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Утицај шума на детекцију ивица над сликама различите комплексности

Impact of noise to edge detection on images of different complexity

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***Abstract* — У овом раду урађена је анализа детекције ивица над сликама ралзичите комплексности које су погођене Salt and Pepper, Gaussian и Speckle шумомо. Урађена је анализа за три нивоа шумности и то 0.01, 0.05 и 0.1. За анализу су коришћене преко 100 слика из BSD базе и свака слика поседује GroundTruth помоћу којих је извршена објективна процена детектованих ивица помоћу ПР и Ф мера. Такође. Коришћена су пет детектора ивица Canny, LoG, Sobel, Prewitt и Roberts оператор. Резултати су приказани графички. Добијени резултати показују да шум знатно утиче на детекцију ивица. Када је у питању Salt and Pepper шум, Canny оператор је остварио најбоље резултате за све нивое шумности и комплексности слике. Код Speckle типа шума за велики и средњи број детаља у слици, такође је Canny дао најбоље резултате, док за мали број детаља у слици то је Prewitt оператор. Када је у питању Гаусов шум, за све три категорије комплексности слике најбољи оператор је Prewitt.**

***Abstract* — In this paper, an analysis of the edge detection over images of different complexity affected by Salt and Pepper, Gaussian and Speckle noise is performed. An analysis was performed for three noise levels, 0.01, 0.05 and 0.1. Over 100 images from the BSD database were used for analysis and each image has a GroundTruth with which an objective assessment of the detected edges was performed using PR and F measures. Five edge detectors Canny, LoG, Sobel, Prewitt and Roberts operator were used. The results are presented graphically. The obtained results show that noise significantly affects the detection of edges. When it comes to Salt and Pepper noise, Canny detector has achieved the best results for all levels of noise and image complexity. With the Speckle noise type for high and medium number of details in the image, Canny also gave the best results, while for low number of details in the image it is the Prewitt operator. When it comes to Gaussian noise, for all three categories of image complexity the best operator is Prewitt.**

Keywords – ***edge detection; image processing; image noise; image complexities;***

I. INTRODUCTION

When processing images, we strive not to impair the quality of the image and to extract as much information as possible. However, sometimes the quality itself is impaired at the moment when the image is created, and often during its processing or transmission. Common forms of this image distortion are noise. Generally speaking, noise in the image represents unwanted information and as such causes consequences on the image such as the appearance of artifacts, false edges and lines, blurred objects as well as distortion of the background of the image itself. The characteristic and the forest model itself can be represented by histograms and Probability Denticity Function (PDF) [1, 2].

Different types of noise based on the PDF are Gaussian, Raileigh, Uniform, Impulse, Poisson, etc. According to the correlation, noise is classified in white and color noise. White noise has a uniform power spectral density and zero autocorrelation, unlike color noise. If the image is damaged by white noise, it means that not all pixels are interconnected. It is an additive or multiplicative (Speckle) noise according to nature, that is, noise pixels are added or multiplied with the reference image. According to the classification of sources, this is often called quantization noise or photon noise [3].

In this paper, the following types of noise were used to analyze the performance in image edge detection:

1. Gaussian
2. Salt and Pepper
3. Speckle

A. Gaussian

Due to their mathematical properties in the spatial and frequency domain, Gaussian noise models are often used in practice. In general, Gaussian noise disturbs the intensity level of the gray pixel. For this reason, Gaussian noise is characterized by its histogram or PDF due to the dependence of the gray value pixel [1]. It is statistical and additive in nature that follows the normal distribution with zero mean and σ standard deviation and affects all pixels in the image. The cause of its appearance are fluctuations in sensor temperature and variations in ambient lighting [3]. PDF of Gaussian noise that the following equation [2, 3]:

$$P(z) = \sqrt{\frac{1}{2\pi\sigma^2} e^{-\frac{(z-\mu)^2}{2\sigma^2}}} \qquad (1)$$

where z is the value of gray intensity, σ is the standard deviation and μ is the mean. The mathematical model of Gaussian noise represents an exact approximation of a scenario in the real world. In this forest model, the mean value is zero, the values of gray intensity are in the range from 0 to 255 levels of gray in terms of its PDF (Figure 1).

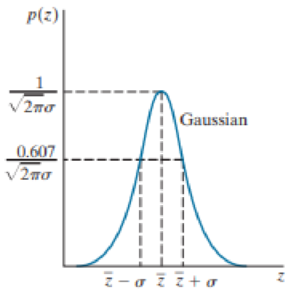


Fig. 1 – PDF of Gaussian noise.

B. Slat and Pepper

Impulse noise is additional noise that is most often caused by faulty sensors and transmission errors. Unlike Gaussian noise, it only affects certain pixels in the entire image, i.e. the image is not completely damaged but only individual pixels in the image. This type of forest includes Salt and Pepper noise [1]. If we take as an example a 3x3 matrix with pixels whose values are from 0 to 255 if the number of bits is 8. If Salt and Pepper noise hit a central pixel whose value was 250, now that value is close to zero, which means that it has become dark pixel while the other pixels remained unchanged. Thus, Salt and Pepper noise affects only certain pixels and replaces their values with dark pixels if that pixel was bright, that is, of higher intensity, and vice versa. Salt and Pepper noise is given [1,3]:

$$p(z) = \begin{cases} P_a \; for\; z = a \\ P_b \; for\; z = b \\ 0, \; \text{за остале случајеве} \end{cases} \qquad (3)$$

where a and b are the minimum and maximum pixel values of the dynamic range of the image. Pa and Pb are probabilities equal to Salt and Pepper noise.

Figure 2 shows a PDF of Salt and Pepper noise.

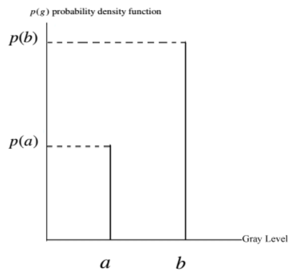


Fig. 2 – PDF of Salt and Pepper noise.

C. Speckle

This type of noise is multiplicative noise. It often occurs in coherent recording systems such as laser, radar and acoustics, etc. Speckle noise in an image can occur similarly to Gaussian noise, only it is much harder on the part of the observer because it makes it difficult to notice fine details in the image. Its probability density function follows the gamma distribution and is given as follows [4, 5]:

$$P(z) = \frac{z^{\partial-1} e^{-\frac{g}{a}}}{\partial - 1!\, a^{\partial}} \qquad (2)$$

Figure 3 shows a PDF of Speckle noise.

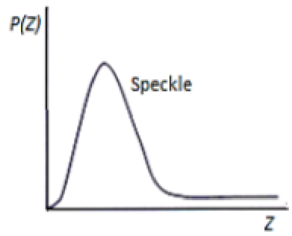


Fig. 3 - PDF of Speckle noise.

II. SYSTEM MODEL

Noise in the image is common and often present and occurs in all levels of the image, which can be seen on the basis of the application of these three types of noise. In this paper, the most important part is the edge detection on images in which there is noise because edge detectors such as Roberts, Sobel and Prewitt based on the first derivative are sensitive to noise [6]. For this reason, the Canny operator first filters the image and then does the detection. Many noises reduction filters have been proposed, and the type of filter also depends on the type of noise [7, 8]. In [9], an approach was proposed to edge detection on image degradation occurred during compression using a median filter. Like image processing itself, there is great interest among researchers in the edge detection in images where there is noise, so many methods have been used to overcome this problem, and more recently by the method of artificial intelligence and neural networks [6].

This paper categorizes images at three levels of complexity, low (Low Details - LD), medium (Medium Details - MD), and high complexity (High Details - HD), which is determined based on spatial information as in [10].

Images from the BSD (The Berkeley Segmentation Dataset and Benchmark) database were tested for three levels of complexity and for five edge detection operators (Canny, LoG, Sobel, Roberts, and Prewitt). In the analysis, noise was added to each image, namely three types of noise: Salt and Pepper, Gaussian and Speckle in intensities: 0.01, 0.05, and 0.5.

III. RESULTS

Figure 4 shows the results of edge detection at different image complexity. Five detectors (Canny, LoG, Sobel, Prewitt, Roberts) and three objective measures (F, PR) were used. Based on the obtained values of these measures, it can be seen that the quality of the detected edge depends on the number of details. Based on this fact and the results shown in Figure 4, it can be seen that when the number of details in the figure is low, the best edge detection was achieved using the Roberts operator, while Sobel and Prewitt gave similar results. When it comes to images with medium number of details, the Roberts operator again achieved the best results. Canny operator is the best choice when it comes to images with a high detail, that is, the best values are obtained using this operator.

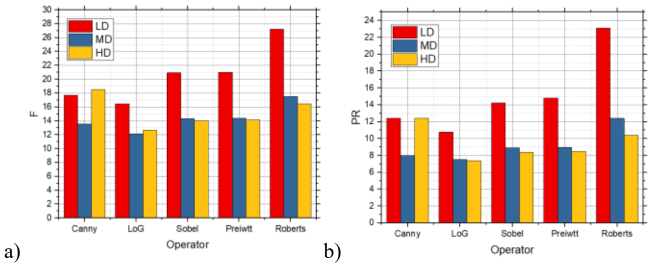


Fig. 4 - Obtained values for images with LD, MD and HD using five edge detectors a) F, b) PR values.

Figure 5, Figure 6 and Figure 7 show the F and PR values for images with low, medium and high number of details over which edge detection was performed and which contain Salt and Pepper noise intensities of 0.01, 0.05 and 0.1, respectively. These images were detected for five edge detection operators. From Figure 5 it can be seen that for all three levels of complexity Canny showed as the best detector. By increasing the noise concentration to 0.05, Canny records the best results, but these values are slightly lower than 0.01, especially for images with a low number of details. By increasing the noise concentration to 0.1, the values are significantly lower, which means that the edge detection is also worse. As in previous cases, Canny recorded the best results and the noise significantly worsened the detection for images with a low number of details. Comparing these results with the results shown in Figure 4, it can be seen that at that time the Roberts operator recorded good results for images with low number and medium number of details, while in case noise is present it records very poor edge detection results for all complexity categories. Also, from Figure 5, Figure 6 and Figure 7 it can be concluded that Salt and Pepper noise affected the edge detection to a great extent, especially in images with a low number of details.

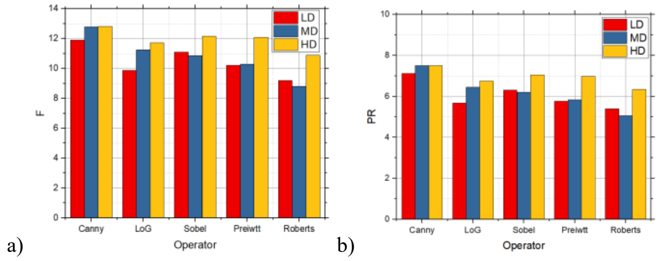


Fig. 5 - Obtained values by the standard method for LD, MD and HD images in the presence of Salt and Pepper noise intensity 0.01 and using five edge detectors: a) F values, b) PR values.

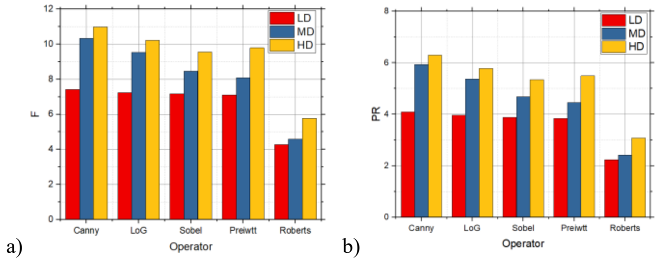


Fig. 6 - Obtained values by the standard method for LD, MD and HD images in the presence of Salt and Pepper noise intensity 0.05 and using five edge detectors: a) F values, b) PR values.

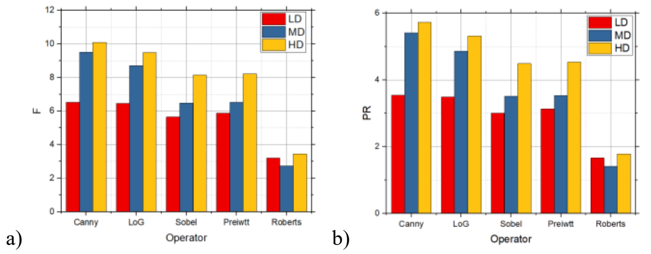
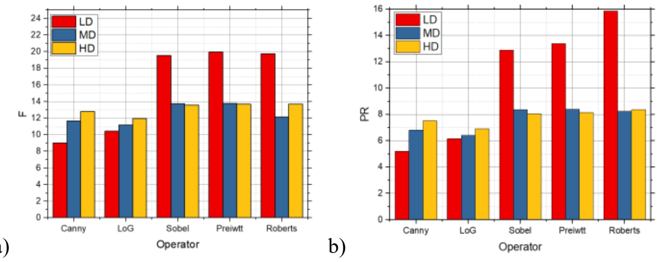


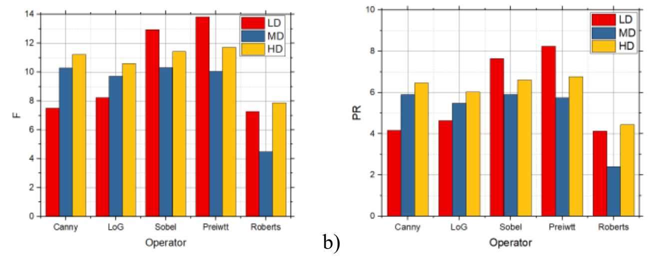
Fig. 7- Obtained values by the standard method for LD, MD and HD images in the presence of Salt and Pepper noise intensity 0.1 and using five edge detectors: a) F values, b) PR values.

Figure 8, Figure 9, and Figure 10 show the F values of the PR values for images with low, medium, and high numbers of detail over which edge detection was performed, and which contain Speckle noise intensities of 0.01, 0.05, and 0.1, respectively. In the case where the noise concentration is 0.01, the gradient operators record significantly better results for images with a low number of details compared to LoG and Canny operators. Also, for medium and high number of details in the image, these operators proved to be a better solution. However, with a further increase noise level in the image with an intensity intensity of 0.05 and when the number of details in the image is low, Prewitt and Sobel recorded good results, while Roberts recorded significantly lower values then Sobel, which can be seen in Figure 9. The Roberts operator records very poor results, especially for images with a medium number of details. For a large number of details, all operators except Roberts operators record quite similar results, and comparing with Figure 4 where there was no noise, it can be noticed that the results are to a good extent satisfactory. When it comes to high noise, i.e., Speckle noise of intensity 0.1, the Canny operator records the best results for medium and high number of details, while for a low number of details in the image it is Prewitt operator. In this case, too, Roberts got the worst results, that is, the worst edge detection, the detection of which is not usable for further processing. Compared to lower noise levels, as expected, the detection is worse, i.e., lower values of F and PR measures are obtained.



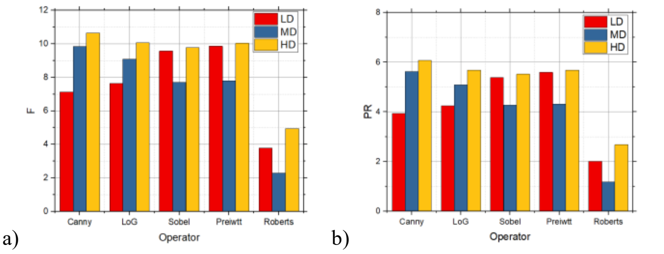
a) b)

Fig. 8 - Obtained values by the standard method for LD, MD and HD images in the presence of Speckle noise intensity 0.01 and using five edge detectors: a) F values, b) PR values.



a) b)

Fig. 9 - Obtained values by the standard method for LD, MD and HD images in the presence of Speckle noise intensity 0.05 and using five edge detectors: a) F values, b) PR values.

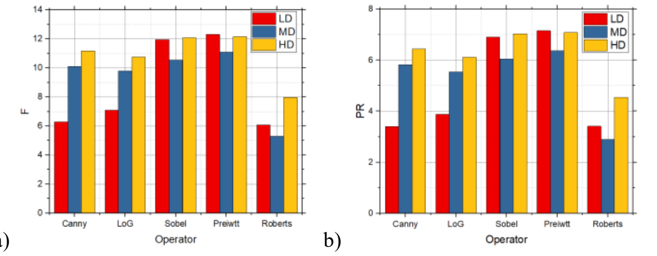


a) b)

Fig. 10 - Obtained values by the standard method for LD, MD and HD images in the presence of Speckle noise intensity 0.1 and using five edge detectors: a) F values, b) PR values.

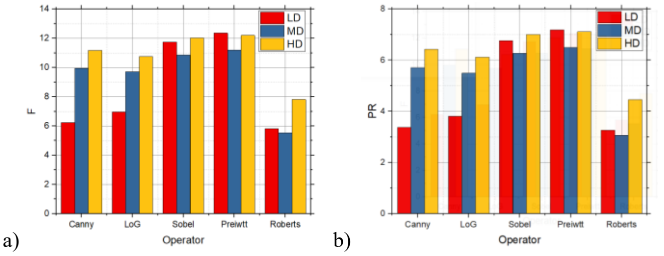
Figure 11, Figure 12 and Figure 13 show the F values and PR values for images with low, medium and large number of details over which edge detection was performed, and which contain Gaussian noise intensities of 0.01, 0.05 and 0.1, respectively. When it comes to noise intensity of 0.01, the best results are obtained using the Sobel and Prewitt operators for case when it comes to low and high number of details in the image. When it comes to the medium number of details in an image, the best results are obtained using the Prewitt operator. The Roberts operator records very bad results in this case as well. By increasing the noise concentration to 0.05, then to 0.1 (Figure 12 and Figure 13), largely similar operator behaviors can be seen, as well as the values obtained for edge detection. We attribute the reason to the Gaussian noise model itself. However, comparing with Figure 4 where there was no noise in the image, it is noticed that Gaussian noise significantly affected the edge detection for all categories of complexity but mostly for images with a low number of details in the image.

If we compare the types of noise on edge detection, it can be noticed that noise greatly affects the quality of edge detection. Salt and Pepper and Speckle greatly influenced images with low number of details, especially at higher noise intensities. When Salt and Pepper noise is present, for all three complexity categories the best operator proved to be Canny. With the Speckle noise type for high and medium number of details in the image, Canny also gave the best results, while for low number of details in the image it is the Prewitt operator. When it comes to Gaussian noise, for all three categories of image complexity the best operator is Prewitt.



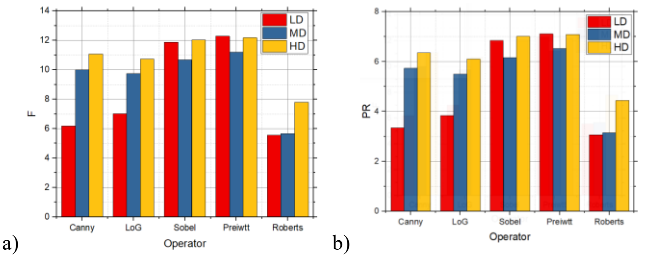
a) b)

Fig. 11 - Obtained values by the standard method for LD, MD and HD images in the presence of Gaussian noise intensity 0.01 and using five edge detectors: a) F values, b) PR values.



a) b)

Fig. 12 - Obtained values by the standard method for LD, MD and HD images in the presence of Gaussian noise intensity 0.05 and using five edge detectors: a) F values, b) PR values.



a) b)

Figure 13 - Obtained values by the standard method for LD, MD and HD images in the presence of Gaussian noise intensity 0.1 and using five edge detectors: a) F values, b) PR values.

IV. CONCLUSIONS

In this paper, an analysis was performed for five edge detectors (Canny, LoG, Sobel, Roberts and Prewitt) on images consisting of different number of details in the image, i.e., complexity. Complexity was calculated on the basis of spatial information in the image and three categories of complexity were created: low, medium and high number of details. The 100 images from the BSD database were used for analysis, each of which has its own GroundTruth. GroundTruth was used to perform an objective assessment of the detected edges, in order to get PR and F objective measures. Noise was applied to each image to perform edge detection analysis on noise-affected images. Three forest types Salt and Pepper, Gaussian and Speckle whose intensities are 0.01, 0.5 and 0.1 were analyzed.

The obtained results show that the noise significantly affects the detection of edges, especially of stronger intensity. From the obtained results it can be seen that when the number of details in the image is low, the best edge detection was achieved using the Roberts operator, while Sobel and Prewitt gave similar results. When it comes to images with medium number of details, the Roberts operator again achieved the best results. The canny operator is the best choice when it comes to images with a high number of details, that is, the best values are obtained using this operator. However, when images are affected by noise, the behavior of the operator is different depending on the type and intensity of noise. When Salt and Pepper noise is present, for all three complexity categories the best operator proved to be Canny. With the Speckle noise type for high and medium number of details in the image, Canny also gave the best results, while for low number of details in the image it is the Prewitt operator. When it comes to Gaussian noise, for all three categories of image complexity the best operator is Prewitt.

The obtained results show an analysis that can help researchers to develop applications and algorithms of practical application.

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