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REMOVAL OF VARIOUS NOISES FROM DIGITAL IMAGES WITH THE APPLICATION OF A SINGLE ALGORITHM

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ABSTRACT

In general, digital images captured by various electronic devices suffer as result of various noise which may be the result of different sources. Noise can be caused by sensors, atmospheric conditions, internal circuits, and so on. As result of the presence of various types of noise, we have degradation of the image. Today, there are different methods and filters that apply to the removal of specific noise that may have corrupted the image. In this paper, we will present a successful algorithm that enables the restoration of corrupt image pixels simultaneously from various types of noises. The working principle of this algorithm is based on that initially, the image is simultaneously corrupted by different types of noise. After the corruption, the algorithm makes the identification and isolation of corrupt image pixels as well as their restoration. This algorithm enables the restoration of corrupted pixels from whatever kind of noise and which may be the result of whatever source.

Key words: Digital Image, Algorithms, Noises, Filter, Pixels.

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1. INTRODUCTION

An image is a visual representation of something. In other words, an image is a picture that has been created or copied and stored in electronic form. They may be captured by different devices, such as cameras, sensors, mirrors, lenses, telescopes, microscopes, etc.

Digital images are prone to different types of noises. Noise is the result of errors occurring during the process of capturing, processing, and transmitting the image. The presence of noise in the image, resulting in values of pixels that do not reflect the true intensity of the real scene.

All digital recording devices have features that make them sensitive to noise during the recording process.

The task of electronic devices in most cases is capturing, processing, and routing images through network to the destination [1]. However, during this process, the presence of noise can affect the performance degradation of the image. Noise can be a random or white noise, coherent or not coherent noise, which is usually caused by device mechanism, processing algorithms, atmospheric conditions, etc. Therefore, removing noise from the corrupted images is absolutely obligatory and very important [2]. For repair *corrupted pixels* of image, special filters for special noise are traditionally used. Each of these traditional filters can have good performance in repair corrupted pixels from a particular type of noise and reciprocally, such as for repair corrupted pixels from Gaussian Noise, is suitable application Gaussian Filter, for repair corrupted pixels from Salt & Pepper Noise is suitable application a nonlinear digital filters, etc. However, the image captured by electronic devices can simultaneously be corrupted by different types of noise [3], such as: Periodic Noise, Salt & Pepper Noise (SPN), Speckle Noise (SPKN), Gaussian Noise, Poisson Noise, etc. To remove these noises, special filters for special noise should be applied.

In order to solve this problem we have developed a new algorithm, which enables the restoration of the corrupted pixels of the image by different types of noise at the same time in successful manner.

2. TYPES OF NOISES

Noise in the image is a factor which affects the change of brightness or colour information of the image. In other words, noise is a general term for unwanted modifications of the image during capture, storage, transmission, processing, or conversion. Since the presence of noise in the image effects in image degradation, it should be eliminated as much as possible. Noise removal and the recovery of the original image from the noise-corrupted is one from the main goals in the design of signal processing systems, especially filters. Noise is undesirable information that is included in the image without our desire. Some of the possible noises are: Periodic Noise, Gaussian Noise, Salt and Pepper Noise, Poisson Noise, Speckle Noise, etc.

Periodic Noise - Periodic noise has a global effect in image degradation captured from electronic device, and it is not easy to remove or decrease its effect using traditional filters. A common source of periodic noise in an image is from electrical or electromechanical interference during the image capturing process [4]. An image affected by periodic noise will look like a repeating pattern has been added on top of the original image. In the frequency domain this type of noise can be seen as discrete spikes. Image with periodic noise usually is severely corrupted by the sinusoidal noise of various frequencies [4]. This type of noise is most effectively reduced with frequency domain filtering. Direct Fourier transform is presented by the mathematical equation.

$$F(u,v) = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)\exp\left[-2\pi i\left(\frac{mu}{M}+\frac{nv}{N}\right)\right] \tag{1}$$

Where $f(x,y)$ is a digital image with size MxN. Equation (1) is evaluated for values of the discrete variables u and v, where u take values $u=0....M-1$, and v take values $v=0...N-1$. Given the transform $F(u,v)$ we can obtain $f(x,y)$ by using the inverse discrete Fourier transform. The inverse discrete Fourier transform is presented by the mathematical equation (2):

$$f(m,n) = \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v)\exp\left[2\pi i\left(\frac{mu}{M}+\frac{nv}{N}\right)\right] \tag{2}$$

Where m take values $m = 0....M-1$, and n take values $n = 0...N-1$. The variables u and v represented in the equations (1) and (2) are frequency variables. The function $F(u,v)$ is often called the frequency domain representation of $f(x,y)$ and it is complex-valued function. In Figure 1 is shown Periodic noise in x, y, z coordinates with period $T=5$.

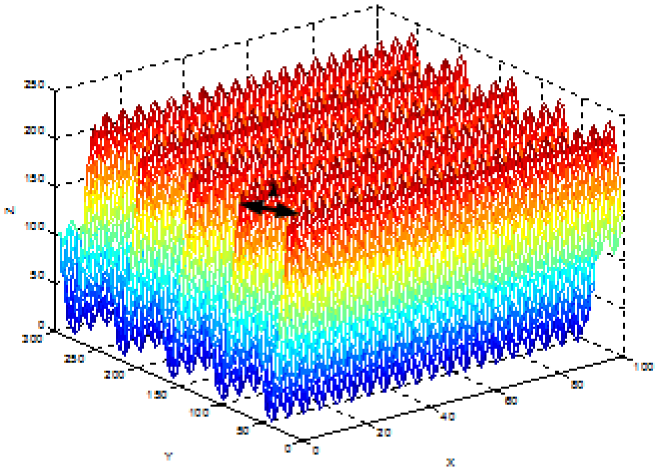

Figure 1 Periodic noise with period $T=5$

Gaussian Noise - The principal sources of Gaussian noise in digital images, are caused during the acquisition process, for example, the sensor noise caused by poor illumination, high temperature and as a result of transmission. A white noise signal is constituted by a set of independent and identically distributed random variables. White noise is seen as a random process composing several random variables following the same Probability Distribution Function. Probability Distribution Function is defined by the mathematical equation (3):

$$P(g) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(g-\mu)^2}{2\sigma^2}} \quad (3)$$

where: g = grey value, σ = standard deviation and μ = mean. In Figure 2 is shown Gaussian white noise signal with length $l=100000$, mean $\mu=0$ and standard deviation $\sigma=2$.

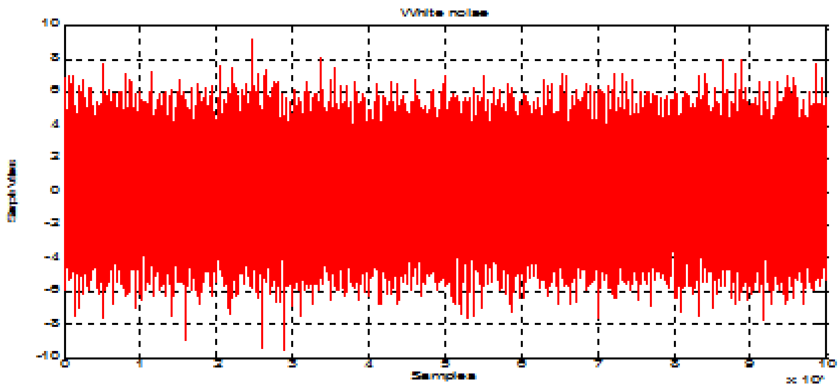

Figure 2 Generate a Gaussian white noise signal

In Figure 3 is shown theoretical Probability Distribution Function of the Gaussian random variable and histogram of the Gaussian white noise.

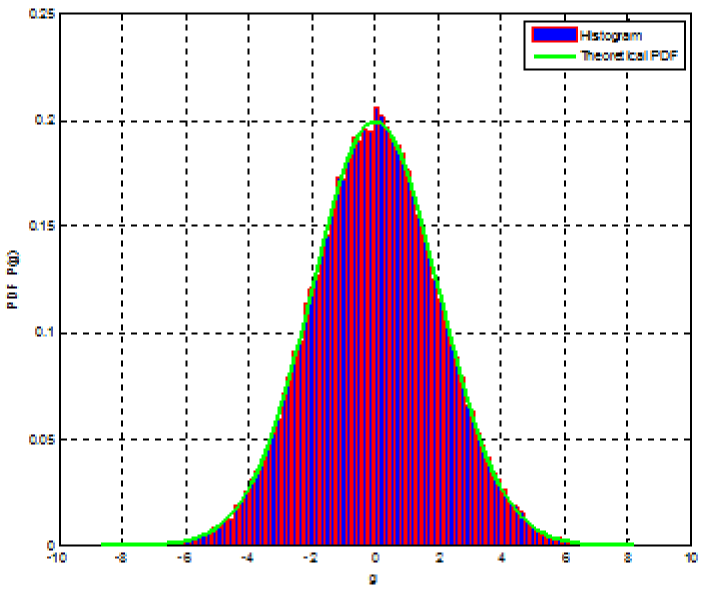

Figure 3 Gaussian distribution with zero-mean and standard deviation σ=2

Salt and Pepper Noise - Impulsive noises are often called as salt and pepper noise. If an image has the presence of Salt and Pepper Noise, then there will have dark pixels in bright regions (it takes a minimum value of 0) and bright pixels in dark regions (it takes a maximum value of 255). In such a case, pixels in the image are very different in colour or intensity from their surrounding pixels. Impulse noise can occur during the image capture process from the electronic device such as camera, sensor, etc., and captured image transmission to the destination. This can happen for many reasons, both natural and non-natural, for example, as a result of errors in the analogue-to-digital conversion process, communication device errors, electromagnetic interference, synchronization errors, atmospheric conditions, etc.

Poisson noise – Poisson noise is a type of noise that occurs as a result of statistical quantum fluctuations, which is a change in the observation the number of photons in a given level of exposure. This noise is dominant in the darker parts of an image captured by sensors. The presence of this noise can be observed in optical devices and depend on the nature of the light particles. This noise is also called as quantum (photon) noise or shot noise [5]. The probability distribution of this noise is defined by the mathematical equation (4):

$$P(\lambda; k) = \frac{\lambda^k e^{-\lambda}}{k!} \tag{4}$$

where: λ – is the average number of events that occur during a time interval; e - Euler's number (2.718...); k – Takes values 0, 1, 2, 3…

This equation is the probability mass function for a Poisson distribution. Graphic presentation of the Poisson distribution is shown in Figure 4. Poisson distribution is shown for λ=4, λ=10 and λ=16.

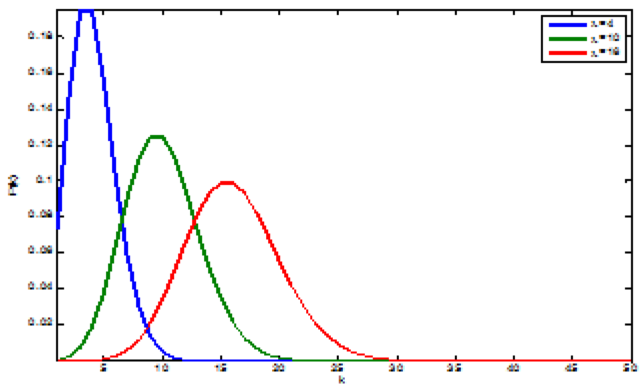

Figure 4 Graphic presentation of the Poisson distribution

Speckle noise - is a multiplicative noise. The presence of this noise we can see in the images captured by coherent systems, such as laser, radar, sensors, camera, acoustic devices, etc. Speckle noise can be present in an image in the same way as Gaussian noise. This noise can be modelled by random value multiplications with pixel values of the image [6] and can be expressed by the mathematical equation (5):

$$J = I + n * I \tag{5}$$

where: *J*- Speckle noise distribution in the image; *I* - input image; *n* - uniform noise image having mean *0* and variance *v*.

3. TRADITIONAL FILTERS FOR NOISE REMOVAL

Filtering is a technique that applies to modifying and improving the image captured by electronic devices. Filters now find a very wide application, but one very important applications is their application to remove noise from the image [10]. Today, there are several types of filters and algorithms that apply to this purpose. Some of the most popular filters that applied for noise removal from image are: Median Filter, Mean Filter, Gaussian Filter, Wiener Filter, Adaptive Filter, etc.

Wiener filter - The purpose of the Wiener Filter, as each other filter is to eliminate noise from the image. Wiener filter is the mean square error optimal stationary linear filter for images degraded by additive noise and blurring [8]. For the designing of this filter one should know the spectral properties of the original signal ,the noise and linear time-variant filter whose output should be as close as to the original as possible. The Wiener filter minimizes the mean square error between the estimated random process and the desired process [9]. The working principle of this filter requires the assumption that the signal and noise processes are second-order stationary.

Median Filter - Median Filter is a nonlinear filter, which is enough suitable for removal of impulsive noise in an image. For noise removal, Median Filter using a 3x3 mask, which is applied along the pixel after pixel image. Then pixels within this mask, depending on the value are sorted from a pixel of lesser value or equal to the pixel of greater value. After ordering, *the true value* of the *pixel* is replaced with the value the fifth pixel of the filter.

Mean Filter – Mean filter is very suitable for application to the removal of impulsive noise. This filter is usually thought of as a convolution filter. Similarly, as other convolutions of this filter is based on a kernel. For noise removal, Mean Filter using a 3x3 kernel mask, which is applied along each pixel of the image. The idea of mean filtering is simply to replace each pixel value in an image with the mean (average) value of its neighbours, including itself [7].

Gaussian Filter - Gaussian filter is a 2D convolution filter, whose application has the effect of smoothing the image. The Gaussian function is presented through the mathematical equation:

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{\left(-\frac{x^2+y^2}{2\sigma^2}\right)} \quad (6)$$

where: x - is the distance from the origin in the horizontal axis; y-is the distance from the origin in the vertical axis, and σ - is the standard deviation of the Gaussian distribution.

The following, in Figure 5 is presented in the x, y, z coordinates the Gaussian function depending on the sigma, respectively for σ = 0.6, σ = 1 and σ = 2.

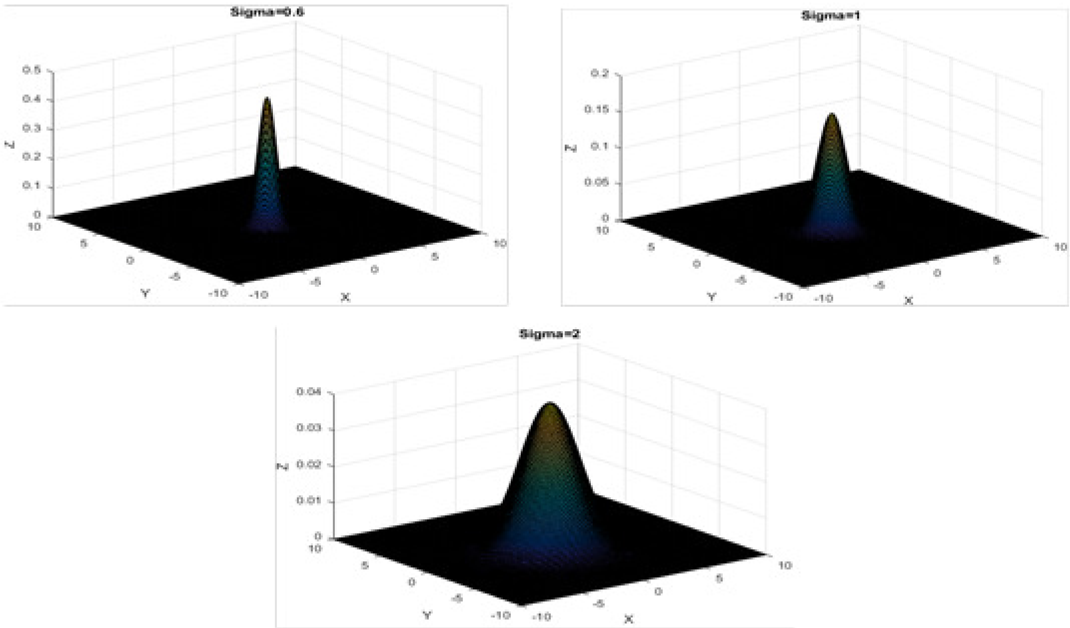

Figure 5 Presentation, in x, y, z coordinates of the Gaussian function depending on the sigma

4. MODELING OF THE PROPOSED ALGORITHM FOR NOISE REMOVAL

Today, there are many methods that can be applied to reduce noise in an image captured by electronic devices. In section 2 we presented traditional filters that can be applied for removal of noise from the image. Each of these traditional filters is suitable for removing [11] a specific noise from the image. However, traditional filters that used for this purpose are not suitable for use in [10] cases where images have been corrupted simultaneously by different types of noise.

Therefore, in this sector, we will present a new algorithm that will enable the repair of corrupted pixels of the image in a successful manner. In this case, in order to understand how this Algorithm works, the following will present the pseudo-code of this algorithm.

Algorithm: The algorithm goes through these steps:

Step 1: *Read input colour image A(i,j),* where ***i*** take values *i*ϵ*(1....m)* and ***j*** take values *j*ϵ*(1...n);*

Step 2: *Determine the number of rows and columns of the image matrix A(i,j);*

Step 3: *Convert read image to grayscale image B(i,j);*

Step 4: *Add Periodic poise in image B (i, j);*

$P = \sin\left({}^{x}/_{3} + {}^{y}/_{5}\right) + 1$, where ***x*** take values *xϵ(1....m)* and ***y*** take values *yϵ(1...n);*

Step 5: *In image B(i, j) with Periodic noise, add salt & pepper noise with noise densities d=0.2 (C(i,j));*

Step 6: *In image C(i, j) with Periodic and salt & pepper noise add Poisson noise (D(i,j));*

Step 7: *In image D(i,j) with Periodic, salt & pepper and Poisson noise add speckle noise E(i,j);*

Step 8: *In image E(i,j) with Periodic, salt & pepper, Poisson, and speckle noise add Gaussian noise with standard deviation σ=0.02 (F(i,j));*

Step 9: *Define the dimensions of the window (3x3 kernel mask) which is applied to the matrix of image corrupted by various noises F(i,j);*

Step 10: *Applying the first loop to the matrix:*

$$A(x,y) = \sum_{x=1}^{n}\sum_{y=1}^{\mathrm{m}} k((x+m-1, y+m-1)$$

Step 11: *Applying the second loop for filter design;*

Step 12: *Start with l=1 within the second loop and grows for one (l=l+1);*

Step 13: 3x3 *kernel mask is applied within the second loop:*

$$K(l) = \sum_{x=1}^{3}\sum_{y=1}^{3} k((i+x-1, j+y-1)$$

Step 14: *Sorting the pixels of the filter applied* from a pixel of lesser value or equal to the pixel of greater value*;*

Step 15: *After sorting the pixels (step 14), pixel medium value (fifth pixel) is selected and the previous pixel value i replaced with the selected pixel value;*

Step 16. *Display image after noise removal;*

Step 17: *Display image in the coordinates (x,y,z), after noise removal;*

5. RESULTS AND DISCUSSIONS

5.1. Results obtained with the application of the traditional filters

In this section we will present and discuss the results obtained by the application of traditional filters for *removal* or *reduction* of noises in an image. Results obtained with the application of these filters will be compared with results obtained with the application of the new algorithm proposed by us. Results were derived by using MATLAB 2016a and an image with 300x600 pixels [10]. Digital image corruption is realized by using different types of noise, such as periodic, salt and pepper, Poisson, Speckle and Gaussian noise. After corrupting the image with various possible noises, we have applied separately the Wiener, Median, Mean, Average and Gaussian filters. The results obtained by applying these filters will be compared with results obtained with the application of our modulated algorithm. The comparison and discussion of the obtained results are presented in a summarized form through the images.

In Figure 6 are presented the results obtained with the Wiener filter application. It should be noted that initially in the image are added various possible noises and after the noises have been added Wiener filter is applied.

Figure 6 Results obtained with the Wiener filter application

From the results presented in Figure 6 it can be seen that the image obtained after the application of the Wiener filter is full of noisy pixels. In other words, the image after noise filtration is quite unclear compared to the original image [12]. Particularly in the image, the presence of periodic noise can be observed. Therefore, based on the results obtained, we can conclude that the application of this filter does not provide the appropriate solution for the case when the image is corrupted at the same time by different types of noise, such as Periodic, Salt and Pepper, Poisson, Speckle, Gaussian, etc. [10]

In Figure 7, are presented the results obtained with the Average filter application. It should be noted that initially the same as in the case of Wiener filters application in the image are added various possible noises and after the noises have been added Average filter is applied.

From the results presented in Figure 7, it can be seen that the image obtained after the application of the Average filter is full of noisy pixels. In other words, the image after noise filtration is quite unclear compared to the original image. Particularly in the image, the presence of periodic noise can be observed. Therefore, based on the results obtained, we can conclude that the application of Average filter, same as the Wiener filters does not provide the appropriate solution for the case when the image is simultaneously corrupted by different types of noise.

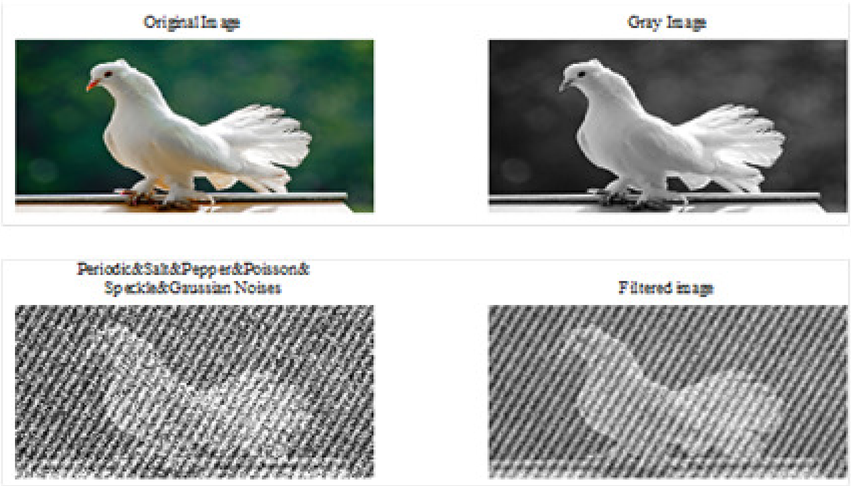

Figure 7 Results obtained with the Average filter application

In Figure 8, are presented the results obtained with the Mean filter application. It should be noted that initially the same as in the case of Average and Wiener filters application in the image are added various possible noises and after the noises have been added Mean filter is applied.

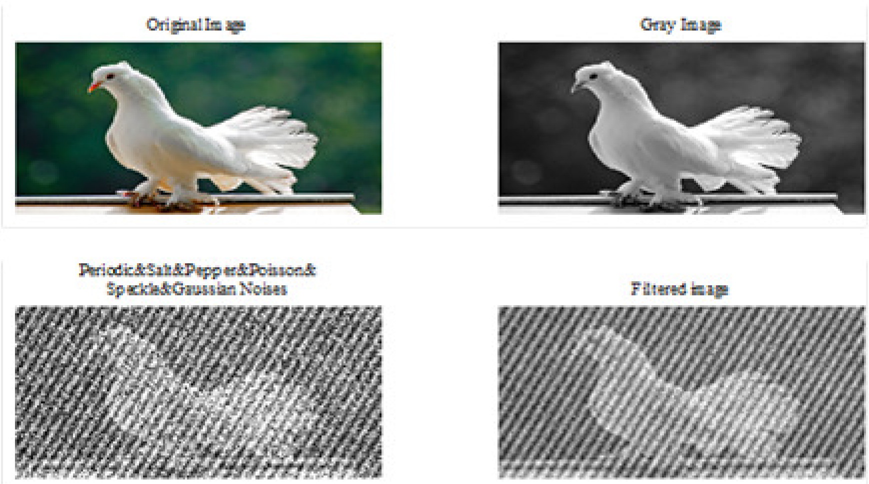

Figure 8 Results obtained with the Mean filter application

From the results presented in Figure 8, it can be seen that the image obtained after the application of the Mean filter is full of noisy pixels. In other words, the image after noise filtration is quite unclear compared to the original image. Particularly in the image, the presence of periodic noise can be observed. Therefore, based on the results obtained, we can conclude that the application of Mean filter, same as the Average and Wiener filters does not provide the appropriate solution for the case when the image is simultaneously corrupted by different types of noise [10].

In Figure 9, are presented the results obtained with the Median filter application. It should be noted that initially the same as in the case of Average, Wiener and Mean filters application in the image are added various possible noises and after the noises have been added Median filter is applied.

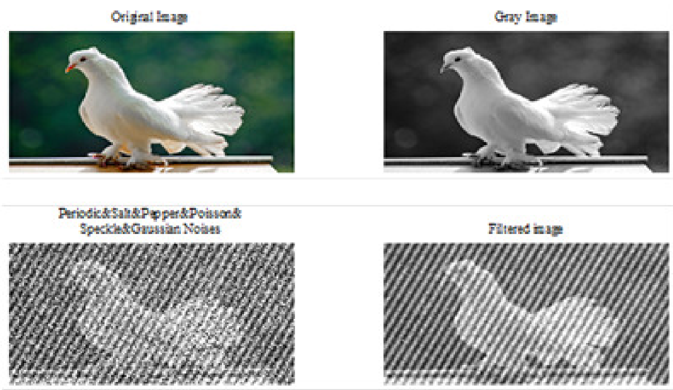

Figure 9 Results obtained with the Median filter application

From the results presented in Figure 9, it can be seen that the image obtained after the application of the Median filter is full of noisy pixels. In other words, the image after noise filtration is quite unclear compared to the original image. Particularly in the image, the presence of periodic noise can be observed. Therefore, based on the results obtained, we can conclude that the application of Median filter, same as the Average, Wiener and Mean filter does not provide the appropriate solution for the case when the image is simultaneously corrupted by different types of noise [10].

In Figure 10, are presented the results obtained with the Gaussian filter application. It should be noted that initially the same as in the case of Median , Average, Wiener and Mean filters application in the image are added various possible noises and after the noises have been added Gaussian filter is applied.

From the results presented in Figure 10, it can be seen that the image obtained after the application of the Gaussian filter is full of noisy pixels. In other words, the image after noise filtration is quite unclear compared to the original image. Particularly in the image, the presence of periodic noise can be observed. Therefore, based on the results obtained, we can conclude that the application of Gaussian filter, same as the Median, Average, Wiener and Mean filter does not provide the appropriate solution for the case when the image is simultaneously corrupted by different types of noise.

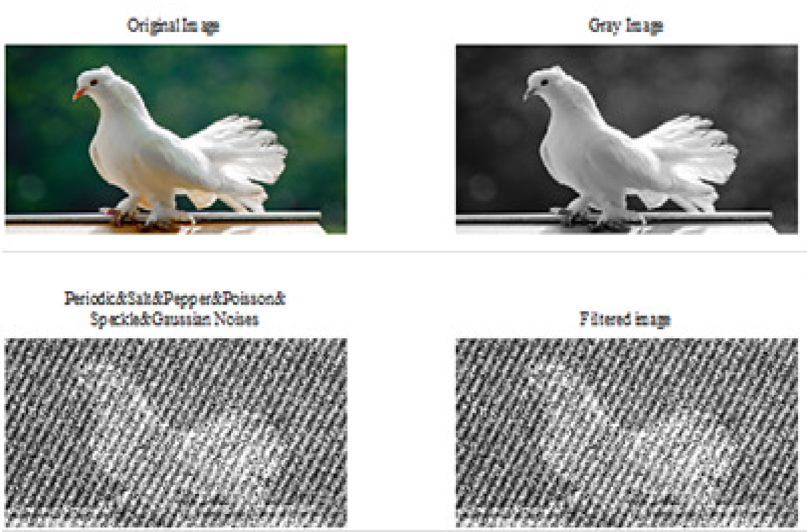

Figure 10 Results obtained with the Gaussian filter application

5.2. Results obtained with the application of the proposed algorithm

In this section are presented the results obtained with the application of the new algorithm designed by us for the detection and restoration of corrupted pixels of the image from different types of noises. The results obtained with the application of this algorithm are compared and discussed with the results obtained with the application of traditional filters for noise removal.

In figure 11, are presented the results obtained with the application of the new algorithm designed by us. In the same way as in the case of application of traditional filters for the removal of noise from the image, initially, in the image are added all possible types of noise as: Periodic, Salt & Pepper, Poisson, Speckle, and Gaussian noises. After the noises are added, the algorithm design for repair corrupted pixels is applied. From the results presented in Figure 11, it can be seen that the image obtained, after the application of the proposed algorithm is enough well cleaned from noises.

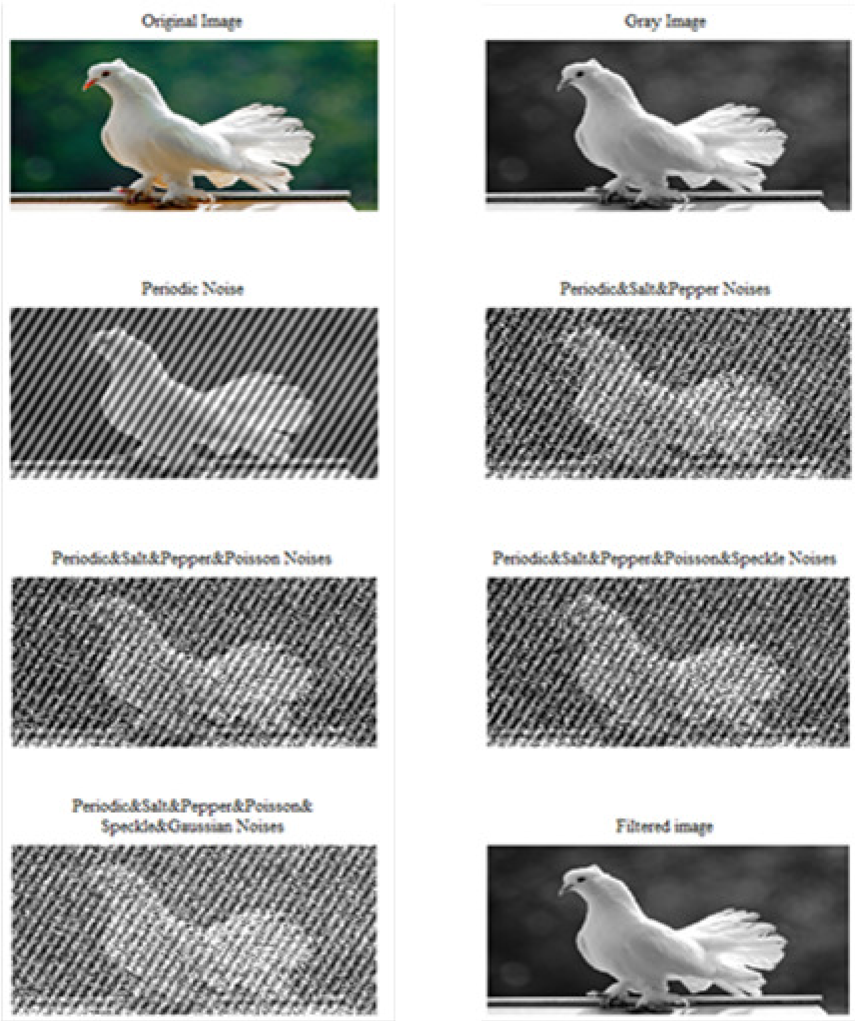

Figure 11 Results obtained with the proposed Algorithm application

From the results presented in Figure 6 to 10, it can be seen that the application of traditional filters is not suitable for the case when the image is simultaneously corrupted with different types of noise. However, it should be noted that these filters can provide good results for cases when the image is corrupted by a particular noise. In other words, when the image is corrupted with Gaussian noise, the Gaussian filter application can give good results or when the image is corrupted with Salt & Pepper noise, the Mean filter application can give good results, etc. Today, regarding these filters and their application a number of publications can be found [10].

If the results obtained from the proposed algorithm (Figure 11) are compared with the results obtained by the application of traditional filters, it can be seen that the proposed algorithm is quite successful for noise removal. This can be noticed especially in the efficiency of the periodic noise removal. In other words, this algorithm gives quite high precision in removal noises of the image. The accuracy of the proposed algorithm is approximately 90%. Based on the accuracy of the results obtained we can conclude that this algorithm is quite hopeful.

In Figure 12, the results obtained are presented in x, y, z coordinates, after the application of the proposed algorithm. From Figure 12, it can be seen that the representation in x, y, z coordinates is realized for each image depending on the noise involved. From Figure 12, it can be seen that higher value pixels represent the concentration of pixels representing the object within the image. So the red, yellow, etc., colour pixels represent the concentration of pixels representing the object within the image, while the pixels with the lowest values in the image (pixels with blue nuance) represent the pixels that represent the part of the image outside the object.

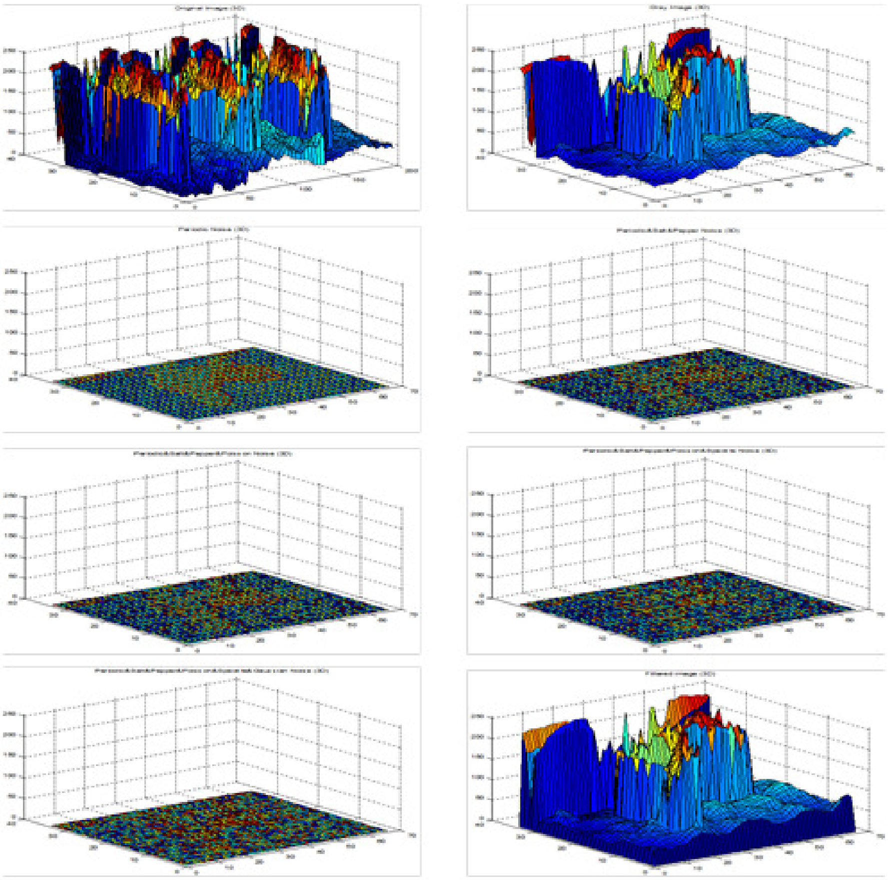

Figure 12 Results obtained with the proposed Algorithm application (x, y, z coordinates)

6. CONCLUSIONS

In this paper, we proposed a very suitable algorithm for restoring corrupt image pixels at the same time from various noise, such as periodic, salt and pepper, and so on. Experimental results show that the proposed algorithm with a high precision allows restoration of corrupted pixels of the image by different noises. The accuracy of this algorithm is approximately 95%.

In the future we will test the application of this algorithm in color images, as well as practical application in electronic devices to test its effectiveness.

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