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# A SURVEY OF IMPULSE NOISE REDUCTION METHODS IN DIGITAL IMAGES

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## ABSTRACT

There is an increasing need for more accurate and visually attractive images as the quantity of digital images captured each day increases. Modern cameras, on the other hand, acquire images that are eventually contaminated by noise, resulting in a decline in visual image quality. Impulse noise is a type of noise that appears as white and black distributed pixels in grayscale and color images. Salt and Pepper noise and random valued impulse noise make up the impulse noise model. There have been a number of impulse denoising algorithms created for images so far (both grey and color). This article examines impulsive noise reduction methods for color images, examining their performance and also provides a detailed comparison among the denoising methods in depth as well as the outcomes they create.

**Keywords**: Denoising, Filter, Image, Impulse Noise, Median Filter, vector median filter, weighted median filter, peer group filtering.

## INTRODUCTION

An image is a two-dimensional numerical data set that comprises the intensities of red, green, and blue hues collected. Computer vision, robotics, biomedical engineering, and target tracking are just a few of the fields where digital image processing is used. Noise frequently corrupts the images utilized in these applications. In this context, noise is defined as a random event that corrupts the original pixel intensity values, whether red, green, blue, or all of them, to a value within the viewable range [1].Noise is an unwanted signal that can be caused by a variety of factors such as poor light, a slow shutter, a heat sensor, transmission errors, system errors and so on. Because noise can have additive, phase, and multiplicative features, there are several forms of noise that can be categorized based on various factors. White and black dots, also known as impulse noise, are caused by sudden, unexpected, and abrupt variations in a visual signal. Many denoising algorithms have been evolved to suppress or decrease impulsive noise and rebuild an original image approximation. In this article compares the functionality, and relative effectiveness of various median-based filter versions for noise reduction. Filters are employed in a variety of applications and are tested against colorimages. The quality prediction of an algorithm can be subjectively or objectively measured, and is divided into two categories: first, metrics like mean square error (MSE), root mean square error (RMSE), peak signal to noise ratio

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(PSNR), mean absolute error (MAE), and others whose functionality is based on statistical errors, and second, metrics like Structural Similarity Index Measure (SSIM), Feature Similarity Indexing Method(FSIM), Visual Information Fidelity metric (VIF), Edge-strength-similarity-based image metric(ESSIM), and others whose functionality is based on the Human Visual System (HVS). Peak Signal to Noise Ratio (PSNR), Normalized Mean Square Error (NMSE), and Structural Similarity Index Measure are some of the quality evaluation measures employed in this study.

## CONVENTIONAL IMPULSE NOISE REMOVAL METHODS

In this section, we present a survey of notable works and methods proposed to reduce impulse noise in digital images in chronological order.

In [2], presented a fast two-dimensional median filtering technique. It works by storing and updating the grey level histogram of the window's image components. Compared to traditional sorting methods, the algorithm is substantially quicker. The computer time required for a window size of $m \times n$ is $o(n)$.

In [3],proposed a method which permits the creation of filters with a wide range of features. Filter requirements in specific instances are explained, as well as the related filters derived. The concept of a minimal weighted median filter, or a subclass of filters that behave in the same way, is introduced and described. For some classes, the problem of determining the number of various ways a class of filters can act is considered and solved. Weighted median filters (WMFs) are a type of filter that can be used to background a raster image or remove undesired content while keeping certain desirable aspects of the image.

In [4],the application of nonlinear means to image processing is discussed. The features of these techniques are explored in the presence of various forms of noise. Nonlinear filters based on these techniques are demonstrated to perform effectively for both additive and impulsive noise. In the presence of signal dependent noise, their performance is good. They keep the edges sharper than linear filters and reject noise more effectively than median filters.

In [5],proposed algorithms For image processing that use adaptive-length median filters to improve impulse noise removal performance. When images are contaminated by impulsive noise, these algorithms can produce much better image quality than ordinary (fixed length) median filters. One of the advantages of the proposed methods is that the additional circuitry required when implemented in hardware is rather simple. Furthermore, the methods can be simply integrated into effective median filter hardware realizations. The proposed filters are compared to ordinary median filters, generalized mean filters, and nonlinear mean filters in terms of performance and hardware complexity. Authors proposed 2 algorithms- one dimensional and recursive two dimensional, out of which, Low-density positive or negative impulse noise can be removed with one-dimensional median filters. The recursive two-dimensional adaptive median filter appears to be advantageous in other circumstances.

In [6],introduced two nonlinear methods for filtering vector valued signals. These two methods called vector median operations are gotten from two complex probability density functions utilizing the maximum likelihood estimate process. The principle probability densities are exponential and the subsequent operations have properties same as to those of the median filter. These features include zero impulse response and edge preservation in the vector-valued input signal. The vector median filters, like the median filter, have root signals. Instead of component-wise scalar processing, the vector median approach processes the samples of the vector valued input signal as vectors. The correlation between the signal components is inherently used by the vector median operation, providing the filters certain beneficial features. Filters with increased

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noise attenuation and excellent edge response are produced by combining the vector median operation with linear filtering.

In [7],the center weighted median (CWM) filter is investigated, which is a weighted median filter that gives more weight to the central value of each window. While suppressing additive white and/or impulsive-type noise, this filter can preserve image features. The CWM filter's statistical properties are investigated. The CWM filter is shown to outperform the median filter. The Winsorizing smoother and the multistage median filter are used to derive certain correlations between CWM and other median-type filters. An adaptive CWM (ACWM) filter with a space variable central weight is proposed in an attempt to improve the performance of CWM filters. authors demonstrate that the ACWM filter is an excellent detail-preserving smoother that can suppress both signal-dependent and signal-independent noise. The authors proposed a two-step approach to designing a nonlinear filter for simultaneous suppression of Gaussian and impulsive noise: The first step is to select a linear filter that will reduce the Gaussian noise superimposed on the original signal. In the second step, a nonlinear filter with a linear component close to the linear filter is chosen from a list of nonlinear filters that can effectively eliminate impulses. ACWM filters have been shown to suppress multiplicative as well as additive white and impulsive noise.

In [8],a novel family of multivariate OS filters is introduced in this study, having applications to color image processing. The median filter and other univariate order statistic (OS) filters have been widely used in black/white image processing. They've been proved to be capable of noise smoothing and edge preservation. The suggested multivariate OS filters preserve information in color images while attenuating various forms of noise. The suggested method outperforms the vector median filter in some noisy situations. This paper presents a statistical study of multivariate OS filtering for color images.

In [9],introduced and investigates vector directional filters (VDF) for multichannel image processing. These filters divide the processing of vector-valued data into two categories: directional and magnitude. This creates a connection between single-channel image processing, in which only magnitude processing is done, and multichannel image processing, in which both the direction and magnitude of the image vectors are significant in the final (treated) image.
Satellite image data processing, color image processing, and multispectral biomedical image processing are all uses for VDF. The findings of color image processing are provided in this study as an essential example of multichannel image processing. VDF is proven to generate excellent filtering performance for a variety of noise source types.

In [10],a switching strategy for median filtering is proposed to reduce impulse noises in digital images with low signal distortion. The method can be used as a prefilter before some future processing, such as edge identification or data compression. The switching technique is based on impulse detection, which is the local measurement of impulses. The important features of a median and weighted median based impulse detector are explained. Authors show that the filtering structure produces an output image that is much superior than median, weighted median, and optimal stack filters using a test image.
Proposed switching Scheme: A hard switching technique for median filtering is created based on the local estimation of the impulses in order to remove impulses with very little signal distortion. The notion is that if the window's center point is determined to be contaminated by noise, the median in the window is used to replace it, and if the center point is not corrupted, it is not modified.

In [11],investigated some deterministic features of center weighted median (CWM) filters. CWM filters' root structures are derived. To determine if a signal is a root of a certain CWM filter, a

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test is designed. After that, the convergence behavior of both recursive and non-recursive CWM filters is investigated. It is demonstrated, in particular, that repeated filtering of any added finite length signal by any CWM filter yields roots in a limited number of filter passes depending on their root structures. A technique for synthesizing CWM filters with structural limitations is provided. As an application of one-dimensional CWM fitters in image processing, a separable CWM filter is suggested. In some circumstances, proposed methods outperform two-dimensional adaptive CWM filters with the same window size. After that, adaptive symmetric weighted median filters are added to adaptive CWM filters.

In [12],proposed two novel adaptive median filter methods based on two types of image models affected by impulse noise. These have a variable window size for impulse reduction while maintaining sharpness. The first, known as the ranked-order based adaptive median filter (RAMF), is based on a test for impulses in the center pixel followed by a test for residual impulses in the median filter output. The second, known as the impulse size based adaptive median filter (SAMF), is based on detecting the size of the impulse noise.
The RAMF outperforms the nonlinear mean $L_p$ filter in removing both positive and negative impulses while maintaining sharpness; the SAMF outperforms Lin's adaptive scheme in removing high density impulsive and non-impulsive noise while preserving fine details. Simulations using real-world images show that these algorithms outperform traditional median filters.

In [13],discussed about two most common types of vector processing filters: Vector Median Filters (VMF), which are MLE estimates from exponential distributions and the other is Vector Directional Filters (DF), investigate the processing of color image data using directional information. Authors presented the Directional - Distance Filters (DDF), a new family of filters that combines VDF and VMF in a novel approach. The suggested approach DDF is substantially more successful than VMF in removing noise (even impulsive noise), and it has the virtue of chromaticity preservation.

In [14],Nonlinear multivariate image filtering algorithms are suggested in this study to manage color images that have been distorted by noise. Examined the notion of reduced ordering (R-ordering) briefly before defining three R-orderings by picking various center positions. R-ordering based multivariate filters are created by mixing R-ordering techniques and taking into account noise attenuation, edge preservation, and detail retention. In this paper, created a locally adjustable version of color image filtering to make it more effective. The closest sample to a central position, which is a weighted linear mixture of the mean, the marginal median, and the center sample, is the adaptive filter's output. Finally, Investigated the adaptive hybrid multivariate (AHM) filter, which combines the mean, marginal median, and identity filters. The two adaptive filtering approaches are compared to several nonadaptive filtering techniques. The color image filtering examples illustrate that adaptive multivariate image filtering improves performance quite a bit.

In [15],proposed a nonlinear technique for suppressing impulse noise while maintaining details and features in highly corrupted images. The approach covers the entire dynamic range and is applicable to all impulse noise models, including fixed valued (equal height or salt and pepper) and random valued (unequal height) impulses. The technique employs a detection-estimation approach. If a signal sample is found to be corrupted, it is replaced with an estimate of the genuine value based on the surrounding area. Otherwise, it is left alone. Without adding extra processing complexity, the approach provides a great tradeoff between noise reduction and maintaining features and edges. The proposed method outperforms other current algorithms, including the well-known median filters, according to extensive simulation results.

In [16],the nature of the filtering operation is conditioned on a state variable in a new framework for removing impulse noise from images. Several sliding-window methods are investigated as part of this state-based framework, each of which is applicable to fixed and random-valued impulse noise models. The current state is computed using the result of a basic classifier that operates on the differences between the input pixel and the remaining rank-ordered pixels in the current window. The algorithm changes between the output of an identity filter and an order-statistic (OS) filter depending on the value of the state variable.
This simple strategy can be readily developed into a multistate approach employing weighted combinations of the identity and OS filters, with the weighting coefficients optimized using image training data for a tiny additional memory cost. Extensive simulations show that these methods outperform a variety of known nonlinear algorithms with up to thirty percent impulsive noise in terms of noise suppression and detail preservation. Finally, the approach is proved to be exceptionally resilient in terms of training data and impulse noise percentage.

In [17],for the reduction of impulsive noise in digital images, a neural network adaptive filter is introduced. The filter successfully eliminates the impulses while maintaining image integrity by using pixel categorization by a self-organizing neural network to locate the locations of the noisy pixels. The suggested adaptive filter has been thoroughly tested on simulated samples, with extremely positive results. To reduce the noise, the median filter, the Center Weighted Median filter, and the suggested approach were used. The NMSE values (normalized mean square error) were explored. In all situations, the suggested technique yielded the least NMSEs. This finding demonstrates the applicability of the proposed method.

In [18],investigated the use of directional information in the processing of color image data. The authors revisit the class of vector directional filters (VDF), which they first presented in a prior paper. VDF is compared to the spherical median, and their relationship to the spatial median is investigated. Furthermore, their statistical and deterministic features are investigated, demonstrating their suitability for image processing. VDF produces excellent directional estimates of image vectors; this is particularly relevant in the case of color images, where the direction of the vectors denotes the chromaticity of a given color. The actual execution of VDF is also taken into account. In addition, effective VDF-based filtering strategies, such as adaptive and/or double-window structures, are provided.

When the error is assessed in the L*a*b* space, experimental and comparative findings in image filtering indicate extremely good performance measures. L*a*b* is a space in which equal color variations result in equivalent distances, and hence it is remarkably similar to human color perception. Furthermore, assessing the error on the Maxwell triangle gives an indicator of the chromaticity error; the findings show that VDF are extremely accurate chromaticity estimators.

In [19],investigated, Compared and contrasted the different Vector Directional Filters that are currently in use. The development of the Vector Directional Filters has heightened interest in the processing of color image data using directional information. To evaluate the effectiveness of the various Vector Directional Filters and to compare them to other frequently used non-linear filters, simulation tests using color images are employed in this work.

In [20],first, they discussed about Median type filters. The majority of impulsive noise removal filters use median-type filters, which process all of the pixels in the noisy image. As a result, a certain percentage of non-noisy pixels are suddenly altered, lowering the quality of the outcome. Because these pixels do not need to be filtered and should not be, the authors offer two methods for selecting the pixels to be processed. For this reason, Authors presented two strategies to choose pixels to be processed. Out of which, the first one is the relaxed median filter, it works online by relaxing the order statistic for pixel substitution. The mask-median filter is the second option, which needs the creation of a mask to specify which pixels arc to be treated a priori. The mask is created utilizing some prior knowledge about the image class in question.

In [21],introduced and analyzed a novel class of filters for multichannel image processing. The generalization of vector directional filters is represented by this class. To adapt to local data in the image, the suggested filters apply fuzzy transformations of angles among the various vectors. The new filters' principle is discussed, as well as compared to previous common nonlinear filters. As an important example of multichannel image processing, the subject of color image processing is investigated. The new filters have good performance and adaptability, according to simulation data.

In [22],proposed a Novel progressive switching median filter method for restoring images that have been distorted by salt–pepper impulse. The following two basic points form the basis of the algorithm: 1) switching scheme—an impulse detection technique is applied before filtering, resulting in only a subset of the pixels being filtered; 2) progressive methods—both the impulse detection and noise filtering procedures are applied gradually over several iterations. Simulation findings show that the proposed technique outperforms existing median-based filters and that it is especially useful in circumstances where images are severely damaged.

In [23],the authors introduced peer group filtering (PGF), a nonlinear technique for image smoothing and impulse noise reduction in color images, in the first section of this study. Each image pixel is replaced by the weighted average of its peer group members, who are categorized based on color similarity of nearby pixels. It successfully eliminates noise and smooths color images without blurring edges and features, according to the results.
In the second section of the paper, PGF is employed as a color quantization preprocessing step. Because human vision is less sensitive to variations in these areas, local statistics acquired after PGF are employed as weights in the quantization to suppress color clusters in detailed regions. As a consequence, extremely coarse quantization can be achieved while the color information in the original images is preserved. This can be beneficial in applications like color image segmentation and retrieval.

In [24],a new method called tri state median filter introduced for successfully suppressing impulsive noise while keeping image details. To evaluate whether a pixel is corrupted, they used the standard median (SM) and center-weighted median (CWM) filters in a noise detection framework before applying them unconditionally to filter. Extensive simulation results show that by balancing the tradeoff between noise reduction and detail preservation, the proposed filter consistently outperforms other median filters.

In [25],presented a novel method to suppress both fixed-valued impulses and random-valued impulse noise. This method creates a novel adaptive operator based on the differences between the current pixel and the outputs of center-weighted median (CWM) filters with varying center weights. Extensive simulations demonstrate that the suggested approach consistently suppresses both types of impulses with various noise ratios.

In [26],discussed in detail about peer group image processing. For each pixel, peer group image processing determines a "peer group" and then replaces the pixel intensity with the peer group's average. The area (number of pixels in the feature) and window diameter parameters give direct control over which image characteristics are selectively improved (window size needed to enclose the feature). The effects of these factors on whether image characteristics are smoothed or maintained are discussed. Authors demonstrated how the Fisher discriminant can be used to update the PGA parameters automatically at each place in the image. Smoothing across uniform regions while keeping characteristics like corners and edges is possible with this local parameter option. This adaptive technique is applicable to PGA multilevel and color forms. Comparisons are done with a range of common filtering algorithms, and computational complexity and convergence difficulties are discussed.

In [27],by considering the importance of a smart switching method as well as an adaptive weighted median filter, authors proposed a novel switching-based median filter called Noise adaptive soft-switching median (NASM) filter, which incorporates the fuzzy-set concept to achieve significantly improved filtering performance in terms of effectiveness in removing impulse noise while preserving signal details and robustness in dealing with noise density variations. There are two steps to the proposed NASM filter. Each pixel is classified as an uncorrupted pixel, isolated impulse noise, non-isolated impulse noise, or image object's edge pixel using a soft-switching noise-detection algorithm. Depending on the character type found, "no filtering" (or identity filter), standard median (SM) filter, or in proposed fuzzy weighted median (FWM) filter will be used. Experiments demonstrate that the proposed NASM filter outperforms existing strategies by obtaining performance that is quite close to that of an ideal-switching median filter over a wide range of noise densities, ranging from 10% to 70%.

In [28],proposed a multi-state median (MSM) filter with broader framework for median-based switching methods. The output of the MSM filter is adaptively swapped among that of a collection of center-weighted median (CWM) filters with variable centre weights using a simple thresholding algorithm. As a result, the MSM filter is comparable to a space-varying center weight adaptive CWM filter that is dependent on local signal characteristics. Extensive simulations have demonstrated that the proposed MSM filter outperforms conventional median-based filters in terms of noise suppression and feature preservation for a variety of images distorted at various noise ratios.

In [29],the resilient order-statistic theory and the optimum filtering scenario are combined to create a novel adaptive vector median filtering method. The collection of vector-valued order-statistics with the shortest distances to other samples in the input set forms the basis of adaptive control. The suggested method's performance is compared to that of well-known vector standards such the VMF, the basic vector directional filter (BVDF), and the directional distance filter (DDF). The suggested method's output demonstrates remarkable signal-detail retention compared to VMF, BVDF and DDF, while simultaneously suppressing impulsive noise. This approach achieves a considerable balance between the major image filtering tasks, resulting in a relatively small estimation error.

In [30],a new filtering strategy is introduced that is designed to remove impulsive noise in color images while keeping image features. The new filter has a much-reduced computational complexity than the Weighted Vector Median Filter (WVMF). The novel filter outperforms the WVMF and other traditional color image filtering processes for removing impulsive noise, according to the comparison.

In [31],presented a novel adaptive multichannel filter for detecting and removing impulsive noise, bit errors, and outliers in digital color images. The suggested nonlinear filter makes use of the local entropy contrast notion as well as the resilient order-statistics theory. The novel entropy-based vector median filter is computationally appealing, resistant against a wide spectrum of impulsive noise corruption, and considerably enhances the traditional vector median filter's signal-detail preservation capacity.

In [32],a peer region determination (PRD) technique is developed for impulsive noise identification in digital images that eliminates random-valued impulsive noise while keeping very fine image features. This technique finds the variation of pixel values in a 5x5 filter window to identify the peer region for each pixel adaptively. The pixel being processed is regarded to be isolated from other pixels if the number of member pixels in the peer region is relatively tiny, and hence is considered impulsive noise. This noise detector may also be readily tweaked to conduct feature selective filtering. The suggested noise detection method outperforms other current non-linear filters and adaptive noise detection-based filters in terms of noise removal and image detail retention, according to experimental data. Finally, the PRD algorithm's notion is examined in relation to various image processing applications.

In [33],described a family of nonlinear multichannel filters that can be used to remove impulsive noise from color images. The suggested generalized selection weighted vector filter class is a strong multichannel signal processing filtering system. The suggested framework is used to address previously specified multichannel filters such as the vector median filter, basic vector directional filter, directional-distance filter, weighted vector median filters, and weighted vector directional filters from a global perspective. The suggested technique is appealing for a number of applications due to its robust order-statistic ideas and greater degree of flexibility in filter construction. According to simulation results, The suggested filter class is computationally appealing, produces high performance, and preserves fine details and color information while effectively suppressing impulsive noise.

In [34],presented a new Adaptive Alpha-Trimmed Mean Filters for restoration of images. Signals and images distorted by additive non-Gaussian noise are frequently restored using alpha-trimmed mean filters. They're especially good if the underlying noise has impulsive noise components that aren't Gaussian. The most important aspect of these filters design is choosing the best $\alpha$ value for a specific noise type. Adaptive filters in image restoration make use of the flexibility of choosing $\alpha$ based on particular local noise characteristics. Reviewed the current adaptive alpha-trimmed mean filter techniques in this study. The performance of these filters is then examined when the underlying noise distribution deviates from Gaussian and violates assumptions such as symmetry. The clipping effect and mixed noise scenarios are examined in particular.
Authors also offer a new adaptive alpha-trimmed filter implementation that detects non-symmetry points locally and applies an alpha-trimmed mean filter that, based on this local choice, trims away outlier pixels such as edges or impulsive noise. Comparisons of the proposed filter's speed and filtering performance under departures from symmetry and Gaussian assumptions reveal that it is a superior option to existing systems.

In [35],a unique technique to impulsive noise reduction in color images is provided in this research. Using the so-called peer group notion, the suggested approach applies a switching system based on an impulse detection mechanism. The suggested approach consistently outperforms the vector median filter and other frequently used multichannel filters in suppressing both random and fixed-valued impulsive noise. The suggested noise detection framework's key benefit is its huge computational speed, which allows for efficient color image filtering in real-time applications.

In [36],presented a new method which removes salt-and-pepper impulse noise with a two-phase strategy. An adaptive median filter is employed in the first step to identify pixels that are likely to be contaminated by noise (noise candidates). The image is reconstructed in the second phase using a specific regularization algorithm that only applies to the selected noise candidates. When compared to images restored utilizing only nonlinear filters or regularization approaches, restored images in the proposed work demonstrate a considerable improvement in edge retention and noise suppression. With a noise level of up to 90%, proposed approach can remove salt-and-pepper noise.

In [37],developed a new algorithm called Boundary discriminative noise detection (BDND), is a new switching median filter that combines a powerful impulse noise detection method with a novel switching median filter for effectively denoising the extremely corrupted images. The suggested BDND algorithm divides the pixels of a localized window, centered on the current pixel, into three groups: lower intensity impulse noise, uncorrupted pixels, and higher intensity impulse noise, to assess if the current pixel is corrupted. The center pixel will then be classified as "uncorrupted" or "corrupted," depending on whether it belongs to the "uncorrupted" or "corrupted" pixel groups. In order to achieve a very high noise detection accuracy—in the proposed example, obtaining zero miss-detection rate while keeping a relatively low false-alarm rate, even up to 70% noise corruption—two boundaries that discriminate these three groups must be precisely identified. For performance evaluation, four noise models are examined. Extensive simulation results on both monochrome and color images under a wide range of noise corruption (from 10% to 90%) clearly show that the proposed switching median filter outperforms all existing median-based filters in terms of suppressing impulse noise while preserving image details.

In [38],proposed a novel Directional weighted median filter for suppressing random valued impulse noise (RVIN) from deeply corrupted digital images. Existing median-based denoising algorithms are good at restoring images corrupted by random-valued impulse noise with modest noise levels, but not so good at restoring images that are deeply corrupted. The proposed method presents a new impulse detector based on differences between the current pixel and its neighbors in four major directions. Then, to create a new directional weighted median (DWM) filter, authors mix it with the weighted median filter. Extensive simulations show that the suggested filter not only suppresses impulses better with higher noise levels but also preserves more detailed characteristics, including tiny lines. This filter also works well when it comes to recovering color images that have been corrupted.

In [39],conducted a statistical analysis on state-of-the-art methods to predict the behavior of random impulse noise and salt and pepper noise. Many state-of-the-art color image restoration filters are made up of two major processes: categorization and reconstruction. Clean pixels are distinguished from damaged pixels via categorization. In reconstruction, values from corrupted pixels are used to interpolate values for pixels that are suspected of being contaminated. Two statistical studies are conducted in this work to investigate how Salt & Pepper and Random impulse noise behave in images. Discovered that, determining the cluster count and probability of occurrence for each noise model in a database of 1000 single color noisy images can enhance the classification and reconstruction process in color image filters.

In [40],proposed a novel impulsive noise reduction filter for color images based on a recently discovered family of vector filters with high detail preservation. To identify and replace impulses, these filters employ a reduced ordering of color vectors. The suggested filter adapts itself using local data to eliminate impulses while preserving image edges and features. The suggested filtering method is stable and achieves a reasonable mix of noise reduction and detail preservation. Furthermore, the proposed method outperforms well-known vector filtering techniques and provides filtered color images that are attractive to the eye.

In [41],provided an improved decision-based approach for restoring images that have been heavily distorted by Salt-and-Pepper noise. The new technique improves image quality by using previously processed nearby pixel values rather than only the previously processed pixel value. The suggested approach outperforms the Standard Median Filter (SMF), Adaptive Median Filters (AMF), Cascade, and Recursive non-linear filters in terms of speed and quality. In the suggested technique, Only the noisy pixel is removed using the median value or the mean of the previously

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processed nearby pixel values. The suggested algorithm (PA) was used to evaluate several images and found to provide superior PSNR and SSIM values.

In [42],a novel spatial-distance weighting function is proposed in this study. A new vector filter, the adaptive distance weighted directional-distance filter (ADWDDF), is presented by integrating the weighting function with the standard directional-distance filter (DDF) in a novel method. In comparison to the standard DDF and some other typical vector filters, the testing findings reveal that the suggested method delivers superior filtering performance and maintains better image chromaticity and edge or detail information.

In [43], provided a novel fuzzy switching median (FSM) filter for image processing that uses fuzzy approaches. The suggested filter effectively removes salt-and-pepper noise from digital images while maintaining image features and textures. The low complexity FSM filter outperforms several well-known current salt-and-pepper noise fuzzy and classical filters by adding fuzzy reasoning in rectifying the identified noisy pixel.

In [44], presented a novel method, for which, A class of adaptive weighted median filters with a switching mechanism is offered as a solution. The new approach uses a weighted median filter with adaptively determined weights from two fixed values to recover the identified noisy pixels while keeping the noise-free ones untouched, using a median-based comparison technique to categorize each image pixel as an impulse or a noise-free one. The experimental findings show that the SAWMF outperforms several known filtering approaches in reducing impulsive noise at various contamination ratios.

In [45],discussed and developed a method called Fuzzy peer group to reduce of mixed noise. A pixel's peer group is a pixel similarity-based notion that has been effectively used to image denoising algorithms. Authors proposed the fuzzy peer group concept by characterizing pixel similarity in fuzzy terms since it is difficult to define pixel similarity in a precise manner. The fuzzy peer group notion is introduced in this study, which expands the peer group concept in a fuzzy situation. A fuzzy peer group will be described as a fuzzy set that uses a peer group as a support set and where each peer group member's membership degree is determined by its fuzzy similarity to the pixel being processed. A unique fuzzy logic-based approach will be used to find the fuzzy peer group of each image pixel. Build a two-step color image filter using the fuzzy peer group idea, cascading a fuzzy rule-based switching impulse noise filter by a fuzzy average filtering across the fuzzy peer group. Both processes make use of the same fuzzy peer group, which saves time and effort. Both Gaussian and impulse noise, as well as mixed Gaussian-impulse noise, are effectively suppressed by the proposed filter.The suggested filter obtains a good performance, as demonstrated by experimental findings.

In [46],presented a novel and efficient method for removing high-density salt and pepper noise from images and videos. At low and medium noise intensities, current non-linear filters such as the Standard Median Filter (SMF), Adaptive Median Filter (AMF), Decision Based Algorithm (DBA), and Robust Estimation Algorithm (REA) produce superior results. Their performance is weak at high noise concentrations. A novel technique is suggested that uses a modified sheer sorting method to reduce high-density salt and pepper noise. When compared to existing common methods, the new algorithm takes less time to compute. The algorithm's results are compared to those of other methods, and it is demonstrated that the new technique has a superior visual appearance and quantitative measures at noise levels as high as 90%.

In [47],presented a novel filter for impulse noise reduction in color images that improves on the standard vector median filter's noise reduction capacity. The use of a vector marginal median filtering method over a specified group of pixels in each filtering window inspired the filter. This

choice, which is based on the vector median, is combined with the marginal median operation to create an adaptive process that results in a more resilient filter design.
In addition, the suggested approach can handle color images without creating color artefacts. Experiments reveal that images filtered with the suggested approach have less noisy pixels than images filtered with the vector median filter.

In [48],the topic of impulsive noise reduction in color digital images is addressed in this work with a unique technique. The switching filter presented here is based on rank weighted, cumulated pixel dissimilarity measurements, which are used to detect image samples tainted by impulsive noise. The filter's settings can be tuned to the amount of impulsive noise that is degrading the image. When compared to existing denoising strategies, the new technique removes the impulses created by the noise process more efficiently while keeping image features. The new filter's low computational cost is a key feature that permits it to be used in real-time applications.

In [49],discussed about filtering of color images. Mixed impulsive and Gaussian noise reduction from digital color images is a difficult problem because it requires processing both forms of noise in a way that distinguishes them from the original image features like edges and details. Fuzzy theory can be applied to this situation to create simple, efficient, and effective solutions. Presented a fuzzy approach for removing Gaussian and impulsive noise from color images in this study. Only one filtering operation is used in proposed method: weighted averaging. The weights in the averaging are assigned using a fuzzy rule approach, which reduces both noise types and preserves image structures.

In [50],a novel method to the problem of mixed noise reduction in color images is provided. The primary principle behind the filtering approach is that impulsive noise is removed using a fuzzy switching filter, and subsequently Gaussian noise is attenuated using better bilateral filtering. The algorithm is capable of dealing with various amounts of mixed noise. The findings suggest that the proposed filter outperforms alternative techniques.

In [51],presented a unique adaptive iterative fuzzy filter for denoising images that have been distorted by impulsive noise. It works in two phases, first detecting noisy pixels using an adaptive fuzzy detector, then denoising the "good" pixels in the filter window with a weighted mean filter. Experiments show that the method outperforms current state-of-the-art filters. The filter has also been found to be resistant to extremely high levels of noise, recovering significant detail at noise levels as high as 97 percent.

In [52],proposed a unique filtering strategy for removing mixed impulsive and Gaussian noise contamination from color images. The robustified vector median, which defines the center of a cluster of most comparable pixels, is the basis for the new denoising approach. The filter output is the average of the cluster's pixels; hence it can be considered an adaptive trimmed averaging filter. The novel filtering design suppresses mixed impulsive and Gaussian noise while maintaining and even improving image edges. According to the experimental results provided, the proposed method surpasses the typical trimmed vector median and other state-of-the-art approaches. The suggested filter's simplicity and low computing burden allow it to be used in real-time image and video enhancing applications.

In [53],investigated a series of switching filters for removing impulsive noise from color images. The suggested denoising approaches are built around the idea of cumulated distances. Between the treated pixel and its immediate surroundings To improve filtering efficiency, a robust technique was devised in which the sum of distances to just the neighborhood's most comparable pixels is used as a measure of impulsiveness. An adaptive technique was included since this

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reduced metric is reliant on the image local structure. In addition, a quick design is provided that permits image denoising in practical applications, as well as the choice of the filter output, which is utilized to replace noisy pixel in the image is explored. On a large set of natural test images, the presented family of filters was tested and compared to state-of-the-art restoration approaches. According to the experimental results, the proposed filters beat conventional strategies in terms of both denoising accuracy and computing complexity. As a result, the presented methodologies suggested for use in a variety of image and video enhancement applications.

In [54],offered a new image filtering technique for removing random-valued impulse noise from a natural-color image. To maintain the detail of an original image with acceptable quality, a switching-type filtering approach, such as the well-known switching median filter, is required in impulse noise reduction. To avoid a color shift after filtering, it is better to treat the red (R), green (G), and blue (B) components of each pixel of a color image as parts of a vectorized signal, as in the well-known vector median filter, rather than as component-wise signals. Presented a switching-type vector median filter with non-local processing that comprises primarily of a noise detector and a noise reduction filter, based on these foundations. In particular, Authors presented a noise detector that proactively detects noise-corrupted pixels by concentrating on the isolation tendencies of pixels of interest in difference images between RGB components rather than in input images. Furthermore, as a noise reduction filter, they presented the non-local vector median filter, which is an enhanced version of the non-local median filter that they suggested before for grayscale image processing and is suited for color image processing. By using proactive noise detection and non-local switching vector median filtering, the suggested technique achieves a superior balance between detail retention and impulsive noise reduction. A set of tests utilizing natural color images are used to verify the efficacy and validity of the suggested strategy.

In [55],for the elimination of high-density impulse noise from color images, an integration of adaptive vector median filter (VMF) and weighted mean filter is proposed in this paper. The noisy and non-noisy pixels are identified in the proposed filtering technique based on the non-causal linear prediction error. The adaptive VMF is applied to a noisy pixel, and the window size is adjusted dependent on the availability of excellent pixels. In contrast, a non-noisy pixel is replaced with the weighted mean of the processing window's excellent pixels. The studies were conducted out on a huge database for several image classes, with peak signal-to-noise ratio, mean squared error, structural similarity, and feature similarity index used to assess performance. The suggested filter outperforms (□ 1.5 to 6 dB improvement) certain existing noise removal approaches not only at low density impulse noise but also at high density impulse noise, according to the results.

In [56],based on Laplacian scale mixture (LSM) modelling and nonlocal low-rank regularization, authors presented an efficient mixture noise reduction approach in this study. Discussed about the difficulty in recovering a noisy image contaminated by both additive white Gaussian noise (AWGN) and impulse noise (IN). Due to the challenges in accurately modelling the distributions of the mixed noise, recovering an image distorted by AWGN and IN is a difficult task. Many efforts have been made to first determine the sites of the impulse noise and then recover the clean image from an incomplete image affected by AWGN using image inpainting techniques. When the combination noise is considerable, however, it is difficult to precisely distinguish the locations of the impulse noise. Proposed LSM distributions are used to describe the impulse noise, and both the hidden scale parameters and the impulse noise are calculated together to adaptively characterize the actual noise. A nonlocal low-rank regularization is used in this paper to regularize the denoising process to take advantage of the nonlocal self-similarity and low-rank character of natural images. The suggested method outperforms known mixed noise reduction algorithms in synthetic noisy images, according to experimental data.

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In [57],a unique approach for filtering mixed noise has been suggested in this paper, which involves the construction of a similarity function and a fuzzy based method. The similarity function is used to identify similarity among pixels in a peer group and is adaptable to local noise level and edge information. Color images contaminated with mixed Gaussian and impulsive noise are filtered based on the peer group. An adaptive weighted average of several sized filters is the unique filtering approach. Local noise and edge information alter the weights of different sized filters. The suggested work has been compared to various cutting-edge methods. The findings suggest that the proposed method preserves edge and color information better than others.

In [58],provided a new approach for removing salt and pepper noise based on pixel density filters (BPDF). The approach begins by determining if a pixel is noisy, after which they choose an adaptive window size that accepts the noisy pixel as its center. The new pixel value is set to the most repeated noiseless pixel value within the window. The peak signal-to-noise ratio (PSNR), structural similarity (SSIM), image enhancement factor (IEF), standard median filter (SMF), adaptive median filter (AMF), adaptive fuzzy filter (AFM), progressive switching median filer (PSMF), decision-based algorithm (DBA), modified decision-based unsymmetrical trimmed median filter (MDBUTMF), noise adaptive fuzzy switching median filter (NAFSM), and BPDF are all calculated using 18 test images. At low and medium noise densities, the findings suggest that BPDF outperforms the above-mentioned approaches.

In [59],presented a novel approach for removing salt and pepper (SAP) noise at all densities called the Different Applied Median Filter (DAMF). Authors then went through some of the fundamental concepts. After that, they used Peak Signal to Noise Ratio (PSNR) and Structural Similarity (SSIM) to compare the results of the DAMF approach and several other methods for various images, such as Cameraman and Lena. For the example taken, PSNR and SSIM results of PSMF, DBA, MDBUTMF, and NAFSM techniques for a Cameraman image with a SAP noise ratio of 30% are 28.27/29.28/ 29.44/ 32.09 and 0.9044/ 0.9324/ 0.7740/ 0.9494, respectively, whereas PSNR and SSIM results of DAMF method are 36.83 and 0.9844, respectively. Finally, they demonstrated that DAMF could effectively reduce SAP noise at all densities.

In [60], proposed A quick approach for impulsive noise reduction in color images. The suggested approach is based on the notion of digital routes, which connect a filtering window's center pixel to its perimeter. Each path has a cost, and the lowest one is used to calculate the center pixel corruption. The center pixel is classified as corrupted if the minimal cost of a connection between the window center and its boundary is high. The proposed filter output is a weighted average of a pixel and its solid estimate, with the filter output being created using the soft switching rule with the lowest cost. Experiments demonstrated that the unique technique had great qualities, especially when dealing with extremely distorted images. The suggested approach has a low processing complexity and can be applied in real-time applications.

In [61], developed A self-tuning variant of the recently disclosed Fast Adaptive Switching Trimmed Arithmetic Mean Filter, which is a very effective approach for impulsive noise suppression. The majority of the approaches described in the extensive literature contain multiple parameters, all of which must be adjusted correctly for effective noise reduction. Although authors frequently offer suggested values for their algorithms' parameters, the final decision is left to the user. Proposed objective is to relieve the operator from the parameter selection conundrum by proposing an algorithm that encompasses all of the relevant expert knowledge. The image itself and the size of the working window are the only mandatory inputs for the suggested method (from the user's point of view). FASTAMF with Self-Tuning modification has been compared to the original FASTAMF in terms of execution time and noise suppression

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efficiency. Surprisingly, because the threshold value is determined to be greater, the Self-Tuning approach is quicker than the original algorithm in some circumstances. As a result, noise suppression (AMF) has less work to complete since fewer pixels are classified as noisy. The main finding is that when the noise density increases, the outcomes for Self-Tuning modification has improved.

In [62],discussed the difficulty in measurement of color distances in color images. In color image processing, the measurement of color distances is crucial. The quaternion representation, which computes a color distance via a weighted average of luminance and quaternion chromaticity distances, is an effective color distance approach. However, because chromaticity may shift greatly in a color image, the process of assigning constant weights to luminance and chromaticity distances cannot always accurately measure color distances. Authors presented an adaptive weighted quaternion color distance approach to handle this problem. The solid distantness ratio and local reachability density, which are described in grayscale images, are extended to color images based on the novel color distance measure to create a coarse-to-fine color noise detection operator. A weighted vector median filter is used in noise filtering to recover the pixels that are determined to be noisy. When compared to existing widely-used color image filtering methods, experimental findings demonstrate the validity of the suggested method by demonstrating superior performance in terms of both objective criteria and visual effect.

In [63],discussed the importance of noise reduction image processing. Due to its considerable influence on object recognition and scene interpretation for computer vision systems, noise reduction is one of the most important and still ongoing research subjects in low-level image processing. they noticed a surge in interest in the application of deep learning algorithms. These deep learning algorithms used in a lot of computer vision systems because of their remarkable feature extraction and categorization capabilities. The majority of the offered methodologies were created for Gaussian noise suppression, albeit they have been effectively implemented in image denoising, greatly boosting its performance. Authors described a deep learning-based switching filtering strategy for removing impulsive noise in this study. The suggested technique uses a deep neural network architecture to identify deformed pixels, which are then corrected using a quick adaptive mean filter. According to the experimental results, the suggested method outperforms state-of-the-art filters for removing impulsive noise in color digital images.

In [64],a unique hybrid filter is presented to reduce contamination on color digital images caused by a combined mixture of impulse and Gaussian noise. There are two steps to the new method. At the first step, impulsive noise is reduced using a filter based on a fuzzy metric. A fuzzy peer group approach is applied to the image created in the previous step in the second stage to reduce Gaussian noise. The performance of the proposed method was assessed using commonly known objective quality criteria on standard test images. Both impulse and Gaussian noise, as well as mixed noise, are effectively reduced using the novel method. The proposed filtering method was compared to the following methods: ANNF, alternating projections filter, color block-matching 3D filter, FPGAF, partition-based TVMF, trilateral filter, fuzzy wavelet shrinkage denoising filter, graph regularization filter, iterative PGSVF, peer group method, and fuzzy vector median method. In terms of the metrics PSNR, MAE and NCD, the results showed that the proposed noise reduction approach outperforms state-of-the-art filters.

## CONCLUSION

In this paper we outlined various methods to reduce impulse noise in digital images developed by several researchers in chronological order.This is useful for the upcoming researchers whose interest is to study or implement algorithms to reduce impulse noise in digital grey or color images. In future we will implement a few impactful methods among the above listed, and will present their performance using numerical simulations.

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**References:**


1. Choppala P, Meka JS, PVGD PR. Vector isolated minimum distance filtering for image de-noising in digital color images. International Journal of Recent Technology and Engineering. 2019;8(4):2401-5.
2. Huang T, Yang GJ, Tang G. A fast two-dimensional median filtering algorithm. IEEE transactions on acoustics, speech, and signal processing. 1979 Feb;27(1):13-8.
3. Brownrigg DR. The weighted median filter. Communications of the ACM. 1984 Aug 1;27(8):807-18.
4. Pitas I, Venetsanopoulos A. Nonlinear mean filters in image processing. IEEE transactions on acoustics, speech, and signal processing. 1986 Jun;34(3):573-84.
5. Lin HM, Willson AN. Median filters with adaptive length. IEEE transactions on circuits and systems. 1988 Jun;35(6):675-90.
6. Astola J, Haavisto P, Neuvo Y. Vector median filters. Proceedings of the IEEE. 1990 Apr;78(4):678-89.
7. Ko SJ, Lee YH. Center weighted median filters and their applications to image enhancement. IEEE transactions on circuits and systems. 1991 Sep;38(9):984-93.
8. Tang K, Astola J, Neuvo Y. Multivariate order statistic filters in color image processing. In[Proceedings 1992] IEEE International Conference on Systems Engineering 1992 Sep 17 (pp. 584-587). IEEE.
9. Trahanias PE, Venetsanopoulos AN. Vector directional filters-a new class of multichannel image processing filters. IEEE Transactions on Image Processing. 1993 Oct;2(4):528-34.
10. Sun T, Neuvo Y. Detail-preserving median based filters in image processing. Pattern recognition letters. 1994 Apr 1;15(4):341-7.
11. Sun T, Gabbouj M, Neuvo Y. Center weighted median filters: some properties and their applications in image processing. Signal processing. 1994 Feb 1;35(3):213-29.
12. Hwang H, Haddad RA. Adaptive median filters: new algorithms and results. IEEE Transactions on image processing. 1995 Apr;4(4):499-502.
13. Karakos DG, Trahanias PE. Combining vector median and vector directional filters: The directional-distance filters. InProceedings., International Conference on Image Processing 1995 Oct 23 (Vol. 1, pp. 171-174). IEEE.
14. Tang K, Astola J, Neuvo Y. Nonlinear multivariate image filtering techniques. IEEE Transactions on Image Processing. 1995 Jun;4(6):788-98.
15. Abreu E. Signal-dependent rank-ordered-mean (sd-rom) filter. InNonlinear Image Processing 2001 Jan 1 (pp. 111-133). Academic Press.
16. Lightstone M, Abreu E, Mitra SK, Arakawa K. State-conditioned rank-ordered filtering for removing impulse noise in images. InProceedings of ISCAS'95-International Symposium on Circuits and Systems 1995 Apr 30 (Vol. 2, pp. 957-960). IEEE.
17. Kong H, Guan L. A neural network adaptive filter for the removal of impulse noise in digital images. Neural Networks. 1996 Apr 1;9(3):373-8.
18. Trahanias PE, Karakos D, Venetsanopoulos AN. Directional processing of color images: theory and experimental results. IEEE Transactions on Image Processing. 1996 Jun;5(6):868-80.
19. Plataniotis KN, Androutsos D, Venetsanopoulos AN. Vector directional filters: An overview. InCCECE'97. Canadian Conference on Electrical and Computer Engineering. Engineering Innovation: Voyage of Discovery. Conference Proceedings 1997 May 25 (Vol. 1, pp. 106-109). IEEE.
20. Garcia-Cabrera L, Luque-Escamilla PL, Martinez-Aroza J, Robles-Perez AM, Roman-Roldan R. Two pixel-preselection methods for median-type filtering. IEE Proceedings-Vision, Image and Signal Processing. 1998 Feb;145(1):30-40.

21. Plataniotis KN, Androutsos D, Venetsanopoulos AN. Color image processing using adaptive vector directional filters. IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing. 1998 Oct;45(10):1414-9.
22. Wang Z, Zhang D. Progressive switching median filter for the removal of impulse noise from highly corrupted images. IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing. 1999 Jan;46(1):78-80.
23. Deng Y, Kenney C, Moore MS, Manjunath BS. Peer group filtering and perceptual color image quantization. In1999 IEEE International Symposium on Circuits and Systems (ISCAS) 1999 May 30 (Vol. 4, pp. 21-24). IEEE.
24. Chen T, Ma KK, Chen LH. Tri-state median filter for image denoising. IEEE Transactions on Image processing. 1999 Dec;8(12):1834-8.
25. Chen T, Wu HR. Adaptive impulse detection using center-weighted median filters. IEEE signal processing letters. 2001 Jan;8(1):1-3.
26. Kenney C, Deng Y, Manjunath BS, Hewer G. Peer group image enhancement. IEEE Transactions on Image Processing. 2001 Feb;10(2):326-34.
27. Eng HL, Ma KK. Noise adaptive soft-switching median filter. IEEE Transactions on image processing. 2001 Feb;10(2):242-51.
28. Chen T, Wu HR. Space variant median filters for the restoration of impulse noise corrupted images. IEEE transactions on circuits and systems II: analog and digital signal processing. 2001 Aug;48(8):784-9.
29. Lukac R. Adaptive vector median filtering. Pattern Recognition Letters. 2003 Aug 1;24(12):1889-99.
30. Smolka B, Szczepanski M, Plataniotis KN, Venetsanopoulos AN. On the modified weighted vector median filter. In2002 14th International Conference on Digital Signal Processing Proceedings. DSP 2002 (Cat. No. 02TH8628) 2002 Jul 1 (Vol. 2, pp. 939-942). IEEE.
31. Lukac R, Smolka B, Plataniotis KN, Venetsanopoulos AN. Entropy vector median filter. InIberian Conference on Pattern Recognition and Image Analysis 2003 Jun 4 (pp. 1117-1125). Springer, Berlin, Heidelberg.
32. Ho JY. Peer region determination based impulsive noise detection. In2003 IEEE International Conference on Acoustics, Speech, and Signal Processing, 2003. Proceedings.(ICASSP'03). 2003 Apr 6 (Vol. 3, pp. III-713). IEEE.
33. Lukac R, Plataniotis KN, Smolka B, Venetsanopoulos AN. Generalized selection weighted vector filters. EURASIP Journal on Advances in Signal Processing. 2004 Dec;2004(12):1-6.
34. Oten R, de Figueiredo RJ. Adaptive alpha-trimmed mean filters under deviations from assumed noise model. IEEE Transactions on Image Processing. 2004 Apr 19;13(5):627-39.
35. Smolka B, Chydzinski A. Fast detection and impulsive noise removal in color images. Real-Time Imaging. 2005 Oct 1;11(5-6):389-402.
36. Chan RH, Ho CW, Nikolova M. Salt-and-pepper noise removal by median-type noise detectors and detail-preserving regularization. IEEE Transactions on image processing. 2005 Sep 19;14(10):1479-85.
37. Ng PE, Ma KK. A switching median filter with boundary discriminative noise detection for extremely corrupted images. IEEE Transactions on image processing. 2006 May 15;15(6):1506-16.
38. Dong Y, Xu S. A new directional weighted median filter for removal of random-valued impulse noise. IEEE signal processing letters. 2007 Feb 20;14(3):193-6.
39. Phu MQ, Tischer PE, Wu HR. Statistical analysis of impulse noise model for color image restoration. In6th IEEE/ACIS International Conference on Computer and Information Science (ICIS 2007) 2007 Jul 11 (pp. 425-431). IEEE.

40. Morillas S, Gregori V, Peris-Fajarnés G, Sapena A. Local self-adaptive fuzzy filter for impulsive noise removal in color images. Signal Processing. 2008 Feb 1;88(2):390-8.
41. Nair MS, Revathy K, Tatavarti R. An improved decision-based algorithm for impulse noise removal. In2008 Congress on Image and Signal Processing 2008 May 27 (Vol. 1, pp. 426-431). IEEE.
42. Jin L, Li D. Improved directional-distance filter. Frontiers of Mechanical Engineering in China. 2008 Jun;3(2):205-11.
43. Toh KK, Ibrahim H, Mahyuddin MN. Salt-and-pepper noise detection and reduction using fuzzy switching median filter. IEEE Transactions on Consumer Electronics. 2008 Dec 22;54(4):1956-61.
44. Jin L, Xiong C, Li D. Selective adaptive weighted median filter. Optical Engineering. 2008 Mar;47(3):037001.
45. Morillas S, Gregori V, Hervás A. Fuzzy peer groups for reducing mixed Gaussian-impulse noise from color images. IEEE Transactions on Image Processing. 2009 May 12;18(7):1452-66.
46. Aiswarya K, Jayaraj V, Ebenezer D. A new and efficient algorithm for the removal of high density salt and pepper noise in images and videos. In2010 second international conference on computer modeling and simulation 2010 Jan 22 (Vol. 4, pp. 409-413). IEEE.
47. Morillas S, Gregori V, Sapena A. Adaptive marginal median filter for colour images. Sensors. 2011 Mar;11(3):3205-13.
48. Smolka B, Malik K, Malik D. Adaptive rank weighted switching filter for impulsive noise removal in color images. Journal of Real-Time Image Processing. 2015 Jun;10(2):289-311.
49. Camarena JG, Gregori V, Morillas S, Sapena A. A simple fuzzy method to remove mixed Gaussian-impulsive noise from color images. IEEE Transactions on Fuzzy Systems. 2012 Dec 20;21(5):971-8.
50. Guo X, Guo B. A fuzzy filter for color images corrupted by mixed Noise. In2014 International Conference on Identification, Information and Knowledge in the Internet of Things 2014 Oct 17 (pp. 177-181). IEEE.
51. Ahmed F, Das S. Removal of high-density salt-and-pepper noise in images with an iterative adaptive fuzzy filter using alpha-trimmed mean. IEEE Transactions on fuzzy systems. 2013 Oct 21;22(5):1352-8.
52. Smolka B, Radlak K. Adaptive trimmed averaging filter for noise removal in color images. In2015 10th International Conference on Computer Science & Education (ICCSE) 2015 Jul 22 (pp. 89-94). IEEE.
53. Malinski L, Smolka B. Fast adaptive switching technique of impulsive noise removal in color images. Journal of Real-Time Image Processing. 2019 Aug;16(4):1077-98.
54. Matsuoka J, Koga T, Suetake N, Uchino E. Switching non-local vector median filter. Optical Review. 2016 Apr;23(2):195-207.
55. Roy A, Singha J, Manam L, Laskar RH. Combination of adaptive vector median filter and weighted mean filter for removal of high-density impulse noise from colour images. IET image processing. 2017 Jun 15;11(6):352-61.
56. Huang T, Dong W, Xie X, Shi G, Bai X. Mixed noise removal via Laplacian scale mixture modeling and nonlocal low-rank approximation. IEEE Transactions on Image Processing. 2017 Mar 1;26(7):3171-86.
57. Dev R, Verma NK. Generalized fuzzy peer group for removal of mixed noise from color image. IEEE Signal Processing Letters. 2018 Jul 4;25(9):1330-4.
58. Erkan U, Gökrem L. A new method based on pixel density in salt and pepper noise removal. Turkish Journal of Electrical Engineering & Computer Sciences. 2018 Jan 27;26(1):162-71.

ISSN- 2394-5125 VOL 7, ISSUE 08, 2020


59. Erkan U, Gökrem L, Enginoğlu S. Different applied median filter in salt and pepper noise. Computers & Electrical Engineering. 2018 Aug 1;70:789-98.
60. Smolka B, Malinski L. Impulsive noise removal in color digital images based on the concept of digital paths. In2018 13th International Conference on Computer Science & Education (ICCSE) 2018 Aug 8 (pp. 1-6). IEEE.
61. Malinski L, Smolka B. Self-tuning fast adaptive algorithm for impulsive noise suppression in color images. Journal of Real-Time Image Processing. 2020 Aug;17(4):1067-87.
62. Jin L, Zhu Z, Song E, Xu X. An effective vector filter for impulse noise reduction based on adaptive quaternion color distance mechanism. Signal Processing. 2019 Feb 1;155:334-45.
63. Radlak K, Malinski L, Smolka B. Deep learning based switching filter for impulsive noise removal in color images. Sensors. 2020 Jan;20(10):2782.
64. Arnal J, Súcar L. Hybrid filter based on fuzzy techniques for mixed noise reduction in color images. Applied Sciences. 2019 Dec 28;10(1):243.