TECH SCIENCE

ISSN 3030-3702

TEXNIKA FANLARINING DOLZARB MASALALARI

TOPICAL ISSUES OF TECHNICAL SCIENCES

№ 10 (3) 2025

TECHSCIENCE.UZ

№ 10 (3)-2025

TEXNIKA FANLARINING DOLZARB MASALALARI

TOPICAL ISSUES OF TECHNICAL SCIENCES

TOSHKENT-2025

OAK Roʻyxati

Mazkur jurnal Oʻzbekiston Respublikasi Oliy ta’lim, fan va innovatsiyalar vazirligi huzuridagi Oliy attestatsiya komissiyasi Rayosatining 2025-yil 8-maydagi 370-son qarori bilan texnika fanlari boʻyicha ilmiy darajalar yuzasidan dissertatsiyalar asosiy natijalarini chop etish tavsiya etilgan ilmiy nashrlar roʻyxatiga kiritilgan.

Muassislar: “SCIENCEPROBLEMS TEAM” mas’uliyati cheklangan jamiyati;
Jizzax politexnika insituti.

TECHSCIENCE.UZ- TEXNIKA FANLARINING DOLZARB MASALALARI elektron jurnali 15.09.2023-yilda 130343-sonli guvohnoma bilan davlat roʻyxatidan oʻtkazilgan.

TAHRIRIYAT MANZILI:
Toshkent shahri, Yakkasaroy tumani, Kichik Beshyogʻoch koʻchasi, 70/10-uy.
Elektron manzil:
scienceproblems.uz@gmail.com

TEXNIKA FANLARINING DOLZARB MASALALARI
3-jild, 10 -son (Noyabr, 2025). – 81 bet.

MUNDARIJA

TECH SCIENCE.UZ

Texnika fanlarining dolzarb masalalari
Topical Issues of Technical Sciences
2025-yil | 3-jild | 10-son
ISSN (onlayn): 3030-3702

COMPARATIVE ANALYSIS OF POTATO DISEASE LEAF IMAGE DENOISING METHODS BASED ON MATLAB

Zhang Hongzhi
National University of Uzbekistan named after Mirzo Ulugbek, Faculty of Applied Mathematics and intellectual Technologies.
JiNing Normal University, School of Mathematics and statistic, Ulanqab, Inner Mongolia, P. R. China
Jining Normal University Scientific Research Project: Convolutional Neural Network-based Potato Leaf Disease Identification Method (jsky2024001)

Annotation. Image denoising is one of the indispensable operations in image preprocessing, and the purpose of denoising is to effectively inhibit the excess noise components in the screen under the premise of ensuring that the original effective information of the image remains unchanged. In order to study the advantages and disadvantages of various denoising algorithms, this paper theoretically analyses Gaussian filtering, Mean filtering, Median filtering, Bilateral filtering and Wavelet filtering, and uses MATLAB to carry out simulation implementation and comparative analysis of various filtering and denoising effects on potato diseased leaf images.

Keywords: image denoising; Gaussian filtering; Mean filtering; Median filtering; Bilateral filtering; Wavelet filtering.

MATLAB ASOSIDA KARTOSHKA KASALLANGAN BARGI TASVIRINI SHOVQINDAN TOZALASH USULLARINING QIYOSIY TAHLILI

Zhang Hongzhi
Mirzo Ulug'bek nomidagi O'zbekiston Milliy universiteti, Amaliy matematika va intellektual texnologiyalar fakulteti
JiNing Normal universiteti, Matematika va statistika fakulteti, Ulanqab, Ichki Mo'g'uliston, Xitoy Xalq Respublikasi
JiNing Normal universitetining ilmiy-tadqiqot loyihasi: Konvolyutsion neyron tarmoqqa asoslangan kartoshka bargi kasalliklarini aniqlash usuli (jsky2024001)

Annotatsiya. Tasvirni shovqindan tozalash — tasvirni oldindan qayta ishlashning ajralmas bosqichlaridan biridir. Shovqinni kamaytirishdan maqsad — tasvirdagi ortiqcha shovqin komponentlarini samarali tarzda bartaraf etish hamda asl foydali axborotning o'zgarishsiz saqlanishini ta'minlashdir. Ushbu maqolada turli shovqinni filtrlash algoritmlarining afzallik va kamchiliklari nazariy jihatdan tahlil qilinadi. Xususan, Gauss filtrlash, o'rtacha (Mean) filtrlash, median filtrlash, bilateral filtrlash va veyvlet (Wavelet) filtrlash usullari MATLAB muhiti yordamida modellashtirilib, kartoshka bargining kasallangan tasvirlari misolida ularning samaradorligi qiyosiy tahlil qilinadi.

Kalit so'zlar: tasvirni shovqindan tozalash; Gauss filtrlash; o'rtacha filtrlash; median filtrlash; bilateral filtrlash; veyvlet filtrlash.

DOI: https://doi.org/10.47390/ts-v3i10y2025No6

In the process of taking or transmitting images, it is inevitable that some electronic impulse noise and other interference will be introduced. The contaminated image, if the degree of contamination is relatively serious, can be observed by the naked eye. But for some subtle noise, the naked eye can not be detected, which often brings great challenges to image recognition. Therefore, how to effectively remove these noises has always been one of the most concerned research problems in the field of image processing [1,2].

1. Gaussian Filtering

Gaussian filtering is a linear smoothing filtering based on a Gaussian function, often used to denoise images with Gaussian noise or low intensity noise. It smoothes the image by averaging the values of the pixels surrounding each pixel in the image according to a Gaussian weight. Gaussian filtering is simple to implement, fast, and suitable for mild noise removal, but may blur image details and is not suitable for removing strong noise [3].

The mean is 0 and the variance is σ^2 The two-dimensional Gaussian function is:

$$f(x,y)=\frac{1}{2\pi\sigma^2}e^{-\frac{x^2+y^2}{2\sigma^2}}$$

The pixel values of the smoothed image are:

$$I_{smoothed}(x,y)=\frac{1}{\sum_{i=-k}^{k}\sum_{j=-k}^{k}w(i,j)}\sum_{i=-k}^{k}\sum_{j=-k}^{k}w(i,j)\cdot I(x+i,y+j)$$

where $w(i,j)$ is the weight in the Gaussian kernel .

The results obtained by denoising potato diseased leaf images using Gaussian filtering are shown in Figure 1:

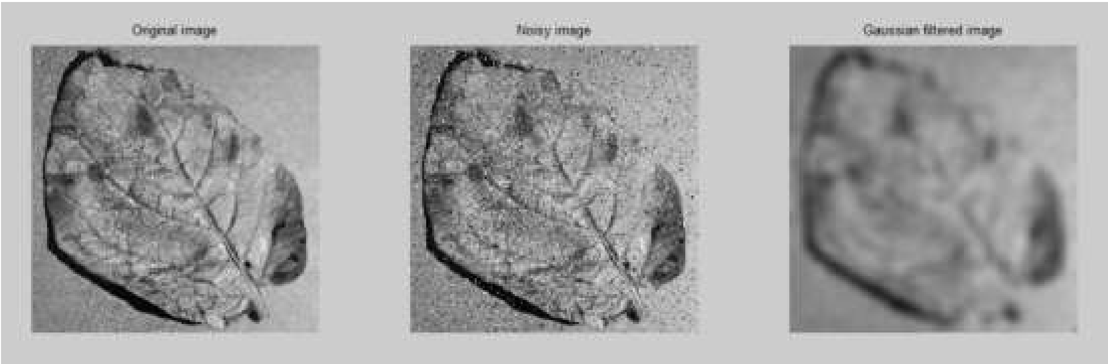

Figure 1: Gaussian filtering denoising result

2. Mean Filtering

Mean filtering is a classical linear smoothing filtering method, which is widely used in image processing and signal processing, mainly for noise removal and data smoothing. The core idea of Mean filtering is to replace the central pixel value with the average value of the neighbourhood pixels, and eliminate the isolated noise points through local averaging, so as to achieve the purpose of smoothing data.The Mean filtering algorithm is simple, easy to implement, has a good removal effect on Gaussian noise, is computationally efficient and suitable for real-time processing, but it leads to blurring of image edges (edge degradation) and is ineffective in removing pretzel noise [4].

For image processing, 2D Mean filtering can be expressed as:

$$g(x,y)=\frac{1}{N}\sum f(i,j)$$

Where : $f(i,j)$ is the pixel value of the original image at (i,j), $g(x,y)$ is the pixel value of the filtered image at (x,y), N is the total number of pixels in the neighbourhood window, the summing range is the neighbourhood window centred on (x,y).

The results obtained by denoising potato diseased leaf images using Mean filtering are shown in Figure 2:

Figure 2: Mean filtering denoising result

3. Median Filtering

Median filtering is a classical nonlinear filtering technique, mainly used for removing noise while maintaining edge information, which is especially widely used in the field of image processing. The core idea of Median filtering is to replace the central pixel value with the median value of the neighbourhood pixels, and effectively remove isolated noise points by sorting and selecting the middle value.Median filtering can effectively remove pretzel noise, better maintain the sharpness of the image edges, excellent for the removal of isolated noise points, do not need to know the statistical properties of the noise, but the computational complexity is higher than the Mean filtering (the need for sorting operations), the removal of Gaussian noise is generally effective, the filtering of the large window may lead to the loss of detail, and may change some of the features in the image (such as fine lines, corners) [5].

For a 2D image, Median filtering can be expressed as:

$$g(x,y) = median\{f(i,j)\},(i,j)\in S_{xy}$$

Where : $f(i,j)$ is the pixel value of the original image at (i,j), $g(x,y)$ is the pixel value of the filtered image at (x,y), S_{xy} denotes the neighbourhood window centred on (x,y), median means the median operation.

The results obtained by denoising potato diseased leaf images using Median filtering are shown in Figure 3:

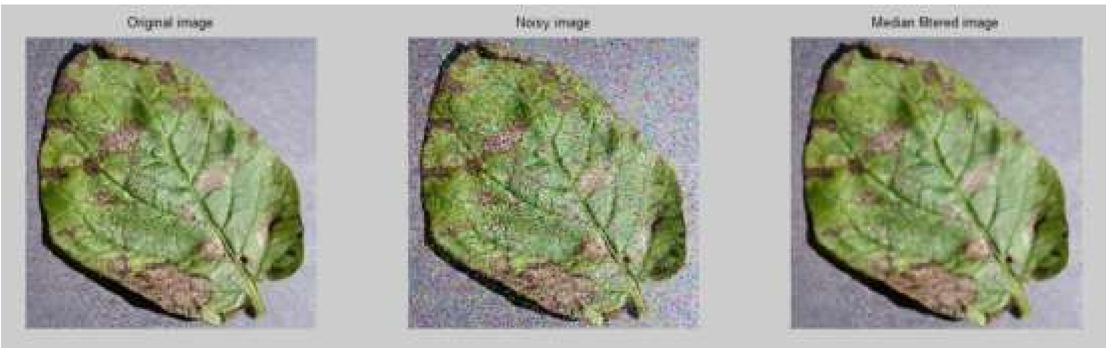

Figure 3: Median filtering denoising result.

4. Bilateral Filtering

Bilateral filtering is a nonlinear filtering technique that can retain the edge information while smoothing the image, overcoming the shortcomings of the traditional Gaussian filtering that blurs the edges when smoothing the noise. Bilateral filtering is a compromise between spatial proximity and pixel value similarity of an image, considering both spatial information and grey scale similarity, this dual consideration makes the Bilateral filtering both smooth homogeneous regions and retain edge information.Bilateral filtering is simple, effective and easy to implement, it can keep the edges well and does not need a priori knowledge, but the computational complexity is high, the parameter selection needs experience, and the effect on the strong noise is limited.

The output value $I'(p)$ for position p can be expressed as:

$$I'(p) = \frac{1}{W(p)} \sum_{q \in \Omega} I(q) \cdot f(\|p-q\|) \cdot g(|I(p)-I(q)|)$$

Where :$W(p) = \sum_{q \in \Omega} f(\|p-q\|) \cdot g(|I(p)-I(q)|)$ is the normalising factor, f is the spatial weight function, usually a Gaussian function, g is the value domain weight function, usually also a Gaussian function, Ω is the filtering window.

The results obtained by denoising potato diseased leaf images using Bilateral filtering are shown in Figure 4:

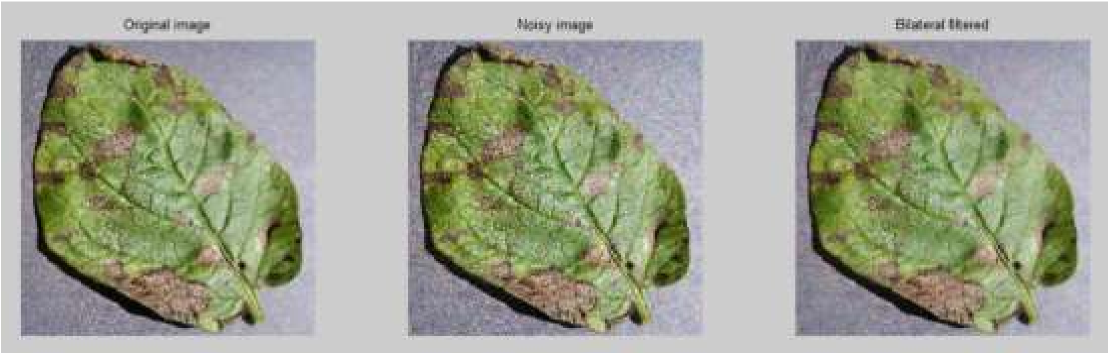

Figure 4: Bilateral filtering denoising result

5. Wavelet Filtering

Wavelet filtering is a signal and image denoising method based on Wavelet Transform [6]. Wavelet transform has the characteristics of time-frequency localisation, which can better retain the local characteristics of the signal and effectively remove the noise, but it also has the disadvantages of empirical selection of the wavelet basis, high impact of threshold selection and high computational complexity. The core idea of Wavelet filtering is:

Wavelet decomposition:Decomposition of the noise-containing signal into low-frequency Approximation Coefficients and high-frequency Detail Coefficients at different scales.

Thresholding: Noise is usually concentrated in the high-frequency part, and is suppressed by shrinking the high-frequency wavelet coefficients by setting a suitable threshold.

Wavelet reconstruction:The signal is reconstructed with the processed coefficients and the denoised result is obtained.

Wavelet filtering denoising step:

Given a noise-containing signal

$$y(t) = x(t) + n(t)$$

Where: $x(t)$ is the real signal and $n(t)$ is the noise (usually assumed to be Gaussian white noise) .

（1）Wavelet decomposition:Calculate the wavelet coefficients $W_y = W\{y(t)\}$;

（2）Thresholding:Thresholding $\hat{W}_x = T(W_y)$ on W_y;

（3）Wavelet reconstruction: The inverse transform obtains the denoised signal $\hat{x}(t) = W^{-1}\left\{\hat{W}_x\right\}$.

The results obtained by denoising potato diseased leaf images using Wavelet filtering are shown in Figure 5:

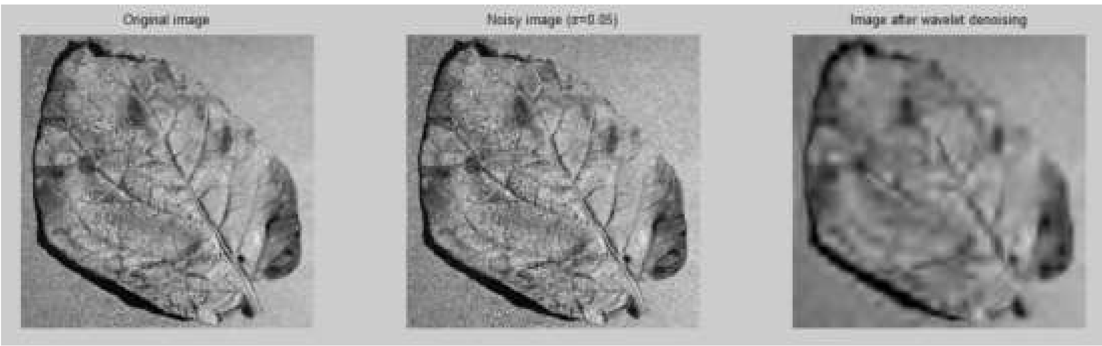

Figure 5: Wavelet filtering denoising result

6. Comparative Analysis of Various Filtering Denoising

In image processing, commonly used quantitative evaluation metrics include Peak Signal-to-Noise Ratio (PSNR) [7] and Structural Similarity Index (SSIM) [8]. Among them, the PSNR metric is used to quantitatively assess the similarity of image grayscale in simulation experiments, while the SSIM metric is used to quantitatively evaluate the sensitivity of human vision to the structure of target objects. The Mean Squared Error (MSE) metric directly calculates the degree of deviation in pixel grayscale values between the denoised image and the original noise-free image, providing the most basic numerical error reference for image quality.

This study conducted tests on potato disease leaf images with a noise pollution degree of 10% to 80%. Through three indicators—PSNR, SSIM, and MSE—it systematically compared the denoising performance of Gaussian filtering, mean filtering, median filtering, bilateral filtering, and wavelet filtering. The specific results are shown in Figure 6, Figure 7, and Figure 8.

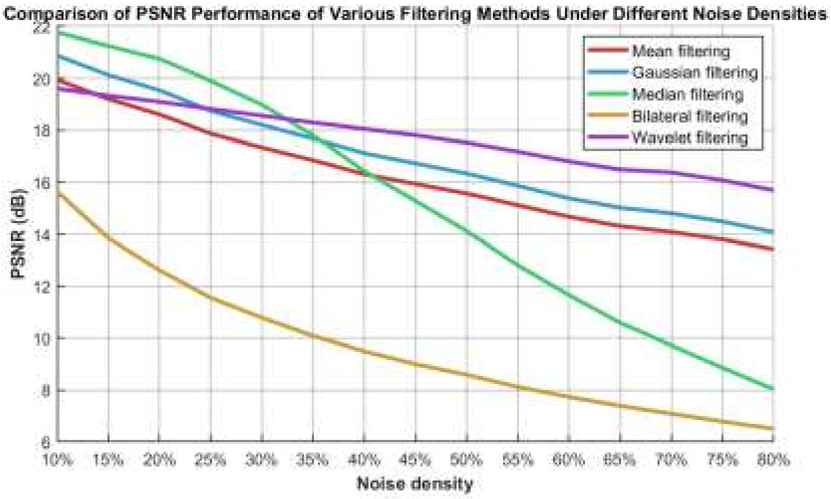

Figure 6: Comparison of PSNR Performance of Various Filtering Methods Under Different Noise Densities

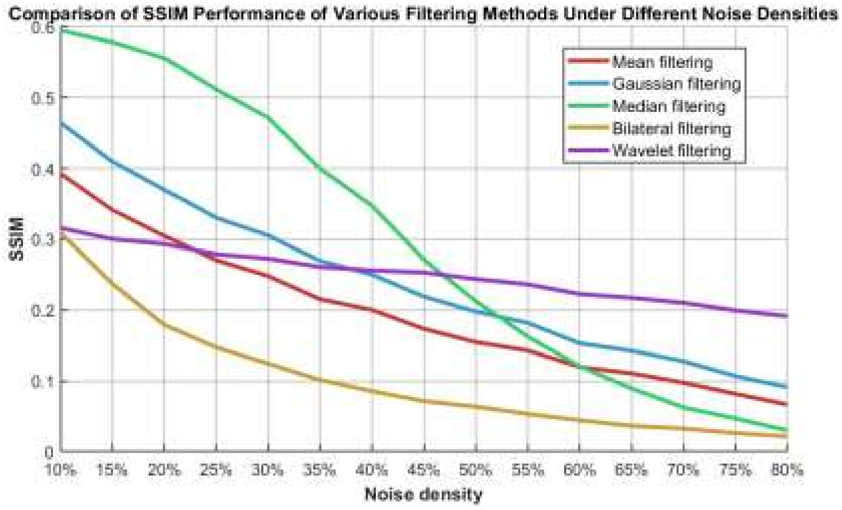

Figure 7: Comparison of SSIM Performance of Various Filtering Methods Under Different Noise Densities

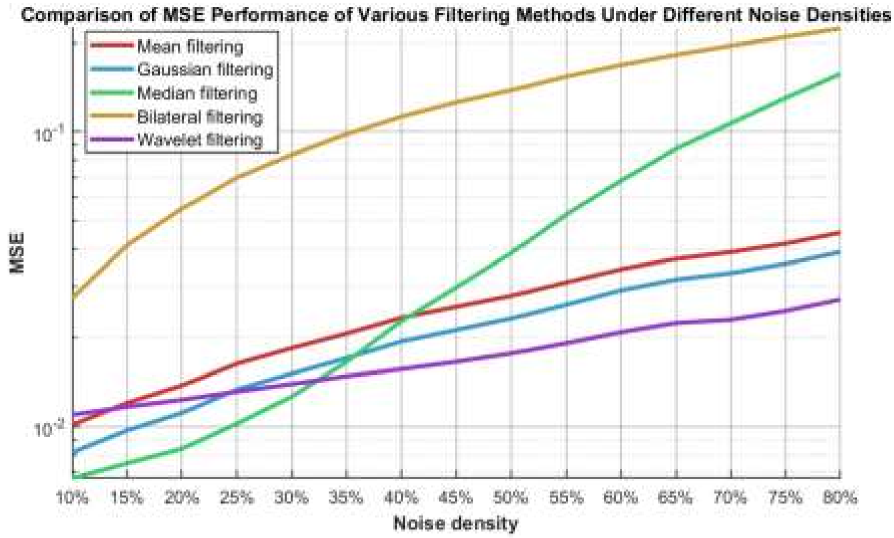

Figure 8: Comparison of MSE Performance of Various Filtering Methods Under Different Noise Densities

Through experimental comparison, the key performance indicators of various image denoising filtering methods show significant differences. The comparative analysis results are presented in Table 1 below :

Table 1:Comparative analysis of various filtering denoising

Filtering Type	**Keep the edge**	**Computational complexity**	**Applicable noise types**
Mean filtering	Poor	low	Gaussian noise
Median filtering	Better	Medium	Impulse Noise
Gaussian filtering	Average	Medium	Gaussian noise
Bilateral filtering	Good	High	Multiple Noise
Wavelet filtering	Good	Medium	Multiple Noise

7. Conclusion

This study focuses on the denoising requirements in the preprocessing of potato disease leaf images. From three dimensions—theoretical principles, MATLAB simulation implementation, and effect comparison—it systematically analyzes the performance of five classic denoising algorithms: Gaussian filtering, mean filtering, median filtering, bilateral filtering, and wavelet filtering. It clarifies the adaptability of different algorithms in the scenario of potato disease leaf image processing, with the conclusions as follows:

Gaussian filtering and mean filtering both achieve smoothing through local pixel weighting or averaging. They feature low computational complexity and fast operation speed, and have a certain effect on removing mild Gaussian noise. However, they share a common drawback: linear operations can blur the lesion edges of potato disease leaves (such as the water-soaked spot boundaries of late blight and the concentric ring edges of early blight). Additionally, they have weak suppression ability against impulse noise like salt-and-pepper noise, making it difficult to meet the core requirement of "clear lesion details" in disease identification.

Median filtering selects values through neighborhood pixel sorting, enabling efficient removal of salt-and-pepper noise (with a significant denoising effect on leaf images with a noise density of less than 0.1). It also preserves the sharpness of lesion edges relatively well, making it the preferred solution for removing impulse noise from potato leaf images. However, its performance in handling Gaussian noise is mediocre, and filtering with a large window tends to cause loss of fine lesion textures (such as pinpoint spots in early-stage diseases).

Bilateral filtering combines dual weights of spatial proximity and pixel value similarity, solving the problem of "smoothing inevitably blurring edges" in traditional Gaussian filtering. When removing mixed noise (low-intensity Gaussian + slight impulse noise), it can not only smooth the background noise of leaves but also accurately preserve lesion boundaries. However, its computational complexity is high (about 3-5 times higher than median filtering), and the standard deviation parameters of the spatial domain and range domain need to be repeatedly adjusted according to the characteristics of leaf images, which requires high operational experience.

Wavelet filtering relies on the time-frequency localization characteristic and adopts the "decomposition-threshold processing-reconstruction" process. It can targetedly suppress high-frequency noise (such as electronic pulse noise in image transmission) while preserving the detailed features of lesions (e.g., lesion color gradients and texture differences) to the greatest extent. Its adaptability to various types of noise (a mixture of Gaussian and impulse noise) is superior to that of single filtering algorithms. However, its performance depends on the selection of wavelet bases and threshold setting; improper parameter adjustment may easily cause artifacts at lesion edges. Additionally, its computational complexity is higher than that of median filtering, resulting in slightly weaker real-time processing efficiency.

Adabiyotlar/Литература/References:

1. BERTALMIO M.Denoising of photographic images and video: fundamentals, open challenges and new trends[M].Barcelona, spain: springer, 2018.
2. Sanaa A, Kruglova L V. Basic mathematical models for pattern recognition and image quality improvement[J]. Current Research, 2025 (18 (253)): 7-15.
3. Sun, M. (2013). Fundamentals of Digital Image Processing and Analysis: Implementation with MATLAB and VC++. Beijing: Publishing House of Electronics Industry.

4. Guan, X. P., Zhao, L. X., & Tang, Y. G. (2005). Hybrid filtering methods for image denoising. Journal of Image and Graphics, (3), 332-337.
5. KO S J, LEE Y H. Center weighted median filters and their applications to image enhancement[J]. IEEE transactions on circuits and systems,1991,38(9): 984-993.
6. MALLAT S G,Multifrequency channel decompositions of images and wavelet models[J]. IEEE transactions on acoustics, speech, and signal processing, 1989, 3 7(12): 2091-2110.
7. WANG Z, BOVIK A C, SHEIKH H R, et al. Image quality assessment: From error visibility to structural similarity[J].IEEE transactions on image processing, 2004,13(4): 600-612.
8. WANG Z, BOVIK A C. Mean squared error: Love it or leave it? A new look at signal fidelity measures[J]. IEEE signal processing magazine,2009,26(1): 98-117.

ISSN: 3030-3702 (Online)
САЙТ: https://techscience.uz

TECHSCIENCE.UZ

TEXNIKA FANLARINING DOLZARB MASALALARI

№ 10 (3)-2025

TOPICAL ISSUES OF TECHNICAL SCIENCES

TECHSCIENCE.UZ- TEXNIKA FANLARINING DOLZARB MASALALARI elektron jurnali 15.09.2023-yilda 130346-sonli guvohnoma bilan davlat roʻyxatidan oʻtkazilgan.
Muassislar: "SCIENCEPROBLEMS TEAM" mas'uliyati cheklangan jamiyati;
Jizzax politexnika insituti.

TAHRIRIYAT MANZILI:
Toshkent shahri, Yakkasaroy tumani, Kichik Beshyogʻoch koʻchasi, 70/10-uy.
Elektron manzil:
scienceproblems.uz@gmail.com