Comparison and Denoising of OCT Images with Filters

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Abstract: ***Digital image processing involves various algorithms and mathematical operations to analyze or enhance the images. Several types of noises are induced into the images during image transmission or generation. Noises such as gaussian noise, salt & pepper noise, speckle noise and Poisson noise are generally present in most of the images. Different approaches like mean filter, median filter, mode filter, adaptive filter are also available in literature. In this course project, we are trying to analyze the effect of various types of noise on a retinal OCT image by adding different noises to the image and studying which filter is better at reducing different types of noise. Also, we are trying to reduce the noise already present in the OCT image by applying various filters. Quantitative analysis is performed by comparing the PSNR and SNR values.***

Keywords: OCT image, Filter, SNR, PSNR, Gaussian noise

1. Introduction

Optical Coherence Tomography (OCT) machine generates cross sectional images of tissue in the human eye with high resolution and is valuable in the assessment of different diseases related to retina. Compared to ultrasound imaging, OCT utilizes light rather than sound and OCT images have higher axial resolution. OCT is fiber optic based and can be associated with a number of medical devices.

OCT images often exhibit noises, and we can apply different image denoising techniques, for improving image quality. In this work we are trying to add different types of noises to OCT images and checking which filter is best in removing each type of noise.

The different noises added to OCT images are
- Gaussian Noise
- Salt and pepper noise
- Speckle Noise
- Poisson Noise

We tried to remove these noises by using
- Mean filter
- Median filter
- Mode filter
- Wiener filter
- Wavelet filter
- Non local means filter

We have also tried to remove the noise already present in the sample OCT images using different filters. The mean, median, mode and Wiener filter are implemented from scratch and when compared to the matlab built in functions, its results are less. This is because of the various optimization techniques used in the matlab built in functions.

Noises

Gaussian Noise (Amplifier Noise)
Gaussian noise is a type of statistical noise that follows a Gaussian or normal distribution. In the context of digital images, Gaussian noise manifests as random variations in pixel intensity values that are normally distributed. This type of noise is commonly encountered in various imaging and signal processing applications.

Salt and Pepper
Salt-and-pepper noise is a type of image noise characterized by randomly occurring white and black pixels, resembling grains of salt and pepper scattered on an image. This type of noise can significantly degrade the quality of an image and is often caused by various factors such as transmission errors in communication channels or faults in imaging sensors.

In an image affected by salt-and-pepper noise, some pixels have their intensity values set to the maximum (white pixels, often represented by 255 in an 8-bit gray scale image), while others have their intensity values set to the minimum (black pixels, often represented by 0 in an 8-bit gray scale image). The rest of the pixels retain their original intensity values.

Shot Noise (Poisson Noise)
Poisson noise is a type of statistical noise that follows a Poisson distribution. It is often observed in situations where events happen randomly and independently of each other over time or space. Poisson noise is particularly relevant in imaging applications where the detection of discrete events, such as the arrival of photons in a camera sensor, is involved.

Speckle Noise
Speckle noise is a type of noise that commonly occurs in images as a granular interference resembling grains or speckles. It can be caused by factors such as electronic interference, sensor limitations, or variations in the imaging medium. Speckle noise can affect the quality and clarity of an image, making it desirable to apply denoising techniques

to improve the overall visual appearance. Mathematically, speckle noise is often modeled as a multiplicative noise.

Filters

1) Mean Filter

One of the simplest spatial filtering operations. It replaces the Centre value of the window with the average values of its all nearest pixels together with itself.

Advantage:
- Easy to implement
- Used to remove the impulse noise.

Disadvantage:
- It does not preserve details of the image. Some details are removes of image with using the mean filter

2) Median Filter

Median filter is one of the most important filters to remove random valued impulse noise. In this filter the value of each pixel in a noisy image is replaced by the median value of the corresponding window. The median is calculated by first sorting all the pixel values into ascending order and then replacing the pixel being calculated with the middle pixel value.

3) Mode Filter

The mode filter in digital image processing is a non-linear filter that aims to enhance or modify an image by highlighting the most frequently occurring pixel values in a local neighborhood. Unlike some other filters that focus on central tendencies like means or medians, the mode filter is all about pixel popularity.

4) Wavelet Filter

The wavelet based filter normally performs the following functions

Wavelet Decomposition:

The input signal or image is decomposed into its wavelet coefficients using a specified wavelet. The choice of the wavelet determines the properties of the decomposition.

Thresholding:

After obtaining the wavelet coefficients, a threshold is applied to them. Thresholding involves setting coefficients below a certain magnitude to zero, effectively removing noise. This is a form of signal compression where small coefficients are considered as noise and discarded.

Wavelet Reconstruction:

The denoised wavelet coefficients are used to reconstruct the signal or image. The reconstructed signal should have reduced noise while preserving important signal features.

Choice of Threshold Value:

The threshold value needs to be carefully chosen based on the characteristics of the noise in the signal or image. The threshold is often determined through methods like Stein's Unbiased Risk Estimate (SURE) or cross-validation.

5) Non Local Means Filter

Non-Local Means Filtering:

Non-local filtering is based on the idea that similar patches in an image should have similar intensity values. Instead of averaging pixel values in a local neighborhood (as in traditional smoothing filters), non-local means filtering compares patches of pixels across the entire image.

Patch Matching:

The algorithm identifies similar patches in the image by computing the similarity between patches centered around different pixels. Similarity is typically measured using the Euclidean distance or other distance metrics.

Weighted Averaging:

Once similar patches are identified, the algorithm computes weighted averages of pixel values within these patches. The weights are determined by the similarity between patches. Patches that are more similar contribute more to the average.

Denoising:

The final result is a denoised image where each pixel value is a weighted average of the pixel values in similar patches. This process helps to preserve image structures while effectively reducing noise.

2. Comparison among filters - Denoising OCT images with matlab functions

The images after applying various filters are given below. A table comparing the PSNR and SNR values is also shown.

Table 1

	Mean Filter	Median Filter	Mode Filter	Wiener Filter	Wavelet Filter	Non Local Filter
PSNR	26.11	27.86	27.86	29.72	35	29.83
SNR	14.54	16.29	16.29	18.15	23.43	18.27

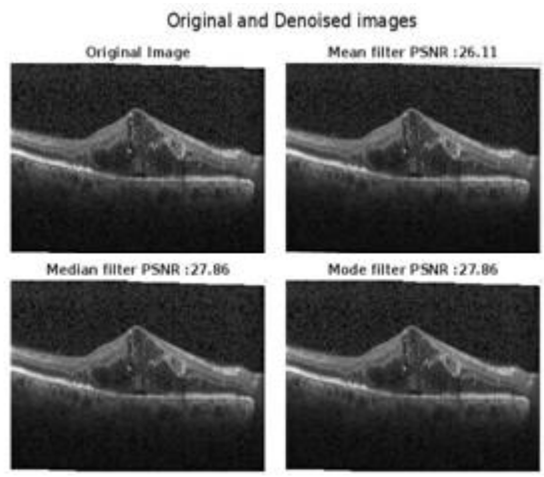

Figure 1: Comparison among filters - Denoising OCT images with matlab functions

3. Comparison among filters - Denoising OCT images without built-in functions

The mean, median, mode and Wiener filters are implemented from scratch and the images after applying these filters are shown below. A table comparing the PSNR and SNR values is also shown.

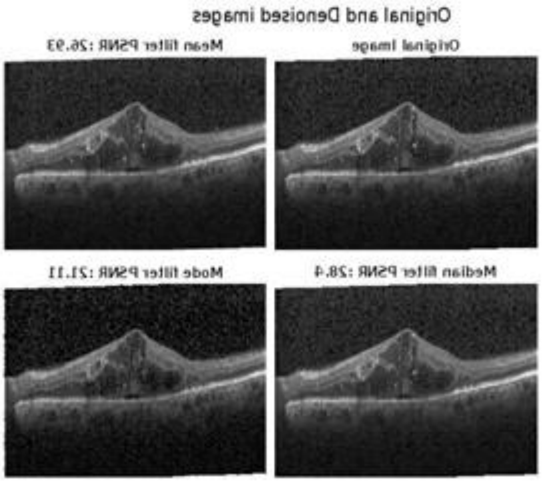

Figure 2: Comparison among filters - Denoising OCT images without built-in functions

Table 2

	Mean Filter	Median Filter	Mode Filter	Wiener Filter
PSNR	26.9291	28.3958	21.1050	24.6440
SNR	15.3538	16.8235	9.5328	13.0717

4. Comparison among filters - Adding noises to retinal OCT images

The following figure shows the original image and images after various noises are added.

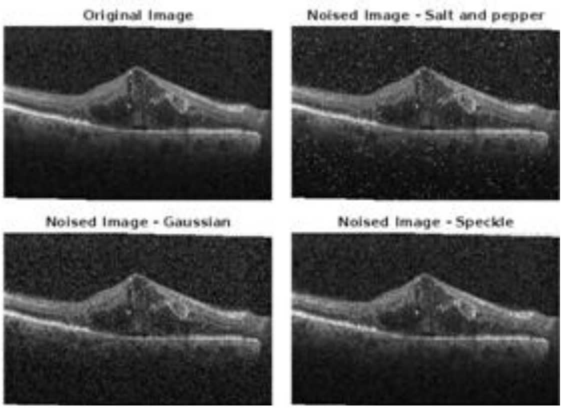

Figure 3: Comparison among filters - Adding noises to retinal OCT images

5. Results

After comparing the results obtained it is understood that for removing all types of noises Wiener filter is better except for salt and pepper noise. For salt and pepper noise both mode and median filters are giving better results. While denoising the images, Wavelet filter is showing a better result compared to other filters.

6. Conclusion

In the course project, we tried to analyze the effect of various types of noise on a sample retinal OCT image by adding different types of noises to the image and compared the results. Quantitative analysis is performed by comparing the PSNR and SNR values. The result shows that the Wiener filter is giving a better result when different noises are added to the image and then removed using various filters. For denoising the OCT image, Wavelet filter showed a better performance

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