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Denoising and Contrast Enhancement of CT Brain Image Using Median Filter and HE

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Abstract:
In current medical procedures, healthcare professionals possess various supplementary diagnostic instruments that offer immediate, and accurate results. The picture of the anatomical structure of the human body is mostly achieved by using Computed Tomography (CT), and X-ray images. These methodologies are widely employed and considered as essential tools in the field. In recent decades, numerous algorithms have been put forth to assist medical professionals in improving CT images for disease diagnosis purposes. The act of enhancing images has the potential to unintentionally intensify the presence of noise or introduce distortions, ultimately compromising the accuracy of diagnostic outcomes. Consequently, utilizing suitable methodologies to mitigate noise and amplify contrast efficiently is paramount to alleviate the adverse consequences. The algorithm presented in this paper utilizes linear and nonlinear filters, including mean and median filters, to achieve optimal results. The proposed algorithm effectively addresses the Salt and Pepper Noise (SPN) impact on CT brain pictures. This is achieved by utilizing the median filter, which enhances the overall image quality and conserves important structures, such as edges, at various intensity levels. Afterward, the contrast of the CT brain images is improved by utilizing an enhanced median filter. This is achieved by implementing the Histogram Equalization (HE) technique, and it is contrasted with the Adaptive Histogram Equalization (CLAHE) method. The effectiveness of the implemented enhancement techniques can be assessed by comparing their outcomes using the Peak Signal-to-Noise Ratio (PSNR) metric.

Keywords: CT brain image, SPN, Median filter, Contrast enhancement, HE.

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إزالة الضوضاء وتحسين التباين في صورة الدماغ المقطعية باستخدام مرشح المتوسط Median (filter) وتقنية تسوية المدرج التكراري (HE)

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الملخص:
في المجالات الطبية الحالية، يمتلك الاخصائيون مجموعة واسعة من أدوات التشخيص التكميلية التي تقدم نتائج فورية ودقيقة .يتم الحصول على الصور التركيب التشريحي للجسم البشري في الغالب من خلال استخدام الأشعة السينية، والتصوير بالرنين المغناطيسي(MRI) ، والتصوير المقطعي(CT) .في العقود الأخيرة، تم طرح العديد من الخوارزميات لمساعدة المهنيين في تحسين صور الأشعة المقطعية لأغراض تشخيص الأمراض بدقة عالية. إن عملية تحسين الصور لديها القدرة على تكثيف وجود الضوضاء عن غير قصد أو إحداث تشوهات، مما يؤدي في النهاية إلى حدوث خطأ في نتائج التشخيص الطبي وبالتالي، فإن استخدام المنهجيات المناسبة للتخفيف مثل هذه الضوضاء وزيادة التباين بكفاءة له أهمية قصوى في تقليل احتمالية حدوث هذه الأخطاء في التشخيص. الخوارزمية المقترحة في هذه الورقة مبنية على استخدام المرشحات الغير الخطية ومقارنتها بالمرشحات الخطية لإزالة الضوضاء من نوع الملح والفلفل(SPN) بنسب مختلفة من على صور الدماغ المقطعية لتحسين جودة الصورة مع الحفاظ أيضًا على الهياكل المهمة للصورة، مثل الحواف وايضا تحسين التباين للصور الداكنة من خلال تطبيق التقنيات التباين مثل تسوية المدرج التكراري محدود التباين (CLAHE)، مقارنتها بتقنية بتسوية المدرج التكراري (HE). أظهرت النتائج أن المنهجية المتضمنة تطبيق مرشح الغير خطي نوع المتوسط وتقنية HE حققت دقة أعلى مقارنة بالمرشح الخطي وتقنية CLAHE.

الكلمات المفتاحية: صورة الدماغ المقطعية، ضوضاء نوع ملح وفلفل، المرشح المتوسط، تحسين التباين، تسوية المدرج التكراري.

1. Introduction

Medical images are frequently impacted by noise due to image acquisition and transmission from medical modalities to the main computer system. The presence of noise in medical images can significantly impact their visual quality, thereby hampering the accuracy of diagnoses. Image de-noising techniques have been widely employed in medical image processing to address this issue. These techniques aim to enhance the efficiency of diagnosing procedures by improving the clarity and accuracy of the images. Image de-noising is a crucial aspect of image processing and recognition, as it falls under the broader category of image restoration. Restoration techniques' primary objective is to enhance an image's quality according to predefined criteria. Therefore, de-noising plays a pivotal role in this process [1].

The de-noising process reduces noise elements in the noisy image while maintaining its crucial features, such as edges, corner points, and more [3]. Researchers continue to face the persistent challenge of image de-noising due to the introduction of artifacts and blurring caused by noise removal [4]. The paper authored by [3] presents a novel de-noising filter for the brain image. This filter is derived from the concept of an established bilateral filter and aims to produce a clear and smooth image while also maintaining the original features and edges [3]. In their study, a weighing function is implemented to regulate the influence of bilateral filters for de-noising. This function is dependent on the "Rough Edge Map (REM) and Rough Class Label (RCL)" [3]. According to [2], a" Recursive Mean Filter (RMF)" was proposed to eliminate" Salt Paper Noise (SPN)". It compared the effectiveness of RMF with similar methods such as "Decision-Based Algorithm (DBA)" [2]. The analysis conducted by Ashish, investigated de-noising techniques, including "Spatially Adaptive Nonlocal Means (SANLM) " to eliminate SPN from brain images effectively [3].

The objective of this paper is to remove the SPN from the CT brain pictures by implementing two different types of filters, linear and nonlinear. The nonlinear filters like median filter provide a more sophisticated technique for enhancing the pictures as opposed to linear filters like mean filters which often result in the blurring of edges and intricate details within the images. These filters effectively eliminate impulsive noise, such as SPN, while preserving edges and image details. Among the different types of nonlinear filters, median filters have demonstrated superior performance in removing SPN. A filtering scheme is implemented using a median filter and applying contrast enhancement techniques such as HE, and CLAE respectively [10,11]. Furthermore, the efficacy of the implemented enhancement techniques can be assessed by conducting a comparative analysis of their outcomes using the PSNR evaluation [12].

2. Material and methods

A Proposed method is visually represented in Figure 1 through a flow chart consisting of four essential components: a noisy CT brain image by SPN, de-noising filters by median filter and mean filter, contrast enhancement techniques via HE and CLAE, and a comparative analysis is conducted to compare the outcomes, utilizing the PSNR evaluation. A detailed explanation of each part is provided in the subsequent subsections of the methodology.

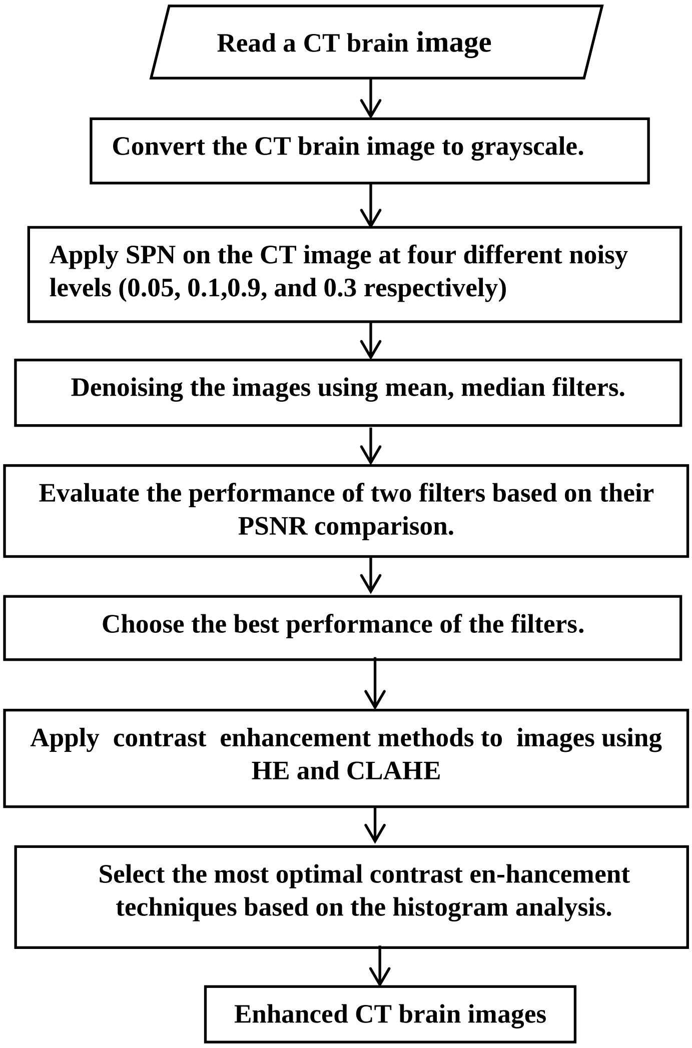

Figure 1 A schematic diagram presenting the proposed work.

2.1 Denoising filters:

2.1.1 Median Filter:

The median filter is frequently employed for eliminating the noise from images, similar to the Mean filter. Nevertheless, it often outperforms the Mean filter in terms of retaining valuable details within pictures. Its algorithm systematically evaluates all pixels in an image and determines the compatibility with its immediate neighbors [5, 6]. The output of the Median filter is indicated by equation (1) [7].

$$O(x,y) = med\{\, I(x-i, y-j), j \ \in w\} \qquad (1)$$

Where I (*x*, *y*), and *O* (*x*, *y*) denote input and output images respectively. While two-dimensional mask is indicated by W. The mask can take various shapes, including linear, square, circular, cross, and others with odd number size such as3x3, 5x5, and so on [8,14].

The procedure for implementing the median filter algorithm involves moving a mask or window with an odd dimension size 3 by 3 across the image. At each window position, the values of the image are arranged in order, and subsequently, the median value replaces the value located at the center of the window, as illustrated in Figure 2, the procedure are repeated to process all pixels in the input image.

….	….	….	….	….
….	10	8	23	….
….	15	**60**	14	….
….	9	11	21	….
….	….	….	….	….

(a)

….	….	….	….	….
….				….
….		**14**		….
….				….
….	….	….	….	….

(b)

8	9	10	11	14	15	21	23	60

(c)

Figure 2 showcases the selected window, as depicted in Figure (2, a), whereas Figure (2, b) exhibits the median filter procedures. Within these procedures, the original median value of 60 has been substituted with a value of 14. This particular value is determined by organizing the pixels of the image sequentially, as demonstrated in Figure (2, c).

2.1.2. Mean filter:

The mean filter is a fundamental technique employed for noise reduction. The procedure involves calculating a mean value of all pixels through the surrounding area of each pixel (m, n) in the de-noised image x. This process is illustrated by equation (2) [9,10]:

$$\forall\, m,n \quad \hat{x}\,(m,n) = \frac{1}{|V_{m,n}|} \sum(u,v) \,\in\, V_{m,n} \;\; y(u,n) \qquad (2)$$

The neighbourhood, denoted as $\boldsymbol{V_{m,n}}$, refers to pixels surrounding the coordinates (m, n). The cardinality of $\boldsymbol{V_{m,n}}$, represented as $\left|\boldsymbol{V_{m,n}}\right|$, corresponds to the pixels in the neighborhood.

Figure 3 shows an example of applying mean filter, the initial value of the pixel at the center is 60. However, this pixel undergoes filtering, resulting in its replacement with the average value (19) derived from the surrounding nine pixels [15]. The mean value is as stated below:

$$(10 + 15 + 9 + 8 + 60 + 11 + 23 + 14 + 21)/9 = 19$$

….	….	….	….	….
….	10	8	23	….
….	15	**60**	14	….
….	9	11	21	….
….	….	….	….	….

(a)

….	….	….	….	….
….	10	8	23	….
….	15	**19**	14	….
….	9	11	21	….
….	….	….	….	….

(b)

Figure 3 Mean filter processing, where the average value (19) has replaced the initial value of the pixel at the center, which was 60.

2.2 Contrast Enhancement Methods

2.2.1 Histogram equalization:

"Histogram equalization (HE)" is particularly beneficial in medical image applications as it effectively enhances global contrast, particularly in cases where the desired region and background exhibit similar contrast values. By modifying the intensity values, the HE significantly improves the brightness and contrast of low-contrast images, aligning the histogram of the resulting image with a predetermined histogram [10].

2.2.2 Contrast-limited adaptive histogram equalization:

"Contrast-Limited Adaptive Histogram Equalization (CLAHE)", is a widely employed technique in the field of medical image processing to improve contrast [9].It aims to improve the contrast resulting in an output with a histogram that closely resembles a specified histogram. After the equalization process, neighboring is smoothly merged through the utilization of bilinear interpolation, effectively removing any boundaries that may have been artificially caused [11].

2.3 Peak Signal-to-Noise Ratio Performances:

The "Peak Signal-to-Noise Ratio (PSNR)" method is utilized to evaluate the quality of an image. This method accurately assesses the quality by determining the ratio between the peak signal power and the noise power. The PSNR can be mathematically represented by the following equations [12,8].

$$PSNR = 10\ log_{10}\left(\frac{255^2}{MSE(X,Y)}\right) \quad (3)$$

MSE is also known as "Mean Squared Error," is a quantitative measure employed to evaluate the squared difference between the noisy image and the image obtained after noise reduction, and noisy image, enhanced image are represented by *X, and Y* respectively[13].

3. Results and discussion

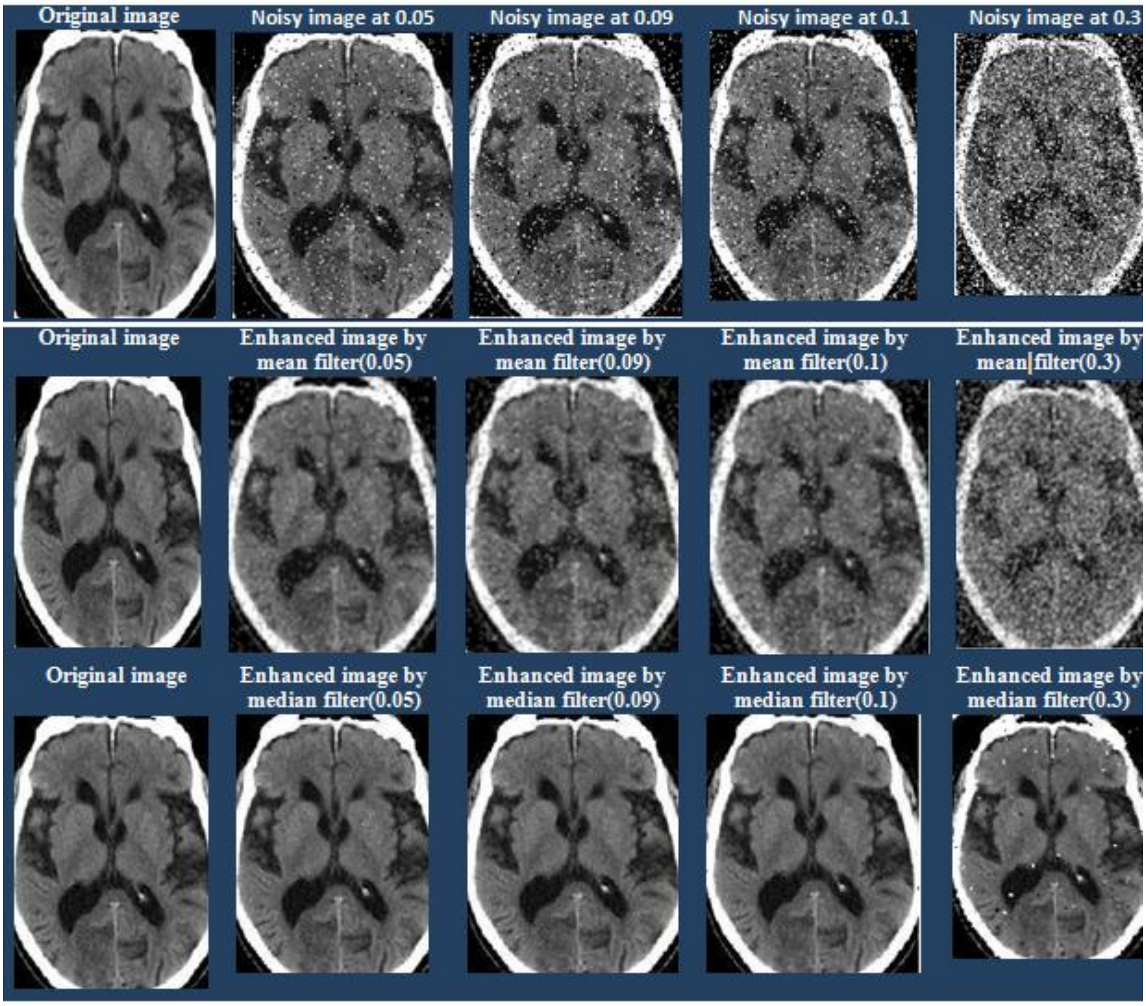

Figure 3 CT brain images, which initially affected by noise at varying levels of SPN at (0.05, 0.09, 0.1, and 0.3, respectively), de-noised CT brain images based on mean filter, and median filter respectively

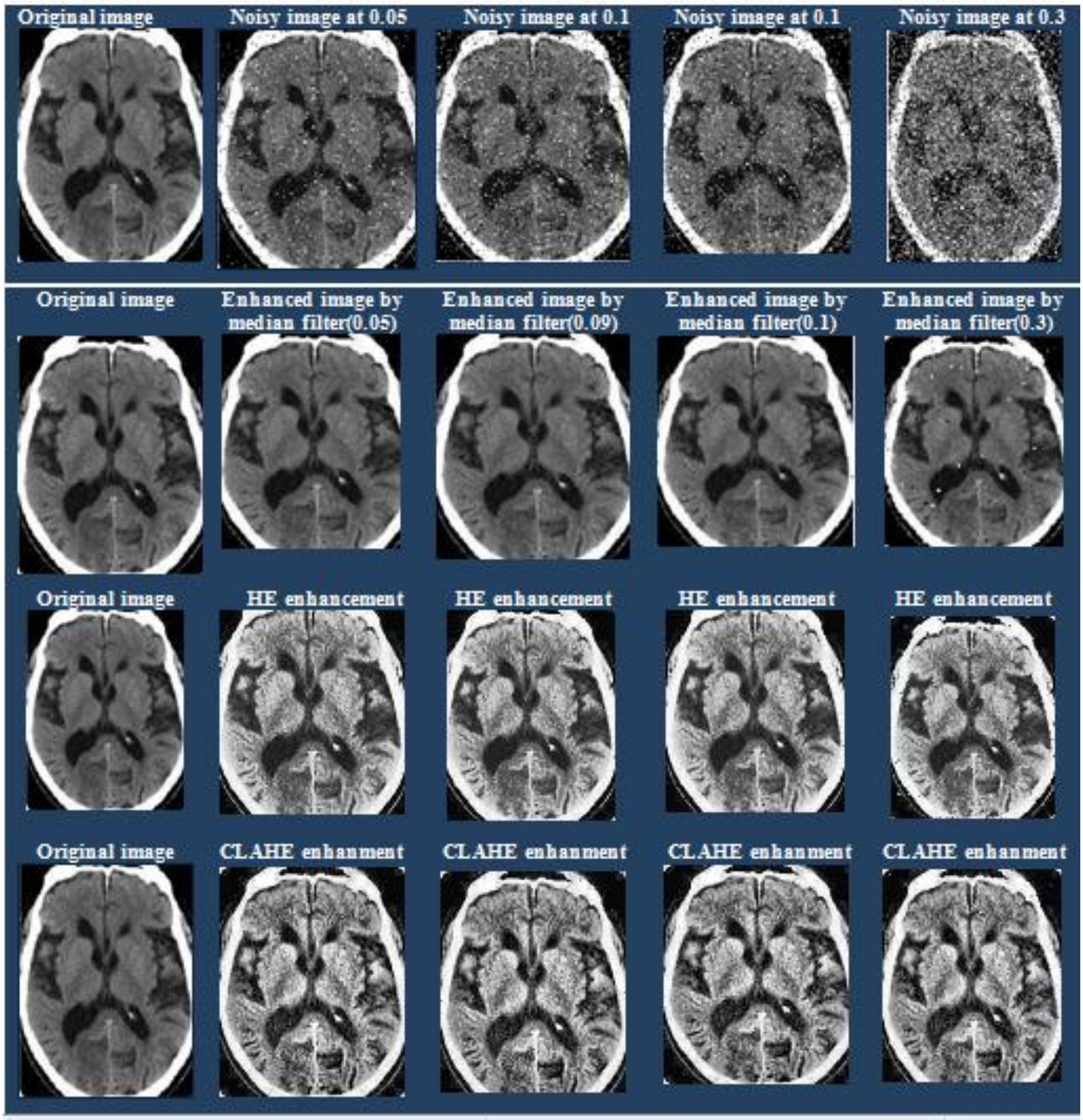

Figure 4 A comparative analysis of the contrast enhancement techniques of HE and CLAHE based de-noised CT images by median filter.

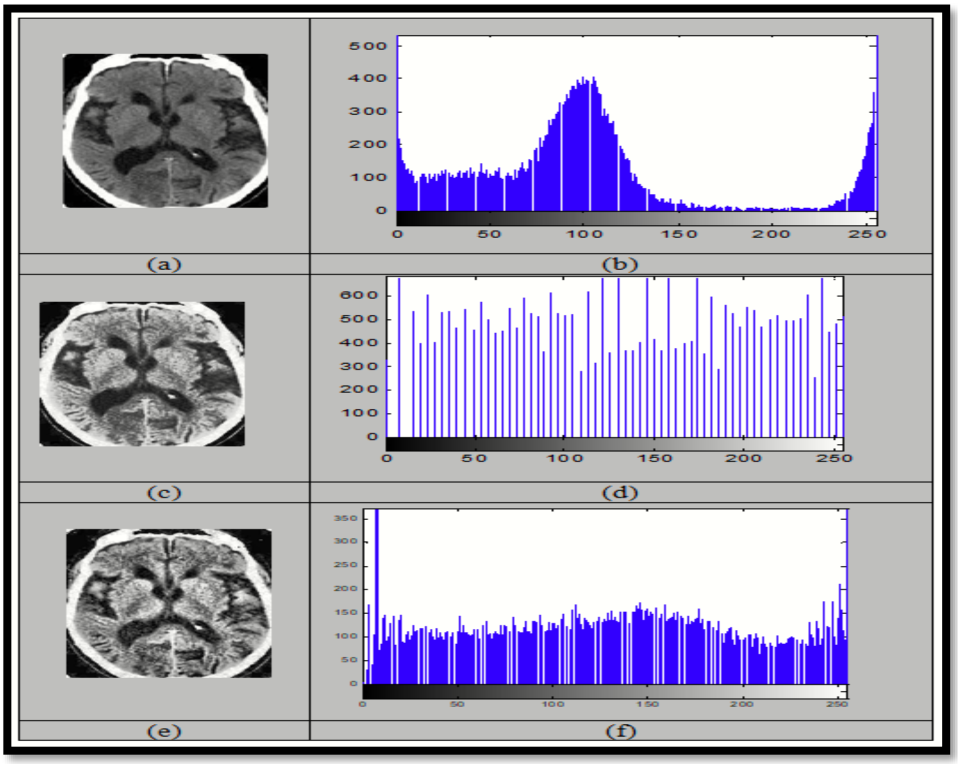

Figure 5 CT brain images; (a): low contrast of the de-noised image at (0.3) by the median filter; (b): Input image histogram; (c): Enhanced contrast of de-noised CT brain image by HE; (d): HE histogram of enhanced image; (e): Enhanced contrast of de-noised CT brain image using CLAHE; (f): CLAHE histogram of enhanced CT brain image.

Based on the data presented in Figure 5, it appears that the CT brain image depicted in Figure 5(a) exhibits low contrast. This is evidenced by the histogram in Figure 5 (b), which displays intensity values confined to the range's middle section. In Figure 5(c), the image exhibits a high contrast, resulting in brighter highlights and darker shadows. This is further illustrated by the histogram displayed in Figure 5 (d). The image depicted in Figure 5(e) exhibits a heightened contrast, as evidenced by its histogram intensity values that extend the complete intensity range [0, 255] illustrated in Figure 5(f).

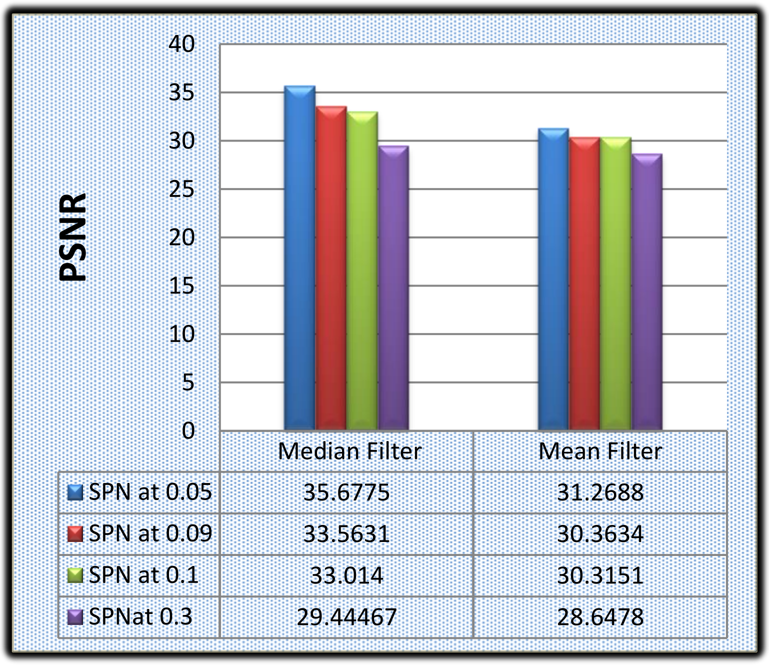

Figure 6 PSNR results of de-noised CT brain images based on mean and median filters.

According to the experimental and mathematical findings depicted in Figures 4 and 6, it has been ascertained that Median filter outperforms Mean filter in effectively reducing SPN. Furthermore, in terms of PSNR performance, the median filter outperforms the mean filter.

4. Conclusion

Eliminating noise from medical images is challenging due to the presence of random and deterministic noises in the environment and medical imaging system. Additionally, the absence of information regarding the noise variance further complicates the process. This paper primarily concentrates on the type of noise known as SPN. The mean and median filters are applied to eliminate the noise from CT brain images. The purpose is to facilitate the comparison of the obtained results. From the experimental results and evaluation performance using PSNR, the CT noised images acquired through the median filter exhibit a noise-free appearance and closely resembles high-quality images. Furthermore, the enhanced CT brain images exhibit improved contrast through the utilization of HE and CLAHE. Finally, the CT brain images are enhanced by employing a median filter in conjunction with HE.

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