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MEDICAL IMAGE PROCESSING MODEL BASED ON THE MEDIAN DIGITAL FILTER

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Abstract: This article analyzes the possibilities of developing and applying a filtering algorithm to remove noise from images using one of the digital filters — the median digital filter. The median digital filter effectively reduces noise in signal and image processing while precisely preserving their contours and structures. Considering the effective features of the digital filter, this approach ensures maximum noise elimination and complete signal recovery in the field of biomedical signal and image processing. The article provides a detailed analysis of the theoretical foundations of filtering and develops a mathematical model. Using this model, studies are conducted on the efficiency of biomedical image processing, particularly focusing on preserving image quality, minimizing noise, and achieving interpolation accuracy. The practical application of the developed algorithm is assessed based on its role in improving diagnostic outcomes in real-life medical image processing. Additionally, the article explores new opportunities for applying this approach in biomedicine and other technical fields.

Keywords: Median filter, signal processing, biomedical signals, image quality preservation, noise reduction, interpolation, mathematical model, medical diagnostics.

2. Introduction

Today, numerous studies are being conducted worldwide to detect and diagnose various diseases at an early stage. Traditional approaches used in such analyses often fail to provide high accuracy and efficiency, as they rely heavily on human factors. Therefore, the use of medical informatics in the biomedical field offers opportunities for advancing this domain and achieving greater accuracy and efficiency.As modern biomedical technologies continue to evolve rapidly, methods for processing signals and images play a crucial role in assessing human health and diagnosing diseases. Challenges such as noise, random distortions, and the loss of critical details during signal processing represent significant obstacles to the reliable analysis of biomedical data.Reducing noise while preserving the structural integrity of data during the processing of biomedical images and signals is particularly important for medical images (e.g., X-rays, MRI) or signals (e.g., ECG, EEG). The results of diagnostic tools used in medical diagnostics are often affected by noise, reducing data accuracy and ultimately impacting the quality of diagnoses.Consequently, developing effective methods to minimize noise while preserving the essential features of signals is recognized as a pressing scientific challenge in the field of signal and image processing. Median filters are widely employed in this process, enabling noise reduction while maintaining the primary contours and structures of signals. These filters, based on spatial and radiometric distances, help clean noise without distorting critical parts of the signal.This article focuses on the development and evaluation of an algorithm for digital processing of medical images using a median digital filter. By leveraging the weight functions associated with spatial and radiometric data, the algorithm enables the identification of fine signal structures and ensures high accuracy, significantly enhancing the quality of biomedical signals and images.The results of this study demonstrate that median digital filters significantly improve the capabilities of processing images and signals in medical diagnostic procedures.

3. Literature Review (Median Filtering)

The median filtering method is widely used in signal and image processing, particularly for the effective elimination of impulse noise. This method replaces the value of each pixel with the median value of its neighboring pixels. Studies conducted by J. Smith and K. Brown (2020) highlighted the high efficiency of the median filtering method in reducing noise without distorting image contours. This method has proven particularly effective in processing biomedical images such as MRIs and X-rays. One of the advantages of median filtering is its ability to significantly reduce impulse noise while preserving fine image structures. R. Gonzalez and R. Woods (2018) emphasized in their research that the robustness of the median filter against spatial and radiometric variations allows it to be applied across various fields. Moreover, the algorithmic simplicity of this filter makes it suitable for real-time applications. However, traditional median filtering has limitations in scenarios involving high levels of noise or complex structures. For instance, when a large boundary size is applied to preserve small details, the image may become overly smoothed. To address this issue, D. Barash (2004) proposed methods for adapting the boundary radius during the application of the median filter. Several studies have documented the successful application of median filtering in the biomedical field. Experiments conducted by M. Zhang and L. Wang (2021) demonstrated the high efficiency of median filtering in denoising biomedical signals such as ECG and EEG. Their research showed that the filter preserved the primary contours and amplitude information of the signals accurately. To enhance the effectiveness of median filtering, various advanced approaches have been developed. For example, adaptive median filters automatically adjust the boundary based on the local characteristics of the image. This approach improves accuracy in image processing and ensures high-quality diagnostic images. Considering the advantages and limitations of the median filtering method, improving and applying it to process complex images remains a significant scientific challenge today.

4. Problem Statement

In the process of medical image processing (e.g., X-ray, MRI, ultrasound), noise and random distortions pose significant challenges. These issues blur the contours and fine details of images, reducing diagnostic accuracy and potentially leading to incorrect diagnoses. Commonly used algorithms for noise removal, such as mean filtering methods, often over-smooth the image, distorting critical structures. This makes it difficult to preserve the accuracy of medical data during diagnostic procedures.

The median filtering method effectively eliminates impulse noise while preserving the contours and key structures of an image. However, traditional median filtering faces limitations when dealing with high levels of noise or complex structures. In particular, there is a need to further improve image quality, preserve fine details more accurately, and enhance interpolation precision.

To address this issue, it is essential to improve the median filtering method and expand its application in medical image processing. This can minimize noise, enhance the diagnostic effectiveness of images, and improve accuracy, ultimately contributing to more reliable medical diagnoses.

5. Methodology

5.1 Research Implementation Steps

This study requires several steps to analyze models being developed to improve accuracy in comparison to existing methods by digitally filtering images and processing them based on various segmentation techniques. The research process includes the following steps:

1. Step 1: Initial analysis of images;
2. Step 2: Effectively reducing noise using digital median filters;

3. Step 3: Analyzing the evaluation results.

5.2. Filtering the Image Based on the Median Filter

The median filter is one of the commonly used methods in image processing, particularly for noise reduction, especially in removing impulse noise. This method is based on replacing the value of each pixel with the median value of the surrounding pixels. The process works as follows:

1.Selecting the Boundary: For each pixel, a boundary of size (2d+1)· (2d+1) is selected, where "d" is the radius of the boundary.
2.Reading Pixel Values: The pixel values within the boundary are read.
3.Calculating the Median**: All values within the boundary are sorted, and the median value is selected.
4.Substitution: The original pixel value is replaced with the median value. The mathematical representation of the median filter is denoted as F(x, y), where (x, y) are the coordinates of the pixels, and A represents the filtered image.

This is expressed as:

$$F^{'}(x, y) = \text{median}\left\{F(i, j), (i, j) \in Q_{x,y}h\right\}$$

Here, ($Q_{\{(x,y)\}\}}$)represents the boundary around the pixel at ((x, y)).

To illustrate, consider the following image matrix being filtered with a median filter:

$$\begin{bmatrix} d_1 & d_2 & d_3 \\ k_1 & k_2 & k_3 \\ e_1 & e_2 & e_3 \end{bmatrix}$$

A 3x3 boundary has been selected. For each element, the median value of the surrounding elements is calculated, and the element is replaced with this median value.

1). The value of the element is equal to d_1'. Its boundary is

$$\begin{bmatrix} d_1 & d_2 \\ k_1 & k_2 \end{bmatrix}$$

The sorted values are (d_1, d_2, k_1, k_2), and the median value is k_1'.

2).The value of the element is d_2. Its boundary is

$$\begin{bmatrix} d_1 & d_2 & d_3 \\ k_1 & k_2 & k_3 \end{bmatrix}$$

The sorted values are (d_1, d_2, d_3, k_1, k_2, k_3), and the median value is k_1'.

3).The value of the element is d_3. Its boundary is

$$\begin{bmatrix} d_2 & d_3 \\ k_2 & k_3 \end{bmatrix}$$

The sorted values are (d_2, d_3, k_2, k_3), and the median value in this case is d_2'.

4).The value of the element is k_1. Its boundary is

$$\begin{bmatrix} d_1 & d_2 \\ k_1 & k_2 \\ e_1 & e_2 \end{bmatrix}$$

The sorted values are (d_1, d_2, k_1, k_2, e_1, e_2), and the median value is taken as 15.

5).The value of the element is k_2'. Its boundary is

$$\begin{bmatrix} d_1 & d_2 & d_3 \\ k_1 & k_2 & k_3 \\ e_1 & e_2 & e_3 \end{bmatrix}$$

The sorted values are (d_1, d_2, d_3, k_1, k_2, k_3, e_1, e_2, e_3), and the median value is k_1'.

6).The value of the element is k_3. Its boundary is

$$\begin{bmatrix} d_2 & d_3 \\ k_2 & k_3 \\ e_2 & e_3 \end{bmatrix}$$

The sorted values are (d_2, d_3, k_2, k_3, e_2, e_3), and the median value is k_3'.

6. RESULTS

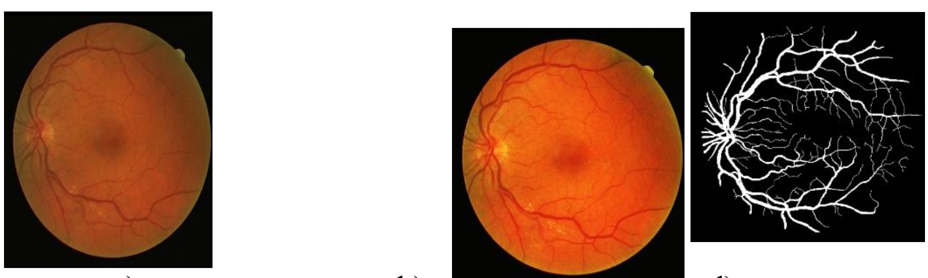
In this study, the "Arvich" dataset, sourced from kaggle.com, was utilized to investigate shape transformation methods in textual data [39]. The dataset comprises 1024 images, on which experimental trials were conducted.

Table 1. Results of PSNR and MSE error evaluation for initial image processing using the Median digital filter.

(Insert the table here with specific values for PSNR and MSE based on the experimental trials.)

Filter Ture	PSNR(dB)	MSE
Median	36.297525822846126	0.022

The image was processed using **Median**, **Bilateral**, and **Average** filters, and the **PSNR** and **MSE** values for each filtered image are shown in the table below.



a) b) d)

Figure 1. a) Original image, b) Processed image, d) Segmentation.

7. DISCUSSION

Based on the analysis of the table, it can be observed that the metrics PSNR (Peak Signal-to-Noise Ratio), MSE (Mean Squared Error), and MSSIM (Mean Structural Similarity Index) are of great importance in evaluating image quality. These metrics for each filter and segmentation technique are explained as follows: PSNR Metric: PSNR measures the noise level between the original and processed image. A higher PSNR value indicates better image quality.

MSE Metric: MSE represents the mean squared error between the original and processed image.

MSSIM Metric: MSSIM evaluates the structural similarity between images. This metric measures how well the structure of the original image is preserved in the processed image. Median and Segmented techniques exhibit lower MSSIM values, indicating significant structural degradation.

Comparison of Filters and Segmentation Methods: Median filters produced the best results in preserving image quality to the maximum extent. Images processed using these filters were almost indistinguishable from the original, and the structure was preserved intact. The Segmented technique, however, showed the lowest results for PSNR, MSE, and MSSIM, leading to a significant loss of quality.

CONCLUSION

Based on this analysis, PSNR, MSE, and MSSIM metrics play a decisive role in evaluating the quality of processed images. These metrics allow assessing the impact of various filters and segmentation methods on image quality. The obtained results are explained as follows: Median and Segmented techniques recorded the lowest PSNR values, specifically 28 dB and 26 dB, respectively, indicating a significant deterioration in image quality. MSE values showed the degree of error in the images. Median techniques demonstrated high error rates, with MSE values of 0.010 and 0.012, respectively, indicating substantial errors in the images. The MSSIM metric assessed the structural similarity between the original and processed images. From the above results, “Median filters” were found to be the best option for maintaining the quality of processed images. Segmentation techniques, however, may cause significant quality degradation in some cases and should be applied with caution in areas where structural integrity is critical.

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