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Comparison of wavelet transform methods and Gaussian filter for noise reduction in PET brain images and evaluation of sequence effect of using these methods in MATLAB

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Abstract
today Noise removal from medical images even with the advancement of technology is still a major challenge for researchers. Many algorithms for noise cancellation have been introduced, each with its own advantages and disadvantages. In this paper, after applying salt&pepper, Gaussian, Poisson and Speckle noise to the brain PET image, wavelet and Gaussian noise cancellation methods have been investigated by image quality evaluation parameters. The combination of these methods has also been investigated. In the meantime, the Gaussian smoothing filter has shown the best result in the SNR index, but this filter reduces the contrast compared to the wavelet, i.e. the edges in the image disappears. Also in the combination of these methods, as expected, the application of Gaussian filter and then wavelet transform to reduce noise and preserve the edges has shown better results of reverse configuration

Keywords: noise cancellation, wavelet, Gaussian filter, image processing, PET, brain

Introduction
The image noise cancellation process is a procedure in digital image processing that aims to eliminate noise generated during image acquisition and transmission while maintaining quality and details. MRI, CT and PET imaging modalities are the most common medical diagnostic tools, but their images are often affected by accidental Gaussian noise. The presence of noise impairs poor visual quality and reduces the visibility of low-contrast objects, resulting in diagnostic error[1]. Therefore, noise cancellation in medical imaging is necessary to improve and recover lost details [2]. However, the noise cancellation process should not significantly reduce the useful features of an image, i.e. its information. In particular, edges are important features for medical imaging, so noise removal should be balanced while maintaining the edges.

Materials and methods
As mentioned earlier, the purpose of removing noise from an image is to remove unwanted information while preserving useful information. There are various methods for noise cancellation which are generally divided into two categories: spatial domain transformations such as Gaussian filtering and frequency domain transformations such as wavelet transformations [3]. In this paper, two methods of noise cancellation for medical images wavelet and Gaussian filter are evaluated and compared.

To evaluate the efficiency of these methods, first salt and pepper, Speckle, Gaussian and Poisson noise were applied to the reference image and then the efficiency of these methods were evaluated by image quality parameters such as peak signal to noise ratio (PSNR) for noise estimation, mean square error (MSE) for error estimation, structure similarity index (SSIM) To compare the reference image with the noise canceled image, and standard deviation (STD) for contrast estimation[4].
Gaussian filters are a group of linear smoothing filters in the category of spatial domain transformations whose weight is selected based on the shape of the Gaussian function [5]. Loss of the edges of the image is a major problem in this method.
The Gaussian filter used has the following specifications:
Standard deviation of distribution(sigma); 0.6, size of filter 2*ceil(2*sigma)+1, image padding: replicate, filter domain: spatial
Wavelet transforms provide a framework for converting signals into low-frequency and high-frequency bands. In general, wavelet transforms are divided into continuous transformations and discrete transformations. We have used discrete wavelet transforms in this article. Wavelets are often used to remove noise from images, which include the steps: 1-Selecting the type and level of conversion 2- Determining the threshold values for each level 3- Reconstructing the image with reverse conversion [6].
The wavelet transform used has the following specifications:
Wavelet:bior4.4, denoising method: Bayes, threshold rule: median, colorspace: PCA, number of circular shift: 0, variance estimating method: level independent

Results

To investigate two noisSpecklellation methods in MATLAB on brain PET image(Figure 1) salt and pepper, Gaussian, speckle and Poisson noise were added to the reference image (Figure 2). The image quality evaluation results after noise application can be seen in Table 1.

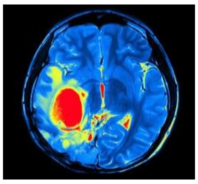

Figure 1 brain PET reference image

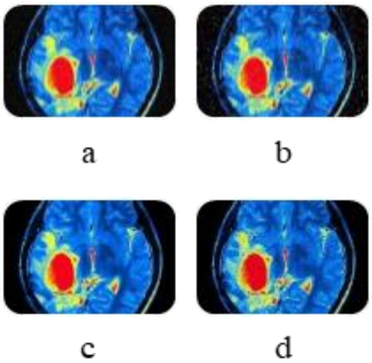

Figure 2 Noise images (a) Gaussian (b) Salt pepper (c) Poisson (d) Speckle

Table 1 Results of noise image quality evaluation

	Salt&pepper	Speckle	Speckel	poison	
PSNR	16.83	21.7	22.13	126.33	
STD	0.34	0.31	0.32	0.33	
MSE	0.0207	0.0068	0.0068	0.0002	
SSIM	0.55	0.58	0.96	1	

The results of evaluating the quality of noise-canceled images by Gaussian filter and Wavelet methods, as well as the effect of applying these two filters consecutively and the role of precedence and latency of applying these filters can be seen in Table 2.

Table 2 Results of image quality evaluation after noise cancellation

	Salt&pepper	Gaussian	Speckle	poison	
PSNR	18.30	25.94	22.47	54.69	Wavelet
STD	0.33	0.30	0.31	0.32	
MSE	0.0150	0.0250	0.0057	0.0003	
SSIM	0.56	0.63	0.95	0.99	
PSNR	20.2	24.52	25.23	36.97	Gaussian
STD	0.32	0.31	0.31	0.32	
MSE	0.0096	0.0035	0.0030	0.0002	
SSIM	0.60	0.61	0.98	0.99	
PSNR	21.55	26.03	25.39	25.39	Wavelet-Gaussian
STD	0.31	0.30	0.31	0.31	
MSE	0.0075	0.0025	0.0029	0.0029	
SSIM	0.61	0.63	0.97	0.97	
PSNR	22.37	26.30	25.37	25.37	Gaussian -wavelet
STD	0.31	0.30	0.31	0.31	
MSE	0.0073	0.0023	0.0029	0.0029	
SSIM	0.61	0.63	0.97	0.97	

Conclusion

In this paper, two methods of noise reduction have been studied. The Gaussian filter has shown the result of 20%, 13%, 14% noise reduction on salt and pepper, Gaussian and speckle noisy image, respectively, in Poisson noise, 56% of the increase in noise was observed, also wavelet method has shown the result of 9%, 19%, and 1.5% noise reduction on salt and pepper, Gaussian and speckle noisy image, respectively, in Poisson noise 70% of the increase in noise was observed The results of noise enhancement indicate that the application of noise cancellation filters on images without noise or with low noise similar to Poisson noise used leads to the opposite result, i.e. increase in noise in the processed image. Better Gaussian smoothing filter results in noise reduction, reducing contrast, and losing edges in the image. This led us to use a combination of these methods, which, as we expected, resulted in the application of a Gaussian filter in the first step to smooth the image and then the application of a wavelet to maintain the contrast of better inversion arrangements. the same results of combining algorithms in mild noise such as Poisson noise due to the fundamental difference between adding Gaussian noise and applying Poisson noise (which is Poisson noise is correlated with the intensity of each pixel and Gaussian noise is independent of the original intensities in the image) is interesting. It also seems that the use of artificial intelligence algorithms such as neural networks to find the optimal combination of noise-canceling filters has a high research value.

References

[1] Pawar, M., Sale, D. and DYPIT, P., *MRI and CT Image Denoising using Gaussian Filter, Wavelet Transform and Curvelet Transform*. IJECE, 7(5), pp.12013-12016.(2017)

[2] Soltanian-Zadeh, H., Windham, J.P., Peck, D.J. and Yagle, A.E., *A comparative analysis of several transformations for enhancement and segmentation of magnetic resonance image scene sequences*. IEEE transactions on medical imaging, 11(3), pp.302-318. (1992)

[3] Jiang, D., Zhuang, D., Huang, Y. and Fu, J., *Survey of multispectral image fusion techniques in remote sensing applications*. Image fusion and its applications, pp.1-23(2011)

[4] Ma, J., Ma, ,Y. and Li, C., *Infrared and visible image fusion methods and applications: A survey*. Inf Fusion, 45, pp.153-178 (2019)

[5] Wang, M., Zheng, S., Li, X. and Qin, X., *A new image denoising method based on Gaussian filter*. International Conference on information science, electronics and electrical engineering (Vol. 1, pp. 163-167).(2014)

[6] Raj, V.N.P. and Venkateswarlu, T., *Denoising of medical images usingdual-treee complex wavelet transform*. Procedia Technology, 4, pp.238-244.(2012)