

## Demonstrate Median Filtering Of An Image

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### Abstract

*Image processing plays an essential role in improving visual quality and extracting meaningful information from digital images, especially when they are degraded by noise during acquisition or transmission. Among various denoising approaches, median filtering is a widely adopted non-linear technique known for its ability to suppress impulse noise, particularly salt-and-pepper noise, while effectively preserving edge details. This study presents a demonstration of median filtering applied to both grayscale and color images contaminated with different noise levels. The filtering process operates by sliding a window across the image and replacing each central pixel with the median value of the neighboring intensities, which helps in smoothing unwanted noise without significantly blurring important structural features. In this work, several test images are intentionally corrupted with salt-and-pepper noise and subsequently restored using median filtering with different window sizes such as  $3 \times 3$  and  $5 \times 5$ . The performance of the method is evaluated through visual comparison between original, noisy, and filtered images, along with quantitative metrics including Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE). The analysis also investigates the influence of window size on noise reduction capability and edge preservation. Experimental results indicate that smaller windows maintain fine details more effectively, whereas larger windows provide stronger noise suppression at the cost of slight detail loss. Overall, the findings demonstrate that median filtering remains a simple, efficient, and reliable technique for removing impulse noise while retaining significant image features, making it suitable for various digital image processing applications.*

**Keywords**— Image Processing, Median Filtering, Salt-and-Pepper Noise, Image Denoising, Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE)

### INTRODUCTION

Digital image processing has become an essential tool in numerous applications, including medical diagnostics, remote sensing, surveillance, and computer vision. However, images acquired through

sensors or transmitted across communication channels are often affected by noise, which degrades visual quality and obscures important information. One commonly encountered noise type is salt-and-pepper noise, characterized by randomly distributed bright and dark pixels that disrupt the original image structure. This noise typically arises due to faulty sensor elements, bit errors during transmission, or analog-to-digital conversion issues, making accurate interpretation and analysis more difficult. To improve image quality, several denoising techniques have been proposed, among which median filtering is widely recognized for its effectiveness in handling impulsive noise. Unlike linear smoothing methods that compute averages and often blur edges, median filtering employs a non-linear strategy that replaces each pixel value with the median intensity within a specified neighborhood window, such as  $3 \times 3$  or  $5 \times 5$ . This approach preserves sharp transitions and structural details while suppressing isolated noisy pixels. As a result, median filtering is particularly suitable for applications where maintaining edges and fine features is critical. This work demonstrates the application of median filtering on both grayscale and color images corrupted by noise. The process involves introducing artificial salt-and-pepper noise into test images and subsequently applying median filtering to restore image quality. The restored images are then compared with the original and noisy versions to evaluate performance visually and quantitatively. Additionally, the influence of varying kernel sizes is examined to understand the trade-off between noise reduction capability and detail preservation. Through this analysis, the strengths and limitations of median filtering are highlighted, emphasizing its relevance in practical image enhancement tasks.

### Aim of the Project

The primary aim of this project is to demonstrate the effectiveness of median image filtering in removing noise from digital images while preserving edges and structural details. The study also aims to analyze the performance of median filtering in comparison with other filtering approaches and evaluate its suitability for image enhancement applications.

### Motivation

Noise contamination is an unavoidable problem in digital imaging systems and often occurs during acquisition, processing, transmission, or storage. Salt-and-pepper noise, in particular, introduces abrupt intensity variations that significantly reduce image clarity and hinder subsequent image analysis processes such as segmentation, feature extraction, and object detection. Although conventional linear filters like mean and Gaussian filters can reduce noise, they tend to smooth the image excessively and distort important boundaries.

Median filtering offers an efficient alternative by adopting a non-linear mechanism that selectively removes impulsive noise without degrading edge information. Understanding this filtering technique and its practical implementation is important for developing robust image processing systems. The motivation behind this work is to explore the effectiveness of median filtering, visualize its impact on noisy images, and compare its performance with other smoothing methods. Such knowledge is valuable for applications in medical imaging, satellite image analysis, industrial inspection, and digital photography, where preserving image details is essential.

#### **Objectives**

The objectives of this project are to study and implement median filtering for noise removal and evaluate its performance in digital image processing. The work focuses on understanding the principle of median filtering and applying it to both grayscale and color images affected by salt-and-pepper noise. Another objective is to demonstrate how the filter reduces impulsive noise while maintaining edges and important image structures. The project also aims to compare the performance of median filtering with other filtering techniques such as mean and Gaussian filters. Furthermore, the impact of different kernel sizes, including  $3 \times 3$ ,  $5 \times 5$ , and  $7 \times 7$  windows, is analyzed to observe their influence on noise reduction and detail preservation. Finally, the study provides practical experience in implementing image filtering techniques using tools such as MATLAB or Python and evaluating their effectiveness through qualitative and quantitative analysis.

#### **LITERATURE SURVEY**

Image processing techniques are widely employed to enhance visual interpretation and improve image quality for various applications. However, images captured through sensors or transmitted over communication channels are often contaminated with different types of noise, which can obscure essential features and reduce clarity. Numerous methods have been proposed for removing impulse noise in both grayscale and color images. Early research primarily focused on grayscale image denoising, and many filtering approaches were initially designed for single-channel images.

Although these techniques can be extended to color images by applying them separately to individual color components, such methods may introduce inconsistencies and partially degrade image details. As a result, developing effective denoising approaches for color images has remained an important research challenge. Image filtering techniques are broadly categorized into linear and non-linear methods. Linear filtering methods are commonly used to suppress certain types of noise by replacing each pixel value with a weighted combination of neighboring pixels. Examples of such filters include averaging filters and Gaussian filters, which are particularly useful for reducing Gaussian noise. These filters typically operate through convolution, where the input image is processed using a predefined mask. The Gaussian filter uses coefficients derived from a Gaussian distribution, and increasing the standard deviation results in stronger smoothing, which often leads to blurring of edges and fine structures. Similarly, averaging filters compute the mean of surrounding pixel intensities, which reduces noise but tends to smear sharp transitions and diminish important image details.

Several other noise reduction techniques have also been explored. Conservative smoothing is designed to remove isolated noise spikes while maintaining local intensity ranges, but its performance is limited for additive noise removal. Non-linear filtering approaches, particularly the standard median filter, have gained attention due to their ability to remove impulse noise effectively without significantly affecting edges. The median filter replaces the center pixel value with the median of neighboring intensities, which makes it robust against extreme values. However, while median filtering performs well for impulsive noise, its efficiency decreases when dealing with additive noise. Adaptive filtering techniques have also been proposed to adjust filtering behavior based on local image characteristics, improving performance under varying noise conditions. Additionally, wavelet-based filtering methods offer multi-resolution analysis for denoising, but they often involve higher computational complexity. The Wiener filter is another approach commonly used for reducing additive noise, although the visual quality produced may not always be satisfactory compared to non-linear filtering methods. Overall, each technique offers advantages and limitations, highlighting the importance of selecting an appropriate method based on the type of noise and application requirements.

#### **Motivation**

The motivation for employing median image filtering arises from the need to effectively suppress noise while maintaining image details. Digital images frequently suffer from degradation caused by acquisition errors, transmission disturbances, or

processing artifacts. Salt-and-pepper noise, in particular, introduces abrupt intensity variations that significantly reduce image clarity. Linear filtering approaches can reduce such noise but often blur edges and distort structural information. Median filtering provides a robust alternative by preserving edge boundaries while removing impulsive noise. Its resistance to outliers and extreme values makes it especially suitable for images affected by impulse noise. Furthermore, the simplicity of implementation combined with reliable performance has made median filtering a preferred choice in many practical applications, including medical imaging, surveillance systems, and digital photography. Understanding the effectiveness of this technique and analyzing its performance motivates the present study.

#### **Problem Statement**

Digital images are frequently degraded by noise during acquisition, transmission, or storage, which adversely affects their quality and usability. Salt-and-pepper noise is one of the most common types of degradation, appearing as randomly distributed black and white pixels across the image. This noise not only reduces visual quality but also interferes with subsequent image processing operations such as segmentation, feature extraction, and object recognition. The presence of noise can lead to loss of critical image details and degrade edge information, making accurate analysis difficult. Therefore, an effective method is required to remove salt-and-pepper noise while preserving essential structural features.

The objective of this work is to develop an approach that effectively removes impulsive noise without degrading image details. The method should maintain edge sharpness, perform consistently under different noise levels, and provide improved visual quality. Median image filtering is considered a suitable solution due to its non-linear nature and robustness against outliers. The effectiveness of the approach is evaluated using quantitative performance metrics such as Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE), along with qualitative visual assessment. By addressing noise removal and detail preservation simultaneously, median filtering enhances image quality and supports more accurate image analysis and processing.

#### **HARDWARE REQUIREMENTS**

The hardware requirements for median image filtering primarily include processing units, memory resources, and optional hardware accelerators such as Field-Programmable Gate Arrays (FPGAs). FPGAs are reconfigurable integrated circuits that can be programmed after manufacturing to perform specific computational tasks. They consist of configurable logic blocks connected through programmable interconnects, enabling flexible

hardware implementation. Due to their parallel processing capability, FPGAs are well suited for real-time image processing applications where multiple pixels can be processed simultaneously. Their reprogrammable nature also allows the implementation of different filtering algorithms without modifying the physical hardware. Memory is another essential component required for storing input images, intermediate data, and final output results. During median filtering, memory is used to hold pixel values within a local neighborhood window for median calculation. It also stores temporary values generated during sorting operations and buffering of adjacent pixels. Efficient memory utilization is important to minimize latency and improve processing speed. Techniques such as buffering, data reuse, and optimized read-write operations help reduce memory access overhead and enhance overall performance. Proper management of memory resources enables faster execution and supports real-time filtering applications.

The processing unit is responsible for executing the filtering algorithm. Various types of processors can be used, including Central Processing Units (CPUs), Graphics Processing Units (GPUs), FPGAs, and Application-Specific Integrated Circuits (ASICs). CPUs provide flexibility and ease of implementation but may not offer optimal performance for large-scale image processing. GPUs, on the other hand, provide highly parallel architecture suitable for handling large image datasets efficiently. FPGAs enable hardware-level parallelism and low latency, making them ideal for real-time processing. ASICs provide high performance and low power consumption but lack flexibility compared to programmable solutions. The choice of processing unit depends on application requirements such as speed, power consumption, and design complexity. Overall, parallel processing capability, high-speed computation, and programmability are important features that enhance the performance of median image filtering.

#### **Software Tools and Platforms**

Several software tools and platforms are available for implementing median image filtering. OpenCV is a widely used computer vision library that provides built-in functions for image filtering, including median filtering. MATLAB offers a high-level programming environment with extensive image processing toolboxes, making it suitable for algorithm development and performance analysis. Python has become increasingly popular due to its simplicity and availability of libraries such as OpenCV, Pillow, and Scikit-image, which support efficient image manipulation and filtering operations. ImageJ is another open-source software commonly used for scientific image analysis, while commercial tools such as Adobe Photoshop provide filtering features primarily for visualization and manual processing.

The implementation can be performed on different operating systems, including Windows, Linux, and macOS, all of which support major image processing tools. Linux is often preferred for research and high-performance computing environments, whereas Windows provides ease of use and broader software compatibility. macOS also supports various development environments suitable for image processing applications. Additionally, GPU-accelerated frameworks such as CUDA and OpenCL can be utilized to improve processing speed by leveraging parallel hardware resources. These software tools and platforms collectively provide a flexible environment for implementing, testing, and evaluating median image filtering techniques.

### **DEMONSTRATION OF MEDIAN FILTERING OF AN IMAGE**

Median filtering is a widely used non-linear technique in digital image processing for removing impulsive noise, particularly salt-and-pepper noise, while preserving important structural information. The technique improves image quality by replacing corrupted pixel values with representative values derived from neighboring pixels. This chapter presents the demonstration of median image filtering and describes the system components involved in the implementation. The process focuses on applying the filtering algorithm to noisy images using appropriate hardware and software resources. The objective is to reduce noise effectively while maintaining edges, textures, and fine image details. The demonstration also highlights the computational steps involved in median filtering and explains how the method enhances visual quality without excessive smoothing.

#### **Block Diagram and Explanation**

The median image filtering system consists of several sequential stages beginning with the input image and ending with the filtered output. Initially, a noisy image is provided to the system, either directly captured or artificially corrupted for testing purposes. In some cases, controlled noise is intentionally added to evaluate the performance of the filtering method. The core stage of the system is the median filter, where a sliding window or kernel is applied to the image. A kernel of predefined size, such as  $3 \times 3$  or  $5 \times 5$ , is selected and positioned over each pixel location. The pixel intensities within the selected window are extracted and arranged in sorted order. The median value of the sorted set is then calculated and used to replace the central pixel value. This process is repeated as the kernel moves across the entire image. After processing all pixels, the system generates the output image with reduced noise and preserved edges. Boundary handling techniques such as zero padding, replication, or mirroring are applied to manage pixels near image borders. The final filtered image is displayed or

stored for further analysis. Key components of the block diagram include kernel size selection, sorting mechanism, median computation, and boundary management, all of which influence the filtering performance.

#### **Working Methodology**

The working principle of median image filtering involves a sliding window mechanism applied to a noisy image. First, a kernel of predefined size is selected and positioned over the image. The pixel values within this window are collected and arranged in ascending order. The median value is then determined from the sorted set, and the center pixel is replaced with this value. After processing the current position, the kernel shifts to the next pixel location, and the same steps are repeated. This iterative process continues until all pixels in the image are processed. As a result, isolated noisy pixels are removed, while edges and structural details remain largely unaffected. The method is particularly effective because it is based on a non-linear operation, making it robust against extreme intensity values. Median filtering offers several advantages, including effective removal of salt-and-pepper noise, preservation of edges, and robustness to outliers. The technique maintains important image details such as textures and patterns while reducing unwanted noise. It is also simple to implement and can serve as a pre-processing step for advanced image analysis tasks. Additionally, median filtering can reduce speckle noise and improve visual clarity in various applications. Despite these benefits, the technique has certain limitations. The computational cost increases with larger kernel sizes, making real-time processing more challenging. Excessive smoothing may occur when large windows are used, potentially leading to loss of fine details. The filter is also less effective for Gaussian noise compared to linear smoothing methods. Furthermore, improper kernel size selection may introduce artifacts or reduce image sharpness. Median filtering is widely applied in several domains, including image denoising, image enhancement, and pre-processing for edge detection algorithms. It is also used in medical imaging to improve diagnostic image quality, in remote sensing for satellite image enhancement, and in computer vision applications requiring noise-free input data. By effectively removing impulsive noise while preserving structural information, median filtering serves as a reliable and practical solution for improving digital image quality.

#### **RESULTS**

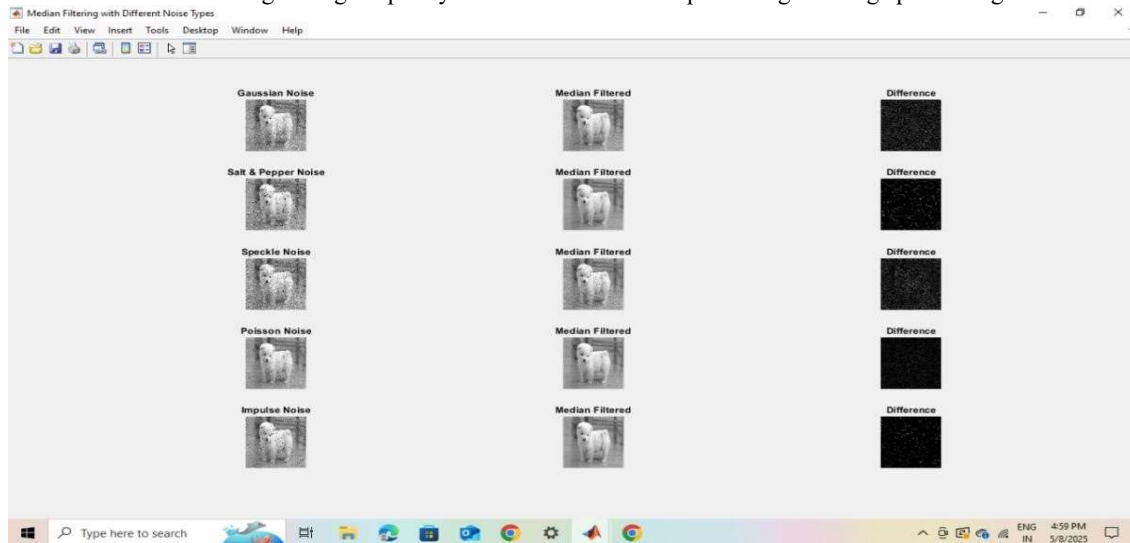
The application of median image filtering produces an output image with significantly reduced impulsive noise while preserving essential structural features. The experimental results demonstrate that the median filter effectively removes salt-and-

pepper noise by replacing corrupted pixels with representative values derived from neighboring intensities. As a result, the processed image appears smoother and visually clearer compared to the noisy input. Unlike linear smoothing techniques, which tend to blur edges, the median filter maintains sharp boundaries and important details. This edge-preserving characteristic ensures that significant features within the image remain intact, making the method suitable for further image analysis tasks.

Visual inspection of the filtered images reveals noticeable improvements in texture and clarity. The removal of isolated noisy pixels leads to a smoother surface with reduced artifacts. Edges become more distinct and well-defined, allowing easier identification of objects and structures. In addition, the filtering process may enhance contrast between different regions, improving overall interpretability. These improvements confirm that median filtering is effective for enhancing image quality while

minimizing distortion. Quantitative evaluation using metrics such as Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE) further supports the visual observations, indicating improved similarity between the filtered image and the original noise-free image.

The enhanced output image can be used in various image processing applications. Median filtering serves as an effective denoising technique where noise reduction is required before performing additional processing steps. It can also act as a preprocessing stage for edge detection algorithms, where preserving boundary information is critical. Furthermore, the improved visual quality makes the filtered image suitable for image enhancement tasks, pattern recognition, and object detection. Overall, the results demonstrate that median filtering provides a balanced trade-off between noise removal and detail preservation, making it a reliable technique for digital image processing.



## Conclusion

Median image filtering is an efficient non-linear technique for removing salt-and-pepper noise while preserving important image details. The implementation and analysis presented in this work demonstrate that the median filter effectively improves image quality by reducing impulsive noise and maintaining edge sharpness. Unlike linear smoothing methods, which often degrade structural information, median filtering retains boundaries and fine features, making it suitable for various image processing applications. The results confirm that the technique enhances visual clarity and produces smoother images without significant loss of detail. The study also highlights the simplicity and robustness of the median filtering approach. Its resistance to extreme intensity values makes it particularly useful for images affected by impulsive noise. Additionally, the method can be applied as a preprocessing step for advanced image processing

tasks such as segmentation, feature extraction, and object recognition. Although the computational complexity increases with larger kernel sizes, the filtering process remains practical and effective for most applications. Overall, median filtering offers a reliable solution for improving image quality and reducing noise while maintaining essential structural information.

## Future Scope

The median image filtering technique offers significant opportunities for further research and development. One potential direction involves the design of adaptive median filters that dynamically adjust window size based on local noise characteristics, thereby improving performance under varying noise conditions. Optimization of filtering algorithms can also reduce computational complexity and enable real-time processing for high-resolution images and video streams.

Integrating median filtering with advanced image processing techniques, including machine learning and deep learning models, may further enhance denoising performance and feature preservation. Future applications of median filtering extend to multiple domains. In medical imaging, improved denoising techniques can assist in accurate diagnosis by enhancing image clarity. In surveillance systems, median filtering can improve visibility in noisy environments and support reliable object detection. Autonomous vehicle systems can benefit from noise-free images for better scene understanding and navigation. Additionally, hybrid filtering methods that combine median filtering with other techniques, such as weighted median or wavelet-based filtering, may provide improved performance for complex noise conditions. With continued advancements in image processing technologies, median filtering is expected to remain an essential component for noise reduction and image enhancement in various real-world applications.

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