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COMPARATIVE RESEARCH OF HAAR AND DAUBECHIES WAVELET IN DENOISING DIGITAL IMAGE OF SEMARANG DISTRICT REGION'S MAP

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ABSTRACT

The objective of this research was to build digital image denoising system with Haar and Daubechies (Db3) Wavelet using Matlab R2009a and compare the effectiveness of the Haar and Daubechies (Db3) Wavelet in performing digital image denoising using parameters Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). A simulation of denoising system using software MATLAB R2009a was made to facilitate this research. The method used to construct simulation of denoising system is linear sequential model. Digital image data used in this simulation is digital image of Semarang District Region's map. From the result of simulation, the method that has the best effectiveness in denoising digital image which generated with Gaussian noise and Speckle noise is the Daubechies (Db3) Wavelet, whereas for digital image which generated by Salt & Pepper noise is the Haar Wavelet.

Keywords: *daubechies wavelet, denoising, digital image, haar wavelet*

1. INTRODUCTION

At the present time, map of the region is a source of information that is needed by societies. The information about the location and condition of the area can be obtained through the maps. Maps can be presented in the form of conventional and digital.

Digital map is one of the digital image forms that display a map object. Digital image it self is a part of the multimedia that has an important role as a source of visual information that contains a lot of information. In its development, sometimes arises disorder of the digital image called noise. Noise is the unwanted information which is contained to the data [1]. It occurs when capturing and delivery through the transmission line.

The more important digital image role will lead the increasing of digital image needs that is free from any noise so that the existing digital image can be seen clearly. Therefore, we need a process of noise reduction (denoising). Denoising has an important role in improving the digital image quality. Denoising is performed to reduce the noise contained in the digital image and retain the important information. The importance of this denoising aims to obtain a digital image becomes more accurately.

One of the methods that can be used to perform denoising is Wavelet. As [1] stated that wavelet can be used to perfom denoising for montly rainfall and number of rain days data and provide a good accuracy in removing the unwanted noise. In digital image, as [2] stated that denoising technique using wavelet can be used to reduce noise in digital images and produces good results.

In the Wavelet Transformation, Haar Wavelet is one of the oldest and the simplest Wavelet family [3]. Haar Wavelet is tough enough to perform digital image denoising which generated with Addictive noise. However, the performance of Haar Wavelet depends on the level decompotition. The greater its level decompotition,the worse Haar Wavelet

performance and the smaller its level decompotition, the better Haar Wavelet performance [4].

Besides using the Haar Wavelet digital image denoising, it can also be performed using Daubechies Wavelet, which is one of the Wavelet families that are orthogonal [5]. Research on digital image denoising using Daubechies Wavelets as expressed [6] that the Daubechies wavelet transform allows a good separation between the signal and noise thanks to the inherent use of multi-resolution techniques by which different frequencies are analyzed with different resolution.

[7] stated that his research about the digital image denoising types of medical X-ray images, MRI, Ultrasound, and CT Scan with Haar and Daubechies wavelet, using the parameters of the Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) concluded that the Daubechies wavelet perform denoising more effectively than the Haar Wavelet. However, it is still limited to medical images generated only by using Speckle noise.

According to its case, the research problem of the studies is how to perform digital image denoisingin which this research is devoted in the form of a digital image of the Semarang District Region'smap which is generated not only by Speckle noise but also Salt & Pepper noise and Gaussian noise with variations of density noise using Haar and Daubechies Wavelet method using Matlab R2009a and which one of both methods that is used and has the best level of effectiveness in terms of optimality value of Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). The purpose of this research is to develop a simulation denoising and compare the effectiveness of both methods are used.

This paper is organized as follows: Section 2 is methodology which describes the theory of Wavelet Transform. Result and interpretation of the outputs are discussed in Section 3. Section 4 is the conclusion.

2. BASIC THEORY
2.1. Wavelet Denoising

Wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale [8]. Wavelet denoising attempts to remove noise which is present in the signal while retaining all the signal characteristics regardless of its frequency contents. In practise, the wavelet transform implemented with reconstruction bank using wavelet families. The use of wavelet transform as filter bank called discrete wavelet transform (DWT).The DWT provides better spatial and spectral localization of signal formation [4]. Also it provides non-redundant and unique representation of signal. Due to this, signal and noise are easily separated in wavelet domain. Here, the signal is decomposed into sub signals corresponding to different frequency content. The result of DWT is a multilevel decomposition which will generate wavelet coefficients. These coefficients include various approximation and detail coefficients at various levels and it leads to four different sub-bands as HH, HL, LH and LL at each level. The approximation sub-band consists of the so called scaling coefficients (LPF) whereas the detail sub-band (HPF) are composed of wavelet coefficients. The role of decomposition in the analysis of N*N image can be explained as:

a) Initial low pass filtering of the rows blurs the image values along each row followed by low pass filtering
b) Along the columns which result in a low pass approximation of the whole image
c) Low pass filtering of the rows followed by high pass filtering of the columns highlights the changes that occur between the rows - horizontal details
d) Initial high pass filtering of the original rows of the image highlights the changes between elements in any given low. Subsequent low pass filtering of the columns blurs the changes that may occur between the rows thus providing the vertical details
e) High pass filtering of the rows followed by high pass filtering of the columns only changes that are neither horizontal are emphasized. This sequence gives the diagonal details of the original image. [9]
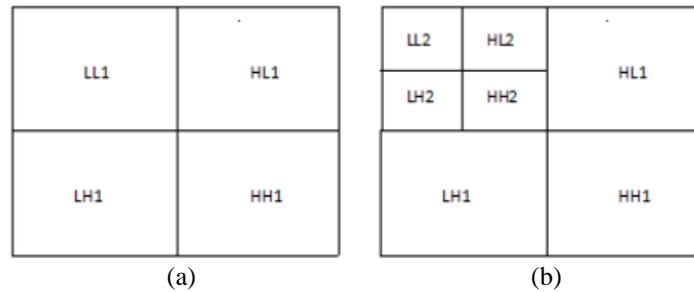
(a)   (b)

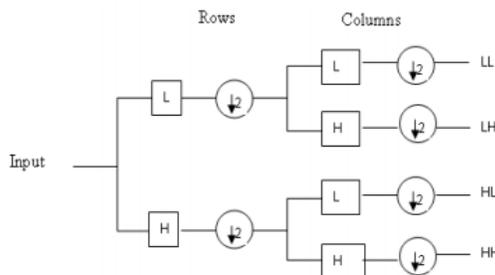**Figure 1.** DWT based image decompotition (a) One level decompotition (b) Two level decompotition

Figure 2. One level decomposition step of two dimensional image using DWT

The digital transformation of image for computer processing requires digitization, so here we are using 2-D discrete wavelet transform which decompose image several sub-bands. In case of two dimensional image, after DWT the image is divided into four corners, upper left of the original, lower left of corner of vertical details upper right of the horizontal details and lower right corner of the image detail. [9]

The decomposed image can be reconstructed using a reconstruction filter as shown in Figure 3. Here, the filters L and H represent low pass and high pass reconstruction filters respectively.[10]
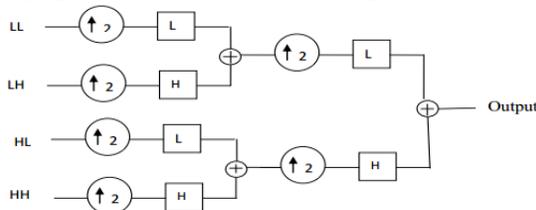

Figure 3. One level reconstruction step of two dimensional image using IDWT

2.2. Haar Wavelet

The Haar Wavelet is a certain sequence of rescaled "square-shaped" functions which together form a wavelet family. The Haar wavelet's mother wavelet function ψ(t) & its scaling function ϕ(t) can be described as [11]:

$$\psi(t) = \begin{cases} 1 & 0 \le t < \dfrac{1}{2} \\ -1 & \dfrac{1}{2} \le t < 1 \\ 0 & otherwise \end{cases}$$

$$\phi(t) = \begin{cases} 1 & 0 \le t < 1 \\ 0 & otherwise \end{cases}$$

(1)

2.3. Daubechies Wavelet

Daubechies wavelets are a family of wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support [5]. The Daubechies wavelet transforms are defined in the same way as the Haar wavelet transform by computing the running averages and differences via scalar products with scaling signals and wavelets the only difference between them consists in how these scaling signals and wavelets are defined [12].

The Daubecchies wavelet's mother wavelet function ψ(t) & its scaling function φ(t) can be described as [13]:

$$\psi(t) = \sqrt{2}\sum_{k=0}^{N-1}(-1)^k c_{N-1-k}\phi(2t-k)$$

$$\phi(t) = \sqrt{2}\sum_{k=0}^{N-1}c_k\phi(2t-k) \qquad (2)$$

Peak Signal to Noise Ratio

For identification of the models performance, the criterion chosen is Peak Signal to Noise Ratio (PSNR). PSNR is a ratio that is often used as a quality measurement between the original and a denoising image. The higher the PSNR, the better the quality of the compressed or reconstructed image [5]. PSNR is described as [10]:

$$PSNR = 10\log\frac{255^2}{MSE}$$

$$(3)$$

MSE is described as [10]:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[x(i,j)-y(i,j)]^2$$

$$(4)$$

Where, x(i,j) is the denoised image and y(i,j) is the noisy image.

MSE of an estimator is one of many ways to quantify the amount by which an estimator differs from the true value of the quantity being estimated.

The Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error.

3. RESEARCH METHOD

The method used in this research consists of several stages, namely, research problem, review of the related literature, data collection, and problem solving, and drawing conclusions. The simulation of denoising system used digital image data of Semarang District Region'smap. Digital image data of Semarang District Region'smap collection is performed online through the capture process on the maps.google.com. Digital image data of Semarang District Region's map which resulted by capturing process, further performed pre-processing stage, in which the pre-processing stage is performed cropping process and conversion of image color (RGB) into a grayscale image. The development of digital image denoising system is performed by making digital image denoising software system with Haar Wavelet and Daubechies Wavelet made using Matlab R2009a. Furthermore, by using Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) parameters that are displayed by the further system is analysed to determine which one of wavelet types that is more effective in the denoising process.

To perform image denoising process, the simulation of denoising system was made using Haar and Daubechies (db3) Wavelet method with Matlab R2009a. The process of making this denoising system software used sequential linear model, which can be seen in Figure 4.
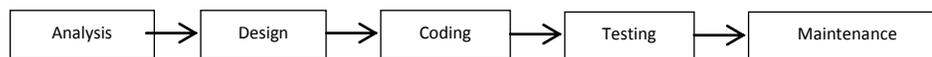

Figure 4. Sequential Linear Model

According to [14] sequential linear proposes an approach to software development that is systematic and sequential start on the level and progress of the whole system in the analysis, design, coding, testing, and maintenance. Analysis stage is the stage of analyzing the cases that are

needed in the implementation of software creation. At this stage the data that has been collected is performed pre-processing to obtain a digital image of Semarang District Region'smap which can be utilized for the system to be created. This process includes cropping and conversion process from RGB to grayscale image form. The design stage is the stage of translation of the analysed data into a form that is easy to be understood by the user. At this stage is performed design process of the denoising system digital. Denoising system is designed by using Matlab R2009a. Coding phaseis a data translation stage or solving the problem that has been designed into a particular programming language. This stage is a real stage in working out a system. In this stage is performed coding of denoising system design in a programming language of Matlab R2009a. The further stage is the testing phase of denoising system software that was built. Testing is performed by pay attention to the result of denoising and the value of the Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) of a digital image of Semarang District Region'smap that has been inputted into the system. The last stage is maintenance, this is the final stage in which a software that has been completed can undergo changes or additions in accordance with user demand.

In this simulation of digital image of Semarang District Region's map denoising system, there are several processes that must be performed. These processes are presented in a denoising system flow chart. Here is a flow chart for digital image of Semarang District Region'smap denoising the system is displayed on Figure 5.
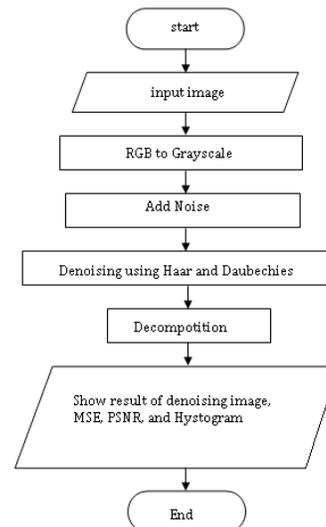

Figure 5. Flowchart of Denoising System

4. RESULTS AND DISCUSSION

The system is made by applying the functions of the Matlab R2009a to convert RGB image into grayscale, generates noise, and perform noise reduction in image which has .jpg format and display the results of the Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). Display of image denoising system that used in this research is presented on Figure 6.
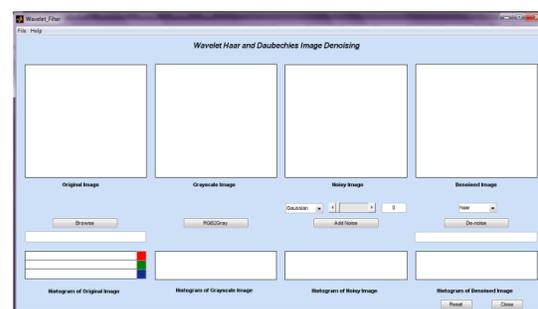

Figure 6. Display of Denoising Systems

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From Figure 6 there are 2 Menu Bars that are File Menu Bar and Help Menu Bar. File Menu Bar has 2 Sub Menus i.e New and Close, while the Help Menu Bar has 2 Sub Menusi.e How to use and About. Close Sub Menu is used to terminate the program or get out of this denoising system. How to use Sub Menu is used to display a brief exposition of the instruction to run the denoising system program. About Sub Menu is used to display a brief description of the denoising system program. In addition, there are six buttons (pushbutton) are used to perform commands against the system, i.e Browse, RGB2Gray, Add Noise, and De-Noise. Browse pushbutton serves to make the search process and the selection of the digital image that will be performed denoising process. RGB2Gray pushbutton serves to make the process of converting an RGB image into a grayscale image. Add Noise pushbutton serves to make the process of generation of noise in grayscale images. Before the generation of noise is performed, first do selection to the type and density of noise that will be raised. In this system there are three choices of types of noise that can be used that is Gaussian, Salt & Pepper, and Speckle. De-Noise pushbutton serves to perform the process of denoising on the grayscale image that has been raised by specific noise. Before denoising process is performed, first do the selection to the type of method used to perform

the denoising process. In this system there are two choices of method types that can be used that are Haar and Daubechies (db3). Reset pushbutton has a function to remove all input and output values that resulted by the system. And the last pushbutton Close that has a function to terminate and exit from the system.

The image which is tested in this denoising system is kab.semarang.jpg image that has been done pre processing. Here, denoising testing has been done by two methods, namely Haar Wavelet and Daubechies Wavelet (db3). Decompotition level that used in this simulation of denoising system is level 2. The following are the values of the Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) of the results of denoising by the system based on each method:

4.1. Haar Wavelet Method

In this paper, the discussion is based on the results of denoising system using kab.semarang.jpg image that has been done through a series of pre-processing and denoising process by generating noise using noise density variations in 0.01, 0.02, 0.03, 0.04, and 005. The following are examples of the denoising results of kab.semarang.jpg image that has been generated using Gaussian noise with noise density 0.03 applied Haar Wavelet method at Figure 7.
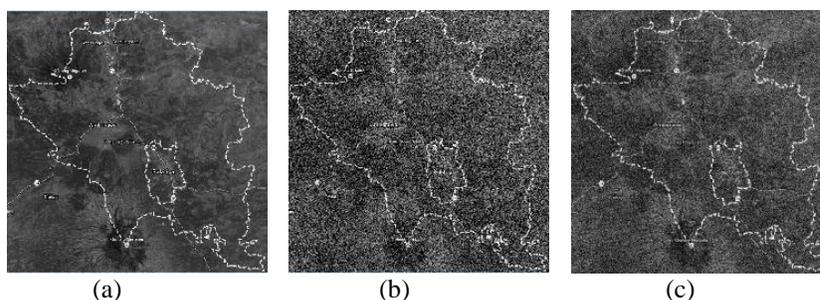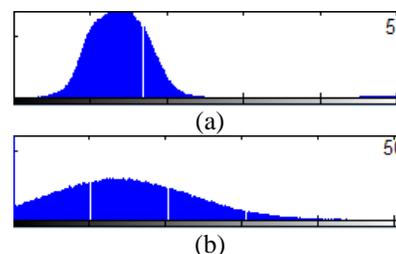

(a)   (b)   (c)
Figure 7. (a) Original Image (b) Noisy Image (c) Result Image

Figure 7a is the original image, then Figure 7b is an image that has been generated using a Gaussian noise with noise density 0.03, and Figure 7c is the resulted image from denoisingprocess using the Haar wavelet method. The following are examples of histogram denoising results of kab.semarang.jpg image which generated using Gaussian noise with noise density 0.03 on Figure 8.
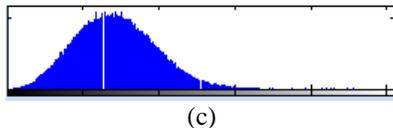

(a)

(b)

(c)

Figure 8. (a) Histogram of Original Image (b) Histogram of Noisy Image (c) Histogram of Result Image

In Figure 8a is histogram of original image, then Figure 8b is histogram of the image that has been generated using a Gaussian noise with noise density of 0.03, and Figure 8c is histogram of the resulted image from denoising process using Haar Wavelet. By pay attention the noisy image and the resulted image from denoising process, it is clear there are differences between both of them. This case shows that the system was successfully performing denoising process. It is also reinforced by the histogram of noisy image and histogram of resulted image from denoising process which show a significant difference.

For the simulation results in image denoising with noise density of 0.01, 0.02, 0.03, 0.04, and 0.05 obtained the following results. Furthermore, the results of digital image of Semarang District Region'smap from denoising process using the Haar Wavelet method is presented on Table 1.

Table 1. Value of MSE and PSNR of kab.semarang.jpg image using Haar Wavelet Method

No	*Noise* Density	MSE (dB)			PSNR (dB)		
		Gaussian	Salt&Pepper	Speckle	Gaussian	Salt&Pepper	Speckle
1	0.01	627.4529	68.2143	116.4904	20.1550	29.792	27.4679
2	0.02	1049.9377	84.3870	176.8043	17.9192	28.871	25.6559
3	0.03	1425.9484	99.4070	229.0170	16.5898	28.1566	24.5321
4	0.04	1771.8519	140.7230	277.1470	15.6465	26.6472	23.7037
5	0.05	2087.7040	192.6929	324.9381	14.9341	25.2821	23.0128

Based on the values of the Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are contained on Table 1 obtained information that the greater the density of noise is given, the greater value of the Mean Square Error (MSE) is obtained which has consequence decrease the value of Peak Signal to Noise Ratio (PSNR). Based on this case it can be concluded that the performance of the Haar Wavelet methods depends on a given noise density variations. It means that the greater the noise density decreases Haar Wavelet performance and conversely the smaller the noise density will increase Haar Wavelet performance.

4.2. Daubechies Wavelet Methods (DB3)

In this paper, the discussion is based on the results of denoising system using kab.semarang.jpg image that has been done through a series of pre-processing and denoising process by generating noise using noise density variations in 0.01, 0.02, 0.03, 0.04, and 005. The following are the examples of denoising results of kab.semarang.jpg image that has been generated using Gaussian noise with noise density 0.03 applied Daubechies wavelet (Db3) method on Figure 9.
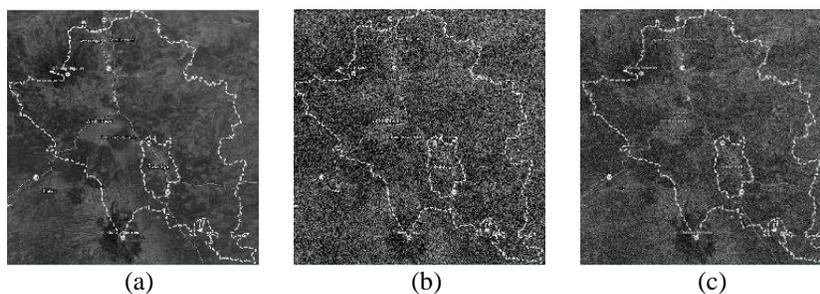

(a)   (b)   (c)
Figure 9. (a) Original Image (b) Noisy Image (c) Result Image

Figure 9a is the original image, then Figure 9b is an image that has been generated using a Gaussian noise with noise density 0.03, and Figure 9c is the resulted image from denoising process using the Daubechies Wavelet (Db3) method. The following are the examples of histogram denoising results of kab.semarang.jpg image which generated using Gaussian noise with noise density 0.03 on Figure 10.
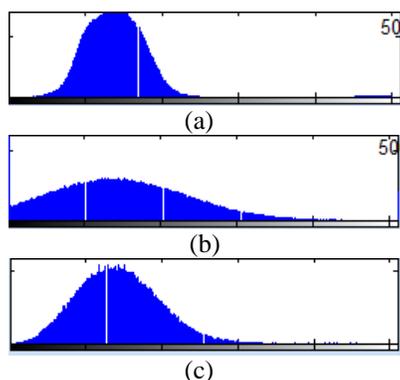

(a)

(b)

(c)

Figure 10. (a) Histogram of Original Image (b) Histogram of Noisy Image (c) Histogram of Result Image

Figure 10a is histogram of original image, then Figure 10b is histogram of the image that has been generated using a Gaussian noise with noise density of 0.03, and Figure 10c is histogram of the resulted image from denoisingprocessusing Db3 wavelet. By pay attention to the noisy image and the resulted image from denoisingprocess, it is clear there are differences between both of them. It shows that the system successfully performs denoising process. It is also reinforced by the histogram of noisy image and histogram of resulted image from denoising process which show a significant difference.

For the simulation results in image denoising with noise density of 0.01, 0.02, 0.03, 0.04, and 0.05 obtained the following results. Furthermore, the result of digital image of Semarang District Region's map from denoising process using the Daubechies Wavelet (Db3) method is presented on Table 2

Table 2. Value of MSE and PSNR of kab.semarang.jpg image using Db3Wavelet Method

No	*Noise* Density	MSE (dB)			PSNR (dB)		
		Gaussian	Salt&Pepper	Speckle	Gaussian	Salt&Pepper	Speckle
1	0.01	584.1681	78.1083	104.0267	20.4654	29.2038	27.9594
2	0.02	1004.9491	109.2035	159.7169	18.1094	27.7484	26.0973
3	0.03	1381.1377	136.5364	210.7770	16.7284	26.7783	24.8926
4	0.04	1726.0085	194.3685	256.4157	15.7604	25.2445	24.0414
5	0.05	2036.9098	262.2237	300.3744	15.0411	23.9441	23.3554

Based on the values of the Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are contained on Table 2 obtained information that the greater the density of noise is given, the greater the value of the Mean Square Error (MSE) is obtained which has consequence decrease the value of Peak Signal to Noise Ratio (PSNR). Based on case it can be concluded that the performance of the Db3 Wavelet methods depends on a given noise density variations. This means that the greater the noise density decreases Db3 Wavelet performance and conversely the smaller the noise density increases Db3 Wavelet performance.

Based on the results of testing on the system, so that to compare which one of the Haar and Daubechies (db3)Wavelet Method which has the best effectiveness in the digital image of Semarang District Region's map denoising used the analysis as follows. Using the value of MSE known that the more effective types of wavelet in denoising process is the one that has the smallest value, while using PSNR known that the type of wavelet which is more effective in denoising process is one that has the largest value (Bire&Cahyono: 2012). Figure 11 is presented an example of kab.semarang.jpg image from denoising process using the Haar and Daubechies (db3) wavelet.
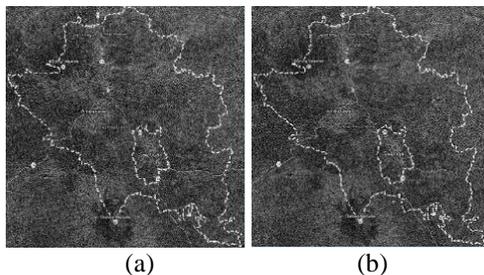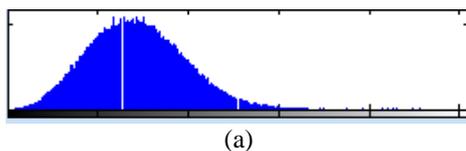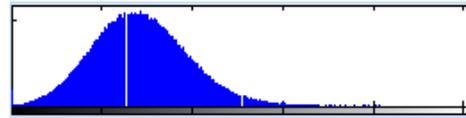

(a)   (b)
Figure 11. (a) Result Image Using Haar Wavelet Method (b) Result Image Using Daubechies Wavelet Method

(a)

(b)

Figure 12. (c) Histogram of Result Image Using Haar Wavelet Method (d) Histogram of Result Image Using Daubechies Wavelet Method

Figure 11a is the image resulted from denoising process using the Haar Wavelet method, Figure 11b is the image resulted from denoising process using Daubechies wavelet (db3), Figure 12a is the image histogram resulted from denoising process using the Haar Wavelet method, and Figure 12b is the image histogram resulted from denoising process using the Daubechies wavelet (db3).

By pay attention to the example of image resulted from denoisingprocess and image histogram resulted from denoising process, in which Figure 8 is seen that the results of denoising using Daubechies Wavelet appears to be more subtle than the results ofdenoising using Haar Wavelet. Based on this case, it can be concluded that the test of kab.semarang.jpg image which generated using Gaussian noise with noise density 0.03, Daubechies (db3)Waveletmethod performs denoising more effectively thanHaar Wavelet. This is reinforced by the results of MSE and PSNR of both methods, in which the Daubechies Wavelet produces the value of MSE and PSNR more optimal than the Haar wavelet.

For the test results as a whole, by pay attention to the value of MSE and PSNR of denoising result processwhich presented in Table 1 and Table 2, it can be concluded that the method that has the best effectiveness in the digital image of Semarang District Region's map denoising which generated with Gaussian noise and Speckle noise is Daubechies wavelet (db3), while for the image generated by Salt & Pepper noise, a method that has the best effectiveness in denoising is the Haar wavelet.

5. CONCLUSION

From the research, pre-processing the image, design, manufacture, testing of systems until compare the results of digital image of SemarangDistrictRegion's map using the Haar

and Daubechies Wavelet (db3) obtained the conclusions that are; (a) The steps that is used to perform digital image denoising with Haar and Daubechies (Db3) Wavelet method using Matlab R2009a is selecting the image, changing the image type of the RGB image into a grayscale image, generating noise in the image, performing image denoising; (b) The method that has the best effectiveness in digital image denoising which generated with Gaussian noise and Speckle noise is the Daubechies Wavelet (db3), while for the image generated by Salt & Pepper noise, a method which has the best effectiveness in digital image denoising is Haar Wavelet.

It is necessary to develop a simulation of denoising system againts the color image and image that has format .bmp, .tiff, .png, and .gif. Simulation ofdenoisingsystem also needs to try with another software than Matlab R2009a, such as Java and C ++ to know which software is fast and easy to use.

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