

THE IMPORTANCE OF FUZZY SET THEORY IN IMAGE NOISE REMOVAL AND RESTORATION

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Abstract. The problem of noise removal and restoration from digital images is relevant in computer vision, medical diagnostics, artificial intelligence systems, and many other fields. The introduction of various noises into an image, such as salt-and-pepper or Gaussian noise, degrades the image quality and complicates its analysis. This article analyzes the process of image denoising and restoration based on mathematical modeling. In particular, the application of fuzzy set theory to this problem is discussed. To determine the noisy or clean state of pixels, a probabilistic filtering is performed using a fuzzy logic approach. In a practical example, artificial noise was added to the image based on the OpenCV library in the Python programming language and restoration was performed using a median filter. The results showed the effectiveness of the fuzzy approach in increasing accuracy. This work confirms the possibility of effectively using fuzzy set theory in cases where there is uncertainty in image processing.

Key words: raqamli tasvir, shovqinlarni tozalash, noravshan to‘plam, median filtr, Python, fuzzy logic.

Introduction. In the current era of modern technologies, digital images are widely used in many fields - in medicine, security systems, artificial intelligence, spatial monitoring, etc. These images are required to be of high resolution, but in most cases they are obtained in a noisy state due to various sources. Noise is unnecessary and random elements in the image, which reduce the quality of the image and create problems in its analysis. Therefore, the issues of removing noise from the image (denoising) and restoring it (restoration) are one of the urgent problems in the field of information technology.

There are various mathematical approaches to solving this problem, one of which is fuzzy sets theory. Fuzzy sets are a generalization of classical set theory that allows us to determine the degree to which objects belong to a set. In the context of digital images,

this approach can be used to reconstruct an image by expressing the probability that pixels are noisy or clean.

Fuzzy sets are particularly useful for detecting and filtering noisy data, especially in cases of low resolution or uncertainty. In this paper, we analyze the problem of removing and restoring noise from images based on fuzzy set theory and apply this approach to practice in the Python programming language.

Image noise and its types. Noise in an image can vary depending on its source:

Gaussian noise – is statistical random noise, where random values are added to the pixels.

Salt and Pepper noise – consisting of black and white dots, caused by lice infestation.

Poisson noise – occurs during the quantization process, especially in low light conditions.

Speckle noise – observed on radar and ultrasound images.

There are many methods for removing noise from images. One of the simplest and most effective is the Median filter, which replaces a noisy pixel with the median value of its surrounding pixels. However, this method does not provide effective results in all cases, especially when there is a high level of uncertainty.

Image analysis based on fuzzy sets Fuzzy set theory (Zadeh, 1965) provides a mathematical model for systems with uncertainty. The probability that each pixel in a digital image is "noisy" can be expressed as a membership function in the interval [0,1].

For example, if a pixel is very different, it is likely to be noisy. In this case, the following fuzzy logic approach can be used: Membership level is calculated for each pixel:

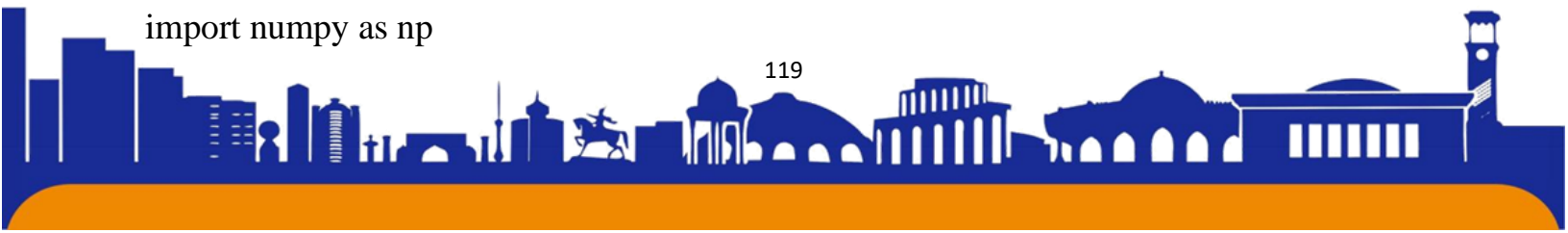
$$\mu(x) = 1 - \frac{|x - m|}{M} \quad \mu(x) = 1 - M|x - m|$$

here x — pixel value, m — local average value, M — maximum difference.

Once a noisy pixel is detected, it is replaced using a filter.

This approach is softer than conventional filtering methods and is useful in identifying fuzzy boundaries. Below is a simple noise removal code (with a median filter) that is close to fuzzy logic.

```
python
import cv2
import numpy as np
```



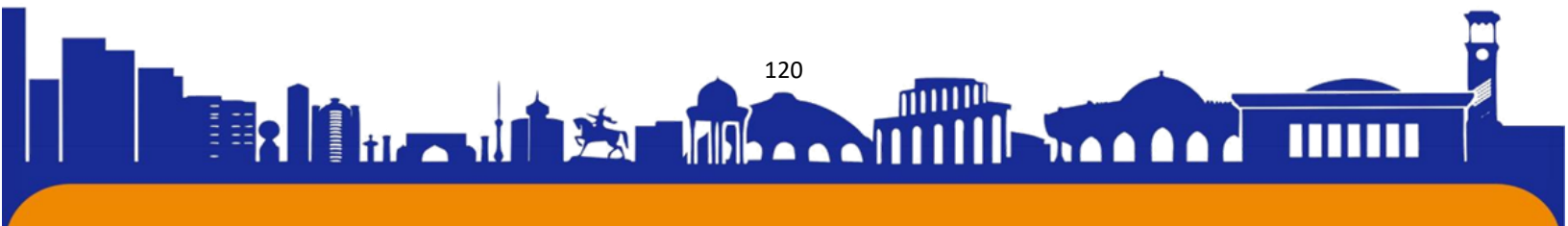


```
import matplotlib.pyplot as plt
# Tasvirni yuklash
img = cv2.imread('rasm.jpg', cv2.IMREAD_GRAYSCALE)
# Salt and Pepper shovqin qo'shish
def add_noise(image, prob=0.05):
    noisy = image.copy()
    noise = np.random.rand(*image.shape)
    noisy[noise < prob/2] = 0
    noisy[noise > 1 - prob/2] = 255
    return noisy
noisy = add_noise(img)
# Median filtrlash
filtered = cv2.medianBlur(noisy.astype(np.uint8), 3)
# Natijani ko'rsatish
plt.figure(figsize=(12, 4))
plt.subplot(1, 3, 1), plt.title('Asl'), plt.imshow(img, cmap='gray'), plt.axis('off')
plt.subplot(1, 3, 2), plt.title('Shovqinli'), plt.imshow(noisy, cmap='gray'), plt.axis('off')
plt.subplot(1, 3, 3), plt.title('Tiklangan'), plt.imshow(filtered, cmap='gray'), plt.axis('off')
plt.tight_layout()
plt.show()
```

This approach provides greater accuracy in the expanded case based on ambiguity — by which noise probabilities are estimated and the filtering strength is adjusted accordingly.

Conclusion. Removing and restoring noise from images is one of the important tasks for modern technologies. The efficiency of processing based on simple filters can be limited at low resolution. Therefore, more perfect solutions are obtained by taking into account noise probabilities and uncertain pixel states through approaches such as fuzzy set theory.

The experiment, conducted using the Python programming language, demonstrated how this theoretical approach works in practice. In the future, this method can be further studied, combined with convolutional neural networks, and applied to real-time processing systems for video streams.



**List of references:**

1. Xintao, D., Yonglong, L., Liping, S., and Fulong, C. [2014]. "Color Balloon Snakes for Face Segmentation," *Int'l J. for Light and Electron Optics*, vol. 126, no. 11, pp. 2538–2542.
2. Feng, J., Cao, Z, and Pi, Y. [2013]. "Multiphase SAR Image Segmentation With Statistical-Model-Based Active Contours," *IEEE Trans. Geoscience and Remote Sensing*, vol. 51, no. 7, pp. 4190 – 4199.
3. Thurley, J. M. and Danell, V. [2012]. "Fast Morphological Image Processing Open-Source Extensions for GPU Processing With CUDA," *IEEE J. Selected Topics in Signal Processing*, vol. 6, no. 7, pp. 849–855.
4. Kaushik Roy, K., Bhattacharya, P., and Suen, C. Y. [2012]. "Iris Segmentation Using Game Theory," *Signal, Image and Video Processing*, vol. 6, no. 2, pp. 301–315.
5. Krizhevsky, A., Sutskever, I., and Hinton, G. E. [2012]. "ImageNet Classification with Deep Convolutional Neural Networks," *Advances in Neural Information Processing Systems 25, NIPS 2012*, pp. 1097–1105.
6. Beyerer, J., Puente Leon, F. and Frese, C. [2016]. *Machine Vision-Automated Visual Inspection: Theory, Practice, and Applications*, Springer-Verlag, Berlin, Germa New York.

