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A NEW IMAGE DENOISING TECHNIQUE VIA MACHINE LEARNING

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ABSTRACT

Image denoising is a pre-processing process usually performed to remove all the noises that might hinder the process of extracting information from an image. Hence several methods have been proposed to tackle this problem, especially for salt and pepper noise. However, the result of the recovery image especially the noisy image with higher noise densities is unsatisfied either the noises are not cleaned or the blurry effect is noticeable on the recovery image. In this paper, a new technique is proposed by infusing the use of a machine learning technique which is a support vector machine (SVM), and an existing image filtering method which is a median filter. Acknowledging that the use of a median filter alone will affect the edge of the recovery image including a blurry effect, the apparent change in the result either qualitative or quantitative can be seen when combining the use of a median filter with the SVM. 8 grayscale images contaminated with salt and pepper noise are used to validate the proposed technique. A comparison with the existing methods in terms of image quality assessment tests is also performed to validate the effectiveness of this technique and from the result of recovery images, it can be seen that the proposed technique had shown a favorable result in terms of qualitative and quantitative results as compared to the other existing methods.

Keywords: *Image Denoising, Machine Learning, Support Vector Machine, Singular Value Decomposition, Median Filter*

1. INTRODUCTION

Image processing is widely employed by many researchers to obtain important information from images. It involves many disciplines and areas where the focus is dependent on what are the aims and objectives to be achieved by the researchers. Pre-processing, detection, and recognition are being common subjects that normally practiced by researchers in image processing. Pre-processing normally utilizes filtering techniques to improve or enhance the quality of raw images before going to further steps of processing. Image resizing, grayscaling, denoising [1-5], normalization, binarization, edge detection [6-7], contrast enhancement, blurring, and segmentation [8-11] are among the processes that utilize the pre-processing process. Image detection is usually employed to find instances and locations of certain objects from the images depending on how we set the criteria of the object [12-23]. Image detection is widely used in image processing for medical and security purposes. Meanwhile, image recognition identifies which object or scene is located in an image [24-33].

Image denoising is the image pre-processing process with the aim of removing noise to recover the original image [34]. The need for this process occurs due to the existence of unwanted parasites known as noise in a digital image. A digital image is an image that is represented digitally and consists of a number of pixels [35]. Sometimes, during the acquiring or transmitting process the digital image can be contaminated with noise which sometimes exists in the form of dirt or random variation of the image's intensity [36]. Apart from disrupting the visual presentation of the image, it also could destroy critical information from an image. These noises may have come from nearby noise sources, faulty memory locations, or imperfections or inaccuracies in image-capture devices, such as cameras with misaligned lenses, weak focal lengths, scattering, and other potentially harmful atmospheric conditions [37]. Thus, the idea

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of the image denoising process is to remove the unwanted noise from the image and substitute the noisy pixel value with a different value that is possibly close to the original pixel value. However, during this process, it may affect the denoised images in the sense of losing some detail on texture and edge, since these are high-frequency components that are difficult to differentiate during the process [34].

These circumstances have inspired some researchers to come up with numerous methods and approaches in dealing with the image denoising process especially when dealing with images corrupted with higher noise density levels. Nonlinear filters, regularization, and fuzzy sets are some approaches that have been used for the image denoising process with the nonlinear filters as the most effective for denoising salt and pepper noise [38]. Among the nonlinear filter methods, the median filter (MF) [39], is a particularly well-known method for removing the salt and pepper noise thanks to its simplicity during the execution process. However, the inability of this method to remove the noises at higher noise densities, and preserve the edge and the details of the recovery images are some reasons this method is constantly been improved [40]. Adaptive Median Filter (AMF)[41] is one of the methods that has been introduced to overcome this shortcoming. Even though the AMF performs better at the lower noise density, the recovery images tend to become blurred when the noise density is increased as a result of increasing the window size [42]. Adaptive Center-Weighted Median Filter (ACWMF) [43] and Different Applied Median Filter (DAMF) [44] are some of the nonlinear filter methods that have been introduced to overcome this problem but still for ACWMF, at the medium and higher noise densities, the edges and details of recovery images cannot be preserved [38]. As for DAMF, a zig-zag defect on the texture and edges of recovery images at higher noise densities can be detected [38].

Meanwhile, the use of machine learning methods for image denoising is not uncommon even though it is might not as popular as the nonlinear filters. [45], [46] and [47] are some examples of research that applied the use of the decision tree technique which is one of the machine learning techniques. One of the similarities between these three methods is the use of the decision three technique for noise detection and different methods are used for the noisy pixel restoration process. Since the use of SVM is scarce compared to the decision tree in image denoising, in this paper, we intend to explore the use of this technique for this purpose.

In this paper, a new approach to solving image denoising process for salt and pepper noise is proposed. Salt and pepper noise is noises containing the damaged pixel values which are 0 and 255 and these values can be randomly distributed around the image while maintaining the other pixel values [48]. It is visually seen as a white (salt) and black (pepper) spot on the image hence the name of salt and pepper noise. The proposed approach is a hybridization between several methods which are singular value decomposition (SVD) for noise detection and database creation, support vector machine (SVM) for database training, and median filter for image filtering. The other contributions of this paper apart from the denoising process are as follows; an alternative approach to noise detection by using SVD and the identification of noise location by using the information from the result of SVD. Later, this information on the location of the noises is compiled into a database and by using this database during the image filtering process, only the noisy pixel based on the location of the noise will be targeted without disturbing the neighborhood pixels. This process is expected to preserve the quality of the image since the restoration of the noisy pixel is performed only on the targeted location without disturbing the non-noisy pixel.

The outline of this paper is organized as follows; the preliminary research on SVD, SVM, and median filter are shown in Section 2. Followed by the procedure of the proposed technique presented in Section 3, the results and discussion of the proposed technique in Section 4, and lastly, the conclusion of this paper in Section 5.

2. PRELIMINARIES

2.1 Singular Value Decomposition

Singular value decomposition (SVD), is a process of extracting a single matrix into three different matrices. From this process, the results of matrix decomposition contain the important information from the original matrix that later will be used in this research. The basic definitions of SVD are shown below [49]:

Definition 1: Assume that the vectors $\boldsymbol{u}$ and $\boldsymbol{v}$ have the same dimension. If $\boldsymbol{u}$ and $\boldsymbol{v}$'s inner product is zero, they are orthogonal and are written as $\langle \boldsymbol{u}, \boldsymbol{v} \rangle = 0$.

Definition 2: An orthogonal set whose orthonormal vectors have the norm 1 is indicated by $\|u\| = 1$.

Definition 3: Assume that $\boldsymbol{A}$ is a matrix of size $m \times n$, and that its SVD is represented by $\boldsymbol{A} = \boldsymbol{UDV^T}$, where $\boldsymbol{U}$ and $\boldsymbol{V}$ are orthonormal singular vectors and $\boldsymbol{D}$ is the singular value's diagonal matrix.

From the **Definition 3**, the SVD of matrix $\boldsymbol{A}$ can be obtained by following the steps below:

1. Performed multiplication between matrix, $\boldsymbol{A}$ and its transpose, $\boldsymbol{A}^T$, to determine the matrix $\boldsymbol{U}' = \boldsymbol{A}\boldsymbol{A}^T$ and $\boldsymbol{V}' = \boldsymbol{A}^T\boldsymbol{A}$.
2. Next, find the eigenvalues and eigenvectors of the matrix $\boldsymbol{U}'$ and $\boldsymbol{V}'$.
3. By applying the orthonormalization process to the eigenvectors of the matrices $\boldsymbol{U}'$ and $\boldsymbol{V}'$, the matrices $\boldsymbol{U}$ and $\boldsymbol{V}$ are derived. Additionally, matrix $\boldsymbol{D}$ is a diagonal matrix whose entries are the square roots of matrix $\boldsymbol{A}$'s eigenvalues.

In this research, SVD is used to identify the presence of noise, and this information later is used to create the database based on the location of the noise

2.2 Support Vector Machine

Support vector machine (SVM) is one of the machine learning techniques that has widely been used in classification and regression analysis. It is classified as supervised learning along with other machine learning techniques which are decision tree and naïve Bayes [50].

The concept of this technique is based on maximizing the lowest distance between the hyperplane to the closest sample point hence minimizing the error. According to [51], this technique requires a complex algorithm, however, will result in high accuracy results. In this research, the SVM technique is used to train the database created by identifying the location of the noise so that the restoration process on the noise pixel can be performed.

2.3 Median Filter

The median filter is one of the nonlinear filter approaches that is widely used in the image-filtering process. According to [52], the median filtering process can be explained as follows:

Given a sliding window with dimension $v = m \times m$, by considering the gray value, the pixel values of a noisy image $z(i, j)$ are rearranged from lowest to highest values with z_{min} as the minimum, z_{max} as the maximum, $z_{x,y}$ as the center pixel and the median of the pixels is denoted by z_{med}.

Based on the gray values in the window, if $z_{x,y} \neq z_{max}$ and $z_{x,y} \neq z_{min}$, then the signal point is at (x, y). However, if $z_{x,y} = z_{max}$ and $z_{x,y} = z_{min}$, then it is assumed that there is a noise point at (x, y). Hence, $z_{x,y}$ is replaced with z_{med} for the denoising process.

In this research, the median filter is used for the image filtering process in which the noisy pixel will be restored by using the pixel value from the median filter result.

3. PROPOSED TECHNIQUE

This research is divided into four phases which are image acquisition, creating a database, image filtering process, and image quality assessment. These phases are explained as follows:

3.1 Phase 1: Image Acquisition

A color or grayscale image denoted as the reference image, $\boldsymbol{R}$ is selected and artificially contaminated with salt and pepper noise ranging from 10% to 90% level of noise density (ND). This image later is used in creating the database.

3.2 Phase 2: Creating Database

In this research, the window size for the images is fixed to a 3x3 window size. The noisy image created before is used and by using the SVD the existence of noise is identified.

3.2.1 Phase 2.1: Noise detection:

Three different matrices (refer to Definition 3) are obtained from the result of performing the SVD on the noisy image created before. One of the matrices which is the diagonal matrix denoted as matrix $\boldsymbol{D}$ is used for noise detection by considering the central pixel of the template which is $d(2,2)$ by referring to the following inequality.

$$\alpha_1 < d(2,2) < \alpha_2$$

where α_1 and α_2 are parameters chosen based on the occurrence of noticeable color changes in the 3x3 window. The parameters of α_1 and α_2 can be any numbers as long as they fit within the range of the interval where the detection rate performs at its best [53]. In this research, $\alpha_1 = 5$, and $\alpha_2 = 20$, which indicates the noise exists if the difference between the pixel values is more than 15.

3.2.2 Phase 2.2: Construction of database:

If there is noise/s in the window template, then the location of the noisy pixel is identified by referring to the coordinates of the pixels as shown in Figure 1. For the 3x3 window size of the noisy image $\boldsymbol{R}$, let $r(i, j)$ be the central pixel and if the neighborhood pixels are symmetric, the window template that contains the noisy pixels can be written as follows:

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$$T = r(i + u, j + v), \qquad -1 \leq u, v \leq 1$$

Figure 1 shows the pixel coordinates and class identification on a 3x3 window size with point *r(i, j)* as the central pixel.

$(i-1, j-1)$ Class 1/10	$(i, j-1)$ Class 2/11	$(i+1, j-1)$ Class 3/12
$(i-1, j)$ Class 4/13	(i, j) Class 5/14	$(i+1, j)$ Class 6/15
$(i-1, j+1)$ Class 7/16	$(i, j+1)$ Class 8/17	$(i+1, j+1)$ Class 9/18

Figure 1: Pixel coordinates for 3x3 template based on point (i, j) [10]

The location of the noise (for salt and pepper noise, the pixel values 255 and 0 are considered as noise) is determined and classified into different classes based on the pixel coordinate as shown in Fig. 1. If the pixel value is equal to 255 (white) then the class will be between class 1 to 9. If the pixel value is 0 (black) then the class will be between class 10 to 18. If no noisy pixels in the 3x3 template, then the template will be considered class 19. For example, if the pixel value is 255 and at coordinate *r(i – 1, j + 1)*, then this template will be considered as class 7. If the pixel value is 0 and at coordinate *r(I, j + 1)*, then this template will be considered class 17. Note that only one class is allowed for one 3x3 window template. Hence, if there is more than one noise in the template, the template will be omitted to be included in the database.

To achieve the best outcomes, it is recommended to combine the collection of the classes from various noisy images. It is anticipated that the outcome results will be better when the number of classes is greater. For instance, in this research, the database is created from the combination of Lena images (color for all noise density and grayscale at 0.1 ND), black and white images (0.1 ND), and grayscale cameraman images (0.1 and 0.2 ND). Figure 2, shows the pseudocode for creating the database used in this research.

Pseudocode for creating a database

```
Input: Let R an array of the noisy image of a 3x3 template with the central pixel, r(i, j) = r(2, 2)
Class classification
  Do
    SVD computation on R
      if α1 < r(i,j) < α2 ; where α1 and α2 are any number,
        then R = class 19 (no noise)
      else
        if r(i ± 1,j ± 1) = 255 or 0 ≥ 1, then discard the template
          else
            Classify the noise based on the coordinate of r(i ± 1,j ± 1):
              r(i ± 1,j ± 1) = 255, class 1 until 9 or r(i ± 1,j ± 1) = 0, class 10 until 18
        end if
      end if
  end do
Output: database noisy image file
```

Figure 2: Pseudocode For Creating the Database

3.3 Phase 3: Image Filtering

A noisy image (any image is acceptable and it is not restricted to the image that is used to create the database) is selected to undergo the training process by using SVM.

A noisy image, *S* is transformed into a 3x3 window size with *s(i, j)* as the central pixel. The training process will be done in four directions, which are from left to right, right to left, upper to below, and below to upper. Noted that, after completing the looping for the first direction, then proceed to the second looping for the next direction and will stop when the outcome image is satisfied. Table 1 shows the class and the direction of training the database.

When training the database for example in the first direction, the class of the noisy pixels is identified. If the noisy pixel exists, then the filtering process will be performed based on the coordinate of the noise. The noisy pixel is then replaced with the new pixel obtained by performing the median filter on that respective template. If the first looping which is in the first direction is unable to clean the noisy pixel, then the same process will be repeated but in a different direction until all the noise is clean. It is important to identify the coordinate direction and the correct class in which the noisy pixel existed so that the filtering process will be performed only on that specific class and coordinate of the noisy pixel.

Figure 3, shows how the class of the noise is identified and the replacement of the noisy pixel with a new pixel and the pseudocode for image filtering are shown in Figure 4.

Table 1: Class And Direction Of Training The Database.

	Direction Sequence

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Class	1st	2nd	3rd	4th
1, 10	$[i-1, j-1]$	$[i+1, j+1]$	$[i-1, j-1]$	$[i+1, j+1]$
2, 11	$[i, j-1]$	$[i, j+1]$	$[i-1, j]$	$[i+1, j]$
3, 12	$[i+1, j-1]$	$[i-1, j+1]$	$[i-1, j+1]$	$[i+1, j-1]$
4, 13	$[i-1, j]$	$[i+1, j]$	$[i, j-1]$	$[i, j+1]$
5, 14	$[i, j]$	$[i, j]$	$[i, j]$	$[i, j]$
6, 15	$[i+1, j]$	$[i-1, j]$	$[i, j+1]$	$[i, j-1]$
7, 16	$[i-1, j+1]$	$[i+1, j-1]$	$[i+1, j-1]$	$[i-1, j+1]$
8, 17	$[i, j+1]$	$[i, j-1]$	$[i+1, j]$	$[i-1, j]$
9, 18	$[i+1, j+1]$	$[i-1, j-1]$	$[i+1, j+1]$	$[i-1, j-1]$

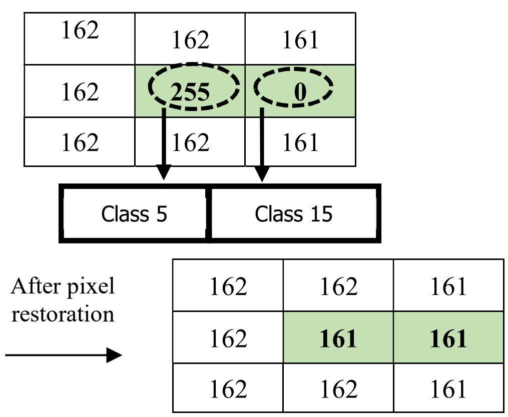

Figure 3: Identifying The Location Of Noise And The Restoration Process

Pseudocode for image filtering

1. **Input**: ***S*** an array of the noisy image of a 3x3 template with the central pixel, *s(i, j) = s(2, 2)*, database noisy image file
2. ***Reading database and image filtering***
3. Train the database using SVM by setting the number of looping, *k*
4. for *k = any numbers* where *k ≠ 0*
5. for 1st *D*. *D* = direction of training,
6. if noisy pixel exists,
7. identify the class and the median filter result is at the respective coordinate
8. else
9. maintain the pixel values
10. end if
11. end for
12. Output 1: A first restored image, ***S1***
13. Perform second image filtering if the noise still exists by using ***S1*** using 2nd, 3rd and 4th *D*.
14. end for
15. Repeat steps 4-14, until all the noise is clean

Figure 4: Pseudocode For Image Filtering

3.4 Phase 4: Image Quality Assessment

The performance of the proposed technique is then measured numerically and visually. For visual analysis, the resulting images are assessed visually if there is any presence of salt and pepper noises on the images. Meanwhile, for numerical analysis, the Peak Signal Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) are used to quantify the performance of the proposed technique. The equations for these methods are shown as follows:

1. The PSNR is used to calculate the deterioration of image quality. If the value of the PSNR is higher, then the quality of the recovery image is considered better. The PSNR is denoted as below [54]:

$$PSNR = 10\log\left(\frac{255^2}{MSE}\right)$$

where 255 is the highest value at the gray level.

2. The SSIM is used to calculate the similarity between reference and output images. Same as the PSNR value, if the value of the SSIM is higher, then the quality of the recovery image is considered better. SSIM is denoted as below [55]:

$$SSIM = \frac{(2\mu_x\mu_y + C_1) + (2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_2) + (\sigma_x^2 + \sigma_y^2 + C_2)}$$

Where μ_x, μ_y, σ_x, and σ_y, are the average intensities, standard deviation, and covariance for the reference and output image.

4. RESULTS AND DISCUSSION

To validate the proposed technique, the experiment was performed on 8 grayscale digital images (512x512 dimension) which are a boat,

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cameraman, castle, house, lake, Lena, mandrill, and peppers. These 8 images (as shown in Fig. 5) are artificially corrupted with 70% and 90% salt-and-pepper noise density (ND). The experimental results of the proposed technique are presented in qualitative and quantitative evaluation.

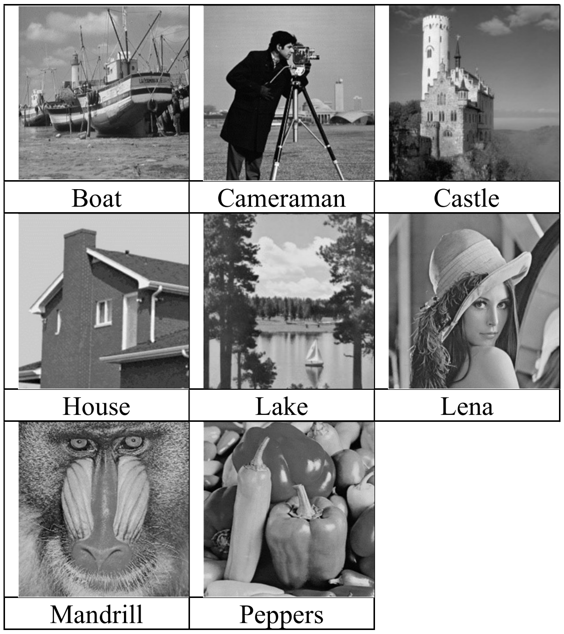

Figure 5: Images Were Used for Experimental Purposes

4.1 Quantitative Analysis

For quantitative analysis, the comparison with previous methods which are adaptive Cesáro mean filter (ACMF) [56], adaptive content based closer proximity pixel replacement algorithm (ACCPPRA)[57], adaptive Riesz mean filter (ARmF)[58], adaptive type-2 fuzzy filters (AT2FF) [59], Based-on Pixel Density Filter (BPDF) [54], different applied median filter (DAMF) [44], different adaptive modified Riesz mean filter (DAMRMF) [60], four stage median-average filter (FoMA filter) [61], iterative mean filter (IMF)[62], a modified form of different median filter (MDAMF) [42] and tropical algebra median filter (TMF) [49], are done to validate the proposed technique (PM). These existing methods were chosen from some of the most recent studies, covering from the years 2018 to 2023 and the approaches are varying which are nonlinear filters and fuzzy sets.

Table 2: Comparison With The Previous Study Of PSNR And SSIM Values For Lena Image At 70% And 90%.

Existing Method	70%		90%	
	PSNR	SSIM %	PSNR	SSIM%
ACMF	30.52	0.88	26.29	0.77
ACCPPRA	32.91	0.9	28.04	0.8
ARmF	30.78	0.88	26.11	0.77
AT2FF	23.95	0.74	18.3	0.5
BPDF	23.04	0.72	10.78	0.29
DAMF	30.24	0.88	25.74	0.76
DAMRMF	31.03	0.89	26.95	0.8
FoMA FILTER	30.19	0.96	26.23	0.88
IMF	31.23	0.9	27.42	0.81
MDAMF	30.25	0.89	26.03	0.78
TMF	26.67	0.8	21.25	0.58
PM	33.5	0.73	32.82	0.71

Based on Table 2, the proposed technique shows a favorable result in terms of PSNR values but not for SSIM values. The PSNR values for the proposed technique recorded the highest values at 70% ND and 90% ND compared to the other methods. It can be seen that at 70% ND, most of the methods recorded the PSNR values at more than 30+dB, however only the proposed technique recorded the PSNR value at 33.50dB. At 90% ND, the difference in PSNR values is more obvious in that most of the methods recorded the values at 20+dB and only the proposed technique recorded the value at 32.82dB. Thus, this result shows that the proposed technique produced a better result compared to others even at the highest ND which is 90% ND when most of the existing methods recorded the lowest PSNR values. However, for SSIM values, the FoMA filter method showed a better result for both ND compared to the proposed technique. Nevertheless, the proposed technique is still in lead compared to BPDF (for 70% and 90% ND) and AT2FF (at 90% ND). The performance is also consistent since it is still in the range of 0.7+ for both ND and not below 0.5.

Table 3: PSNR And SSIM Values For 8 Images At 70% And 90% ND

Images	PSNR		SSIM	
	70%	90%	70%	90%

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Boat	32.6	32	0.67	0.6
Cameraman	34.4	33.9	0.74	0.71
Castle	33.74	33.41	0.74	0.73
House	34.85	34.05	0.83	0.79
Lake	33.23	32.3	0.72	0.65
Lena	33.5	32.82	0.73	0.71
Mandrill	31.69	30.38	0.65	0.48
Peppers	32.71	32.73	0.69	0.66

Table 3 shows PSNR and SSIM values for 8 images. Based on the results above, the PSNR values for all images recorded values around 30+dB for both ND. The consistency in PSNR values between 70% and 90% ND also can be seen for example for the boat image, the PSNR value at 70% is 32.60dB while at 90% is 32 which means the gap is 0.60 which is not too large. Same for SSIM values except for mandrill images in which the gap is quite large between 70% to 90% ND. The other images still show in the range 0.60+ and 0.70+.

4.2 Qualitative Analysis

Figure 6 shows the recovery images of the denoising process at 70% ND and Figure 7 shows the recovery images for lake image at 10%, 30%, 50%, 70%, and 90% ND, and the PSNR and SSIM value for each recovery image.

From Figure 6, the proposed technique managed to denoise most of the noise from the experimental images except the cameraman, castle, and Lena images. The edges for most of the output images except the cameraman image are still preserved and the image clarity is still can be seen even at 70% ND.

From Figure 7 based on the recovery images for each ND, it can be seen that when the ND is increasing, the recovery image is slightly affected. This can be supported by the PSNR and SSIM values for each recovery image in which the PSNR value had been slightly decreased when the ND was increased. However, the performance of the proposed technique is still acceptable as the clarity of the image is still preserved and the PSNR and SSIM are still within acceptable range which is not too low.

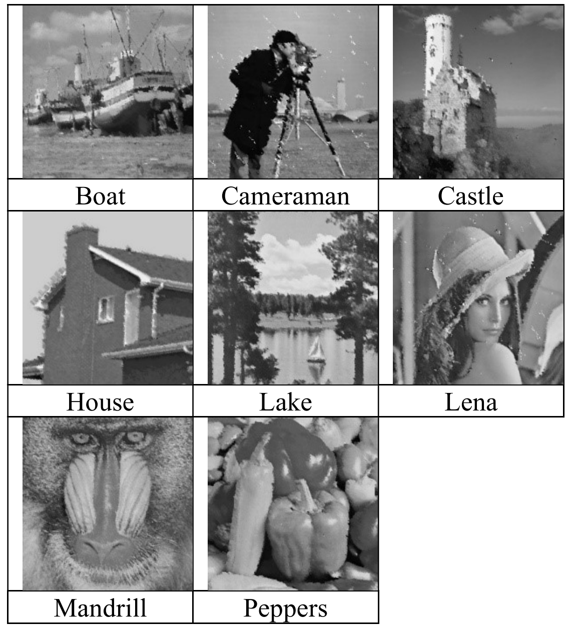

Figure 6: Output images for 70% ND image denoising

5. CONCLUSION

In this research, an alternative technique for image denoising of salt and pepper noise is proposed to remove and preserve the quality of the recovery images. The proposed technique is divided into four phases where the second and third phases which are database creation and image filtering process consist of the new proposed technique. Based on the result obtained, it can be deduced that the proposed technique shows promising results in certain aspects compared to existing methods. Furthermore, for some images the existence of the noises is almost non-existent, and the blurring effect are not noticeable. Although the results show some promising results in certain areas, there are still some areas that can be improved especially on the edge of the recovery image at higher noise density. However, the use of machine learning for image denoising process cannot be underestimated and, in the future, the implementation of other machine learning techniques for example decision tree and k-nearest neighborhood can be applied for more exploration of the machine learning techniques on image denoising.

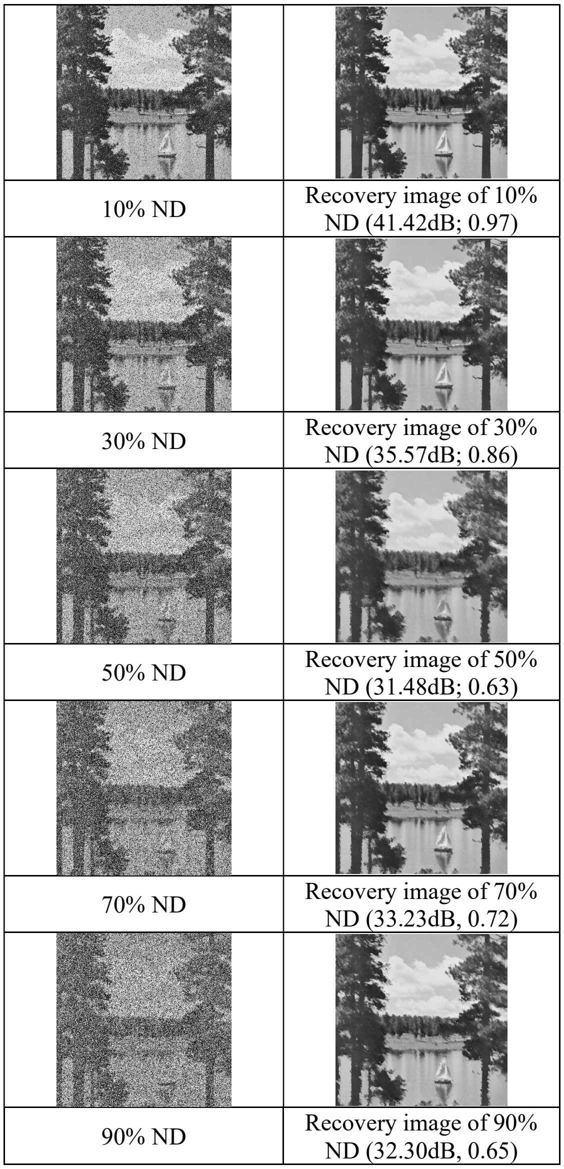

Figure 7: Recovery images, PSNR and SSIM values of lake for 10%, 30%, 50%, 70%, and 90% ND image denoising

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REFERENCES:

[1] B. Charmouti, A.K. Junoh, A. Abdurrazzaq, and M.Y. Mashor, "A New Denoising Method for Removing Salt & Pepper Noise From Image", *Multimedia Tools and Applications*, Vol. 81, No. 3, 2022, pp. 3981-3993.

[2] B. Charmouti, A.K. Junoh, and W.Z.A.W. Muhamad, "Extended Median Filter for Salt and Pepper Noise in Image", *International Journal of Applied Engineering Research*, Vol. 12, No. 22, 2017, pp. 12914-12918.

[3] A. Abdurrazzaq, A.K. Junoh, Z. Yahya, and I. Mohd, "New White Blood Cell Detection Technique by Using Singular Value Decomposition Concept: White Blood Cell Detection Technique", *Multimedia Tools and Applications*, Vol. 80, 2021, pp. 4627-4638.

[4] B. Charmouti, A.K. Junoh, and M.Y. Mashor, "Progression Approach for Image Denoising", *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, Vol. 17, No. 6, 2019, pp. 2948-2958.

[5] M.S.M. Zain, A.K. Junoh, and A. Abdurrazzaq, "Hybrid Singular Value Decomposition Based Alpha Trimmed Mean-Median Filter in Eliminating High Density Salt and Pepper Noise from Grayscale Image", *Multimedia Tools and Applications*, 2024, https://doi.org/10.1007/s11042-023-17902-5.

[6] M.A. Alshorman, A.K. Junoh, W.Z.A.W. Muhamad, M.H. Zakaria, and A.M. Desa, "Leukaemia's Cells Pattern Tracking Via Multi-Phases Edge Detection Techniques", *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, Vol. 10, No. 1-15, 2018, pp. 33-37.

[7] Y. Kalai, A.K. Junoh, W.Z.A.W. Muhamad, A.M. Desa, and M.H. Zakaria, "Sobel-Freichen Hybrid Filters to Improve Edge Detection Performance", *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, Vol. 10, No. 1-15, 2018, pp. 7-10.

[8] L.B. Toh, M.Y. Mashor, P. Ehkan, H. Rosline, A.K. Junoh, and N.H. Harun, "Image Segmentation for Acute Leukemia Cells Using Color Thresholding and Median Filter", *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, Vol. 10, No. 1-5, 2018, pp. 69-74.

[9] L.B. Toh, M.Y. Mashor, P. Ehkan, H. Rosline, A.K. Junoh, and N.H. Harun, "Implementation of High Dynamic Range Rendering on Acute Leukemia Slide Images Using Contrast Stretching", *Proceeding Of 3rd International Conference on Electronic Design (ICED)*, 2016, pp. 491-496.

[10] L.B. Toh, M.Y. Mashor, and P. Ehkan, "High Dynamic Range Implementation on Acute Leukemia Slide Images", *Jurnal Teknologi*, Vol. 77, No. 6, 2015, pp. 29-30.

[11] K.A. Azuddin, A.K. Junoh, A. Zakaria, and M.T.A. Rahman, "Supervised Segmentation on Fusarium Macroconidia Spore in Microscopic Images Via Analytical Approaches", *Multimedia Tools and Applications*, https://doi.org/10.1007/s11042-023-17008

[12] M.N. Mansor, S. Yaacob, and M. Hariharan, "Jaundice in Newborn Monitoring Using Color Detection Method", *Procedia Engineering*, Vol. 29, 2012, pp. 1631-1635.

[13] A.K. Junoh, M.N. Mansor, A.M. Ya'acob, F.A. Adnan, S.A. Saad, and N.M. Yazid, "Crime Detection with DCT and Artificial Intelligent Approach", *Advanced Materials Research*, Vol. 816, 2013, pp. 610-615.

[14] M.N. Mansor, and S.H.F.S.A. Jamil, "Fast Infant Pain Detection Method", *Proceeding of International Conference on Computer and Communication Engineering (ICCCE)*, 2012, pp. 918-921.

[15] M.N. Mansor, A.K. Junoh, A. Ahmed, and M.K. Osman, "Single Scale Self Quotient Image and PNN For Infant Pain Detection", *Proceeding of IEEE International Conference on control system, computing and engineering (ICCSCE 2014)*, 2014, pp. 553-555.

[16] M.N. Mansor, A.K. Junoh, A. Ahmed, H. Kamarudin, and A. Idris, "Infant pain detection with homomorphic filter and fuzzy k-NN classifier", *Applied Mechanics and Materials*, Vol. 643, 2014, pp. 183-189.

[17] M.N. Mansor, S. Yaacob, and M. Hariharan, "Fuzzy K-NN And K-NN Algorithm for Fast Infant Cues Detection", *Proceeding of World Congress on Medical Physics and Biomedical Engineering*, May 26-31, 2012.

[18] A.K. Junoh, M.N. Mansor, A.M. Ya'acob, N. Omar, and S.H. Ismail, "Bandit Detection System under Unstructed Lighting Condition with Different Discriminant Analysis Approach", *Applied Mechanics and Materials*, Vol. 390, 2013, pp. 424-428.

[19] A.K. Junoh, M.N. Mansor, W.S.W. Daud, and W.Z.A.W. Muhamad, "A Robust Crime Detection Method under Different Illumination Levels", *International Information Institute (Tokyo)*, Koganei, Vol. 17, Issue 6, 2014, pp. 2437-2444.

[20] A.K. Junoh, M.N. Mansor, A.M. Ya'acob, F.A. Adnan, S.A. Saad, and N.M. Yazid, "Crime Detection with ICA and Artificial Intelligent Approach", *Advanced Materials Research*, Vol. 816, 2013, pp. 616-622.

[21] A.K. Junoh, M.N. Mansor, A.M. Ya'acob, S.H. Ismail, and N. Omar, "Bandit Detection System under Various Noise Levels with Nearest Mean and Gaussian Classifier", *Advanced Materials Research*, Vol. 816, 2013, pp. 540-544.

[22] M.N. Mansor, M.Z. Hasan, W.A. Mustafa, F.H.M. Faudzi, S.A. Saidi, M.A. Jamlos, N.A.A. Talib and A.K. Junoh, "Leukemia Blood Cells Detection using Neural Network Classifier", *Journal of Advanced Research in Applied Sciences and Engineering Technology*, Vol. 33, No. 1, 2023, pp. 152-162.

[23] A.K. Junoh, M.N. Mansor, M.S. Abu, and W.Z.A.W. Ahmad, "Smart Surveillance System Detection Using PCA-Based Feature Extraction", *Applied Mechanics and Materials*, Vol. 232, 2012, pp. 137-141.

[24] M.N. Mansor, S. Yaacob, and S.N.H. Muthusamy, "PCA-Based Feature Extraction and LDA algorithm for Preterm Birth Monitoring", *JSCSE Journal*, 2012, pp. 2251-7545.

[25] A.A. Shakri, S.A. Saidi, and H. Jaafar, "Entropy Virus Microscopy Images Recognition Via Neural Network Classifiers", *Proceeding of 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, 2017, pp. 348-351.

[26] A.K. Junoh, M.N. Mansor, and S.A. Abu, "Home Security System Based on k–NN Classifier", *Procedia Engineering*, Vol. 38, 2012, pp. 1811-1815.

[27] A.A. Shakri, S.A. Saidi, and M.N. Mansor, "Contrast Virus Microscopy Images Recognition Via K-Nn Classifiers", *Proceeding of 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, 2017, pp. 352-355.

[28] A.K. Junoh, and M.N. Mansor, "Home Security System Based on Fuzzy K-NN Classifier", *Procedia Engineering*, Vol. 38, 2012, pp. 1811-1815.

[29] M.N. Mansor, A.K. Junoh, W.S.W. Daud, W.Z.A.W. Muhamad, and A. Idris, "Nonlinear Fuzzy Robust PCA Algorithm for Pain Decision Support System", *Advanced Materials Research*, Vol. 1016, 2014, pp. 785-789.

[30] M.N. Mansor, A.K. Junoh, A. Ahmed, H. Kamarudin, and A. Idris, "Infant Pain Recognition with Homomorphic Filter and k-NN Classifier", *Advanced Materials Research*, Vol. 1016, 2014, pp. 807-813.

[31] M.N. Mansor, A.K. Junoh, A. Ahmed, H. Kamarudin, and A. Idris, "Single Scale Retinex for Infant Pain Recognition", *Applied Mechanics and Materials*, Vol. 643, 2014, pp. 218-223.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[32] M.F.M. Desa, M.N. Mansor, A.K. Junoh, A. Ahmed, W.S.W. Daud, and A. Idris, "Ultrasonic Sonic Imaging for a Two Phase System Based on Support Vector Machine Classifier", *Advanced Materials Research*, Vol. 1016, 2014, pp. 273-278.

[33] A.K. Junoh, M.N. Mansor, S.A. Abu, and W.Z.W. Ahmad, "SVM Classifier for Automatic Surveillance System", *Procedia Engineering*, Vol. 38, 2012, pp. 1806-1810.

[34] L. Fan, F. Zhang, H. Fan, and C. Zhang, "Brief Review of Image Denoising Techniques", *Visual Computing for Industry, Biomedicine, and Art*, Vol. 2, No. 1, 2019.

[35] A. Abdurrazzaq, I. Mohd, A.K. Junoh, and Z. Yahya, "Tropical Algebra Based Adaptive Filter for Noise Removal in Digital Image", *Multimedia Tools and Applications,* Vol. 79, 2020, pp. 19659–19668.

[36] B. Charmouti, A.K. Junoh, M.Y. Mashor, N. Ghazali, M.A. Wahab, W.Z.A. Wan Muhamad, Z. Yahya, and A. Beroual, "An Overview of The Fundamental Approaches That Yield Several Image Denoising Techniques", *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*, Vol. 17, No. 6, 2019, pp. 2959–2967.

[37] B.K. Boyat, Ajay Kumar and Joshi, "A Review Paper: Noise Models in Digital Image Processing", *Signal & Image Processing: An International Journal*, Vol. 6, No. 2, 2015, pp. 63–75.

[38] N. N. Hien, D. N. H. Thanh, U. Erkan and J. M. R. S. Tavares, "Image Noise Removal Method Based on Thresholding and Regularization Techniques", in *IEEE Access*, vol. 10, 2022, pp. 71584-71597.

[39] J. S. Lim, *Two-Dimensional Signal and Image Processing*. Upper Saddle River, NJ, USA: Prentice-Hall, 1990.

[40] Q. Xu, Q. Zhang, D. Hu, and J. Liu, "Removal of Salt and Pepper Noise in Corrupted Image Based on Multilevel Weighted Graphs and IGOWA Operator", *Mathematical Problems in Engineering*, Vol. 2018, 2018, pp. 1–11.

[41] H. Hwang and R. A. Haddad, "Adaptive median filters: New algorithms and results", *IEEE Transactions on Image Processing*, Vol. 4, No. 4, 1995, pp. 499–502.

[42] N. Aslam, M. K. Ehsan, Z. U. Rehman, M. Hanif, and G. Mustafa, "A modified form of different applied median filter for removal of Salt & Pepper Noise", *Multimedia Tools and Applications*, Vol. 82, No. 5, 2022, pp. 7479–7490.

[43] T. Chen and Hong Ren Wu, "Adaptive Impulse detection using center-weighted median filters", *IEEE Signal Processing Letters*, Vol. 8, No. 1, 2001, pp. 1–3.

[44] U. Erkan, L. Gökrem, and S. Enginoğlu, "Different applied median filter in salt and pepper noise", *Computers & Electrical Engineering*, Vol. 70, 2018, pp. 789–798.

[45] S. Shiby, P. G. Scholar, and A. Sunil, "A Decision tree and Conditional Median Filter Based Denoising for impulse noise in images", OPEN ACCESS, Vol. 4, No. 7, 2014, pp. 83–88.

[46] R. Ravi Nair and R. Poojary, "Image Denoising using Decision Tree Based Method", *SSRG International Journal of Electronics and Communication Engineering*, Vol. 3, Issue. 6, 2016, pp. 1–5.

[47] S. S. Bhapkar and B. V. Pawar, "A Decision Tree Based Denoising Method for Removal of Impulse Noise in Images Processing", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 6, Issue. 3, 2017, pp. 1351–1356.

[48] A. Abdurrazzaq, A.K. Junoh, W.Z.A.W. Muhamad, Z. Yahya, and I. Mohd, "An overview of multi-filters for eliminating impulse noise for digital images", *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*, Vol. 18, No. 1, 2020, pp. 385–393.

[49] [39] A. Abdurrazzaq, I. Mohd, A.K. Junoh, and Z. Yahya, "Modified Tropical Algebra Based Median Filter for Removing Salt and Pepper Noise in Digital Image", *IET Image Process*, Vol. 13, Issue 14, 2019, pp. 2790–2795.

[50] M. Batta, "Machine Learning Algorithms - A Review", *International Journal of Science and Research (IJSR)*, Vol. 9, Issue 1, 2018, pp. 381–386.

[51] A. Singh, N. Thakur and A. Sharma, "A review of supervised machine learning algorithms", *2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom), New Delhi, India*, 2016, pp. 1310-1315.

[52] Y. Qian, "Removing of Salt-and-pepper Noise in Images Based on Adaptive Median Filtering and Improved Threshold Function", *2019 Chinese Control and Decision Conference (CCDC), Nanchang, China*, 2019, pp. 1431-1436, doi: 10.1109/CCDC.2019.8832612.

[53] A. Abdurrazzaq, I. Mohd, A.K. Junoh, and Z. Yahya, "A Hybrid of Tropical-Singular Value

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Decomposition Method for Salt and Pepper Noise Removal", *Turkish Journal of Electrical Engineering and Computer Sciences*, Vol. 27, No. 3, 2019, pp. 1667–1679.

[54] U. Erkan, and L. Gökrem, "A New Method Based on Pixel Density in Salt and Pepper Noise Removal", *Turkish Journal of Electrical Engineering and Computer Sciences*, Vol. 26, No. 1, 2018, pp. 162–171.

[55] S. Rani, Y. Chabbra, and K. Malik, "Adaptive Window-Based Filter for High-Density Impulse Noise Suppression", *Measurement: Sensors*, Vol. 24, 2022, 100455.

[56] S. Enginoğlu, U. Erkan, and S. Memiş, "Adaptive Cesáro Mean Filter for Salt-and-Pepper Noise Removal", *El-Cezeri Journal of Science and Engineering*, Vol. 7, Issue 1, 2020, pp. 304–314.

[57] K. Vasanth, and R. Varatharajan, "An Adaptive Content Based Closer Proximity Pixel Replacement Algorithm for High Density Salt and Pepper Noise Removal in Images," *Journal of Ambient Intelligence and Humanized Computing*, 2020.

[58] S. Enginoğlu, U. Erkan, and S. Memiş, "Pixel similarity-based adaptive Riesz mean filter for salt-and-pepper noise removal", *Multimedia Tools and Applications*, Vol. 78, No. 24, 2019, pp. 35401–35418.

[59] V. Singh, R. Dev, N.K. Dhar, P. Agrawal, and N.K. Verma, "Adaptive Type-2 Fuzzy Approach for Filtering Salt and Pepper Noise in Grayscale Images", in *IEEE Transactions on Fuzzy Systems*, Vol. 26, No. 5, 2018, pp. 3170–3176.

[60] S. MEMİŞ, and U. ERKAN, "Different Adaptive Modified Riesz Mean Filter for High-Density Salt-And-Pepper Noise Removal in Grayscale Images", *European Journal of Science and Technology*, Vol. 23, 2021, pp. 359–367.

[61] B. Garg, and K. V. Arya, "Four Stage Median-Average Filter for Healing High Density Salt and Pepper Noise Corrupted Images", *Multimedia Tools and Applications*, Vol. 79, 2020, pp. 32305–32329.

[62] U. Erkan, D.N.H. Thanh, L.M. Hieu, and S. Enginoglu, "An Iterative Mean Filter for Image Denoising", *IEEE Access*, Vol. 7, 2019, pp. 167847–167859.