINATION

The first threshold T1 is found experimentally by applying the MTS filter, and then the other thresholds can be expanded and obtained one by one. For example, when the one threshold value T1 is tested, x (k) can be indicated to be either corrupted or not according to the value of T1. After that, along with threshold value T1, the second threshold value T2 (T2>T1) can be tested. Likewise, each of the other threshold values T3, T4, T8 can be obtained based on the former threshold values. After testing a large variety of images, we can pick out the most suitable threshold values to obtain the best results and highest PSNR values. More decision thresholds are considered, the more accurately the impulse noise can be detected [12].

ALGORITHM

1 .Get the noisy CT image.
2 .Take Wavelet Transform.
3 .Locate the center pixel.
4 .Select the threshold (T) values.
from the multiple threshold values,
5 .Compare center pixel (C) value
with threshold value (T);
If
C>T
Then
C–upper corner pixel(uc) (# call it as D)
Else
C–lower corner pixel (lc)(# call it as D)
If
D>T
Then
B=0
Else
B=1
6 . Take inverse wavelet transform.
7 . Apply switching median filter.
8 .The output is de noised image.

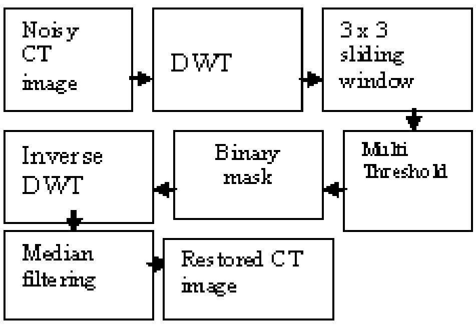

Fig. 2: Impulse Noise Detection.

The pixel value in binary mask with 1 are considered to be noisy pixels and these pixels alone undergo median filtering.

NOISE FILTERING

Median filter is used to reduce salt and pepper noise [12]. The following description explains how noise is filtered if the input pixel is classified as an impulse according to the binary noise flag map. B(i, j), the pixel value is replaced by the estimated central noise-free ordered mean value. Otherwise, its original intensity is the output.

Cmean f(k) { =y’(k) if C=0
fc/2(k)+fc/2+1(k)/2 if C>0

Where Cmean refers to the central mean operation and y′(k) is the filtering result of the left neighboring pixel of x(k). The new nonlinear MTS filter is defined as y(k)=αx(k)+(1–α) Cmean f(k) where the coefficient α □is 0 or 1. The coefficient α □is determined by the binary noise flag map B(i, j) at x(k). If B(i, j) is 1, the pixel x(k) is noise, the coefficient α is set to 0, and the output y(k) of the noise filtering process is Cmean f(k). Otherwise, if B(i, j) is 0, the coefficient α □is set to 1 and the output y(k) is the identity x(k). The result is that the new MTS filter can suppress impulse noise without degrading the quality of the fine details.

RESULTS AND DISCUSSION

In this project, a set of 512×512 test CT mages corrupted with salt- pepper impulse noise are used. The influence of the number of thresholds and the threshold values Ti are first investigated. Image of different patients are taken and applied to wavelet based multiple threshold switching filters. Based on the heuristic approach, the threshold values are obtained experimentally for different test CT images. For the majority of images we tested, the most suitable threshold values employed by the MTS filter are approximately T1=20, T2=25, T3=30, T4=50, T6=60, T7=220 and T8=250 so that we can obtain the best results and highest PSNR values. However, the most suitable number of thresholds is 8.

Table 1: Comparison between MTS Filter and WMTS Filter.

Chest CT Image of Five Patients	**Multiple Threshold Switching Filter**				**Wavelet based Multiple Threshold Switching Filter**			
	MSE	PSNR	NMSE	IEF	MSE	PSNR	NMSE	IEF
Patient 1	158.143	26.1403	2.07171	0	14.7094	36.4549	3.13807	805.628
Patient 2	142.462	26.5938	2.41866	0	10.3755	37.9707	2.86405	884.646
Patient 3	90.8733	28.5464	2.14166	0	12.0905	37.3064	1.95762	1268.73
Patient 4	108.201	27.7885	7.28308	0	9.80526	38.2162	1.0637e	2335.33
Patient 5	114.125	27.557	1.40923	0	12.201	37.2668	2.4463e	1025.57

** MSE-Mean Square Error, PSNR-Peak Signal to Noise Ratio, NMSE-Normalized Mean Square Error, IEF-Image Enhancement Factor.*

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Table 2: *Results of Denoised CT Image of Five Patients.*

Chest Image of Five Patients	Noisy Chest CT Images of Five Patients	Wavelet based Multiple Threshold Switching Filter Output
Patient 1		
Patient 2		
Patient 3		
Patient 4		
Patient 5		

CONCLUSION

It is found that wavelet based multiple threshold filter performs significantly better than many existing, well-accepted decision-based methods in terms of multiple resolution, Mean Square Error, Peak Signal to noise ratio Image enhancement factor, Normalized Mean Square error. In future segmentation of CT image is performed and the segmented image is denoised.

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