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_ University of Science and Technology of Hanoi Information and Communication Technology Department Master Thesis Academic year 2016 - 2017 __ NOISE EVALUATION AND REDUCTION __ presented by HOANG DUC VIET registered at University of Science and Technology of Hanoi(USTH) supervised by Ph.D Tran Giang Son Host organization : ICTLab - USTH Ha Noi - Viet Nam ATTESTATION __ I hereby, HOANG DUC VIET, certify that my report doesn't contain plagiarism (copy/paste) from other sources. In case of plagiarism in my report, I know the consequences and I understand that my report won't be evaluated.

In this case, my M2 internship will be noted as "fail". Date 15/09/2017 Signature _ HOANG DUC VIET __ II Acknowledgements Firstly, I would like to thank my supervisor Dr. Tran Giang Son of the ICTLab at Hanoi University of Science and Technology(USTH).

With his regular supports, his advice and his encouragement have been a key driver for my work. Next, I would like to thank Prof. Daniel Chillet who is my Tutor at Université de Rennes 1. I want to say thank to all members of the ICTLab was always open to welcome me. They were very helpful and creating conditions for me in the internship duration.

Finally, I would like to thank my family all for their loves and their supports to me. My parents and younger sister help me very much. From this, I can devote all time to the graduation internship. I Asbtract A long time ago, image processing have met problem about image quality. Noise usually appear in image and it is main cause to promote technology find solve to remove noise.

Nowaday, science and technology develop to build denoise methods which to help images have best quality. In this report, we propose 4 method: median filter, average

filter, gaussian filter and wiener filter. Methods participate which help SWARMS project to obtain best result. II

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Chapter 1 Introduction 1.1 Context Moreover, noise also appears in the images. Image noise is created by the sensor and circuitry from scanner or digital camera. Film grain and noise of an ideal photon detector are one of cause.

So brightness or color information in images will be changed. Image noise is not same as normal image that have many different information. Although camera technology is very improve over the past decade, it still has not totally remove noise for images. So now, researchers still find to way which improve about camera to have better images is better. Noise can appear in our photo for different reasons.

Noise signal with the light signal increase when high ISO is used. Camera need lighter to creat good image, but noise also more appear. When the image sensor is hot, photons evacuate from the images and damage other images. Long exposures is one of cause to appear noise in image becaue the sensor open to have more image information and electrical noise will appear.

Denoise is a process of remove noise to images. There are ways to noise removal in image, data. With image denoise model is completely remove noise and protect edges. Basically, there are two types of models : linear and non-liner. Linear models is removing models is the speed also as limitations of itself. It's not able to protect edges which are recognized as discontinuities in the image.

It's not able to protect edges which are recognized as discontinuities in the image. So, blur edges could appear in images. On the other hand, non-linear models can solve edges problem much better than linear models. We suppose non-linear image denoising model use the Total Variation (TV)- filter.

Denoise a degraded image X by X = S + N, meaning sum of S (original image) and N (Gaussian noise) with unknown value. We call unknown value is (s) which is the standard deviation of the distribution. 1.1.1 Internship context One of the major problems in

document digitalization is noise.

Image noise is random (not present in the object imaged) when it change brightness level or color in images. It can be generated in many scanning steps, such as grayscaling or thresholding. It can also be caused by image lossy compression algorithms, such as JPEG's discrete cosine transformation and thresholding.

Noise is one of the main factors contributing to degratation of accuracy in optical character recognition of the scanned documents, a process aiming at providing a high semantic description of the content of the document. At ICTLab, we have been dealing with scanned document in the context of project ARCHIVES. A good noise evaluation and reduction algorithm will improve our document analysis (including optical character recognition) results.

We are going to survey different denoising methods. From this, we will compare result of methods as : Median filter, Average filter, Gaussian filter, Wiener filter by we are using PSNR and MSE. Based on the quality characteristics of two methods MSE & PSNR to compare. Created comparison table and showed image result, finally we will know method is the best.

Although, images processing has many method to remove noise but due to limited time, many other methods can not be explored and the results are only relative. 1.2 Problematic We have two problems in this topic: Noise Noise is the cause of errors from image when in pixel values that do not reflect the true intensities of the real scene. ISO values: a standard of absolute sensitivity to light. There are 3 type of noise: Fixed pattern noise appears during long exposures.

When the camera is working for long periods of time and it heats up, the sensor starts to produce these strange dots of color in our image. Our camera is hotter, more fixed pattern noise will appear. Fixed pattern noise usually easier to remove since it is repeatable. A camera just has to know the pattern and it can remove fixed pattern. _ Long Exposure Low ISO Speed Random noise may be the most common image noise.

Random noise appears whenever we are using high ISO values. ISO has mean is a standard which describes its absolute sensitivity to light. Quality of camera is good when it remove random noise through software. Example: Neat Image and Noise Ninja programs, they can be removing noise and protect image information.

When technology continues to improve, we can shoot in low light situation. _ Short Exposure High ISO Speed Banding noise is dependent on what type of camera we are

using. With high end cameras, we have never seen banding noise. Banding noise will appear when lower quality photograph are shot with higher ISO value.

There are causes help banding noise appear: in the dark of photos or increase exposure too much and digitally make a photograph too bright. We may also see more banding noise in certain white balances which is the process of removing unreal color. _ Susceptible Camera Brightened Shadows Denoise Noise removal is very important task in image processing.

It will help to remove the noise from the image and rebuild to original image is the best quality. In modern digital image processing, data denoising is a hard problem and it used to application areas. Noise removal is popular solution for photography or improve the image was degraded. Filtering is technique which can be decreasing or increasing an image.It's processed value for current pixel will depends itself and surrounding pixels .

The value of any pixel in the output image is used by applying algorithms to the values of the pixels in the place which corresponding input pixel. Follow Image Processing, there are 4 types of filtering : Median Filter. The median filter method is very popular in image processing and it protects edges while removing noise in certain environment Average Filter.

Average filtering is simply to replace each pixel value in an image with the average value of its area, including itself. Its meaning is remove pixel values which aren't types of their environment. Gaussian Filter. Gaussian filters never go through to function input while minimizing the time.

Wiener Filter The Wiener filter decreases the mean square error between the random process and the desired process. 1.3 Report organization In this report, we have 5 chapters as below : Chapter 1 : Introduction This chapter included presentation of: Context and Problematic. Context is the part that describe about problems and solutions through this report. Problematic is determination and analysis to problem in this topic.

Chapter 2 : State Of The Art Collected different papers addressing the same topics of internship. Next to explain the work published, by giving the context of the work, the main idea, the main results. From this, we can learn more about how to present and solve problems of the authors.

Chapter 3 : Contribution In this part, proposed method to solve the problem in the introduction chapter. Beside this, explain method/algorithm/system in proposition.

Chapter 4 & 5 : Result & Conclusion This part include the result of the method/algoritm/system developed. Moreover, it contain comparisons table, figures, graphics and comment. Recall the problematic, methods used, contribution, results obtained and future developed.

Chapter 2 State of the art 2.1 Noise Removal in Image Processing using Median [2] This paper was written by Monika Kohli and Harmeet Kaur. Authors research and analyze median filter. From this, the filter is compared with median and Adaptive median filter. Types of noise Impulse noise (Salt & pepper noise): Used for this type of noise Black and white dots appear in this noise so the name salt & pepper noise.

Amplifier noise (Gaussian noise): is the sum of the actual pixel value and a random Quantization noise (Uniform noise): It appears because quantization process the pixels to a number of discrete levels Multiplicative noise (Speckle noise): It appears because random value multiplications with pixel values of the image as modeled process. Periodic noise(Stationary noise):It appears because attend between electronic components and appear from interference during image acquisition.

After image noise can be classified as above, characteristics of each type are specified. They analyse algorithm of filters : Median filter, Adaptive median filter, Proposed Median Filter. Finally, Comparison of filters when used PSNR to calculate quality of images with 3 methods : Median filter, Adaptive median filter, Proposed Median Filter.

They obtained result show that the proposed method is the best. In future, result can be improved by different noise such as : Gaussian noise, Speckle noise etc 2.2 The Sure-Let Approach to Image Denoising [3] [Thierry Blu & Florian Luisier] It's a new approach to noise removal by the image-domain minimization of an estimate of the mean squared error(MSE). They called Stein's unbiased risk estimate (SURE).

They called Linear expansion of thresholds (LET) by combination of elementary denoising processes. Evaluate this denoising performances by comparing PSNR. Combined 3 step above to SURE-LET Approach. Result: _ Follow SURE-LET program in Matlab, input MSE is compare between noisy image and original image, output MSE is compare between denoise image and original image. So they use output MSE result to table of Comparison Of The Results. 2.3

Study on Methods of Noise Reduction in a Stripped Image [4] [Chi Chang-yan, Zhang Ji-xian, Liu Zheng-jun] Noise is one of image quality problem in the image processing major. Noise reduction is necessary for us to do remove noise and description useful information more prominent. The Gray Value Substitution and Wavelet Transformation

are methods in noise removal. Finally, MSE and PSNR are evaluated the processed image suitable in this paper.

_ Image processing results of gray value substition We can see from this image, most noise line is changed and it is not affected by this method. However, some small noise still appear, and the brightness after processing is stronger than that before. _ Image decomposition using Wavelet and usual wavelet denoising result Wavelet method haven't solution remove noise in the horizontal domain, the vertical and cross part of image. Moreover this image haven't much noise so they obtain result as above.

From result tables, they can see that, low pass filter can't use to remove noise. And the other two methods is relatively accepted 2.4 Different Noise Types and Digital Image Processing[5] [Gursharan Kaur, Rakesh Kumar, Kamaljeet Kainth] As know, image is used in various fields like medical and education. Noise appear everywhere including images. From this, noise reduction is the main focus to retain the quality of the image.This paper is review problem to types of noise and solution.

Types of noise: Gaussian noise, Salt and pepper noise, Poisson noise Different types of linear and non-linear filters. Mean Filter: Mean filter is a type of linear filter that computes average value of the corrupted image. Median Filter: Median filter is a type of non-linear filter. It used to reduce the measure of intensity variation between one pixel and the other pixel. In this paper, the purpose is denoising of the images.

Techniques that are already using may not be able to find the best result so in the future they may find the techniques that provide optimum solution to the noise. 2.5 Impulse Noise Reduction methods in Digital images [6] [Himani Goel, Seema Rani] They review this paper about denoise. From this, compare results by PSNR and MSE to obtain best result. Linear Filters: Mean filter, Wiener filter.

Non Linear filters: Adaptive median filter, Improved progressive switching median filter. By the results, they see the median filtering is better than mean or average filter to remove impulse noise but it affect the edge details. 2.6 Optimal Gaussian Filter for Effective Noise Filtering [7] [Sunil Kopparapu and M Satish] Noise removal is important problem in many signal processing applications.

In this paper, they have show the optimal Gaussian filter that best filters noise, with the noise is AWGN. The contribution of this paper is identification of a method to obtain the optimal Gaussian filter which best filters a signal contaminated with AWGN. Gaussian Approach There are basic two ways of remove noise in the signal: Pre-processing of the signal to enable noise removal Use of a set of robust algorithms that can compensate

for the inherent noise. In signal processing, pre-processing of the signal is the preferred approach.

They have shown that the method works well for signals whose bandwidth and the input signal . We are in the process of verifying the validity of their approach for practical signals and finish in the next time. 2.7 Image Enhancement with Noise Reduction in Spatial Domain[8] [S. Shyam Prasad, R. Priya] Digital images are mostly corrupted by mixed noise from several sources.

It is a big problem have long existed. Generally, some filters can reduce additive or impulse noise, but it can't remove impulsive noise and additive noise. This paper propose change mutual filtering method, which can remove both impulsive and additive noise, when compared to average filter and median filter. The solve show that the proposed filtering action can remove impulsive and additive noise while protecting edge.

MODELING NOISE OF THE IMAGES Additive Noise: Additive noise is noise of an image sensor. It's meaning the constant noise in dark areas of the image. Impulse Noise: Impulse noise is called Salt and pepper noise or spike noise. Mixed Noise: Mixed noise is the combination of additive noise and impulse noise. REMOVING NOISE FROM IMAGES BY FILTERING Linear Filter Average filter is one of the linear filter.

Non-Linear Filters Median filter and Bilateral filter are the non linear filters. PROPOSED APPROACH Average Filter The idea of average filtering is simply to replace each pixel value in an image with the average value of its area, including itself. Median Filter The median filter is popular technique nonlinear in digital filtering.It removes noise from an image or signal (speckle noise & salt-pepper noise).

Bilateral Filter This is a non-linear technique which can blur an image while taking strong edges. Solve to by combine nonlinear means with nearby image values. _ Quality Measures of Einstein image Bilateral filtering method is changed in this paper. It can removed 2 types of noise : impulsive noise and additive noise.

Chapter 3 Contribution Spatial filtering is a types of <mark>finite impulse response (FIR)</mark> filtering. It is a mask of weights with shape as rectangular.

It mean that sliding the mask along the image and apply to multiplication and collection operation on the pixels protected by the mask. Original Image First, <mark>we are going to</mark> read and show original image as below : _ Original Image _ Add noise (gaussian noise & 0.05 variance.) 3.1 Median Filter Median Filter is family of order filters. It has process : Replace the value of a pixel with the median value of the neighborhood.

Imedian = median(I[i,j]) with (i,j) ? neighborhood 30 _10 _20 _ _10 _250 _25 _ _20 _25 _30 _ _? 10 10 20 20 25 25 30 30 250 ? median

_ Filter 3×3 _ Filter 5×5 _ Filter 7×7 3.2 Average Filter Feature: Average Filter is spatial filter that applies to a neighborhood (local method). It's a linear filter as a convolution. This mean a pixel is replaced by the average of itself and its neighbours which size <mark>determines the amount of</mark> smoothing.

And equivalent to a filtering operation lowpass. Average Filter have: Filter 3×3 __ Filter 5×5 1 _1 _1 _1 _1 _1 _ _ _1 _1 _1 _1 _1 _ _ _1 _1 _1 _1 _1 _ _25 _ _ _ _ _ _ _ _1 _1 _1 _1 _1 _ _ _1 _1 _1 _1 _1 _ _Filter 7×7 1 _1 _1 _1 _1 _1 _1 _1 _ _ _1 _1 _1 _1 _1 _1 _1 _ _ _1 _1 _1 _1 _1 _1 _ _ _1 _1 _ _ _1 _1 _1 _1 _1 _1 _1 _ _49 _ _ _ _ _ _ _ _ _ _1 _1 _1 _1 _1 _1 _1 _ _ _1 _1 _1 _1 _1 _1 _1 _ _ _1 _1 _1 _1 _1 _1 _1 _ _ Filter 3 × 3 _ Filter 5 × 5 _ Filter 7 × 7 3.3

Gaussian Filter The Gaussian kernel in dimension 2: _ Define the Gaussian mask(s = 2): Filter 3×3 1 _1 _2 _1 _ _ _2 _4 _2 _ _16 _ _ _ _ _ _1 _2 _1 _ _Filter 5×5 1 _1 4 7 4 _4 16 26 16 _7 26 41 26 _4 16 26 16 _ _ _273 _ _ _ _ _ _ _ _1 _4 _7 _4 _ _ _Filter 7×7 1 _0 0 1 2 1 _0 3 13 22 13 _1 13 59 97 59 _2 22 97 159 97 _1 13 59 97 59 _0 3 13 22 13 _ _ _1003 _ _ _ _ _ _ _ _ _ _0 _3 _13 _22 _13 _3 _ _ _ _0 _0 _1 _2 _1 _0 _ _ _From theory above, <mark>we are going to</mark> build function for gaussian filter : _ Filter 3 × 3 _ Filter 5 × 5 _ Filter 7 × 7 3.4

Wiener Filter Result: _ Filter 3 × 3 _ Filter 5 × 5

_ Filter 7 × 7

Chapter 4 Results Mean Square Error In statistics, the mean squared error (MSE) is used to calculate the average of the squares of the errors. It mean that the difference between the estimator and what is estimated. The MSE is one of quality evaluation method. In this internship, it help us to know best result when it is the smallest. _ Peak signal to noise ratio The PSNR is also one of quality evaluation method.

In this internship, it help us to know best result when it is the biggest. _ Construction Image __ (a) Original 1 (b) Original 2 (c) Original 3 (d) Original 4 (e) Original 5 _Median _Average _Gaussian _Wiener _ _Image 1 _MSE _0.0097 _0.022 _0.0095 _0.007 _ _ _PSNR _68.269 _64.7115 _68.3762 _69.6511 _ _ _MSE 1 _0.0125 _0.0251 _0.012 _0.0084 _ _ _PSNR 1 _67.1535 _64.1264 _67.3409 _68.8738 _ _Image 2 _MSE _0.0055 _0.0166 _0.0056 _0.0044 _ _ _PSNR _70.7071 _65.9348 _70.6237 _71.654 _ _ _MSE 1 _0.0096 _0.0219 _0.0096 _0.0075 _ _ _PSNR 1 _68.298 _64.7271 _68.2967 _69.3898 _ _Image 3 _MSE _0.0034 _0.0122 _0.0035 _0.0028 _ _ _PSNR _72.761 _67.2713 _72.6781 _73.6324 _ _ _MSE 1 _0.0078 _0.0178 _0.0077 _0.0061 _ _ _PSNR 1 _69.2093 _65.638 _69.2572 _70.2559 _ _Image 4 _MSE _0.0026 _0.0144 _0.0031 _0.0022 _ _ _PSNR _73.9221 _66.5571 _73.1714 _74.65 _ _ _MSE 1 _0.0065 _0.0183 _0.0067 _0.0054 _ _ _PSNR 1 _69.9904 _65.5003 _69.8929 _70.8107 _ _Image 5 _MSE _0.0048 _0.0243 _0.0056 _0.0046 _ _ _PSNR _71.3083 _64.2764 _70.6356 _71.5275 _ _ _MSE 1 _0.0125 _0.0351 _0.0131 _0.0098 _ _ _PSNR 1 _67.1789 _62.6729 _66.9615 _68.2047 _ _Comparison Table Rubbish Image __ (a) Original 1 (b) Original 2 (c) Original 3 (d) Original 4 (e) Original 5 _Median _Average _Gaussian _Wiener _ _Image 1 _MSE _0.0032 _0.0156 _0.0036 _0.0025 _ _ _PSNR _73.1106 _66.1969 _72.5825 _74.1694 _ _ _MSE 1 _0.007 _0.0198 _0.007 _0.0053 _ _ _PSNR 1 _69.6741 _65.1589 _69.6536 _70.8804 _ _Image 2 _MSE _0.0036 _0.00126 _0.0038 _0.0029 _ _ _PSNR _72.5146 _67.1263 _72.3851 _73.4524 _ _ _MSE 1 _0.0078 _0.0173 _0.0076 _0.0061 _ _ _PSNR 1 _69.2119 _65.7582 _69.3064 _70.2561 _ _Image 3 _MSE _0.0083 _0.0246 _0.0081 _0.0063 _ _ _PSNR _68.9656 _64.2139 _69.0718 _70.1636 _ _ _MSE 1 _0.0158 _0.0336 _0.015 _0.0115 _ _ _PSNR 1 _66.1394 _62.8625 _66.3823 _67.5195 _ _Image 4 _MSE _0.0207 _0.0424 _0.0185 _0.0161 _ _ _PSNR _64.9661 _61.8601 _65.4527 _66.0756 _ _ _MSE 1 _0.0313 _0.0567 _0.0287 _0.0235 _ _ _PSNR 1 _63.1696 _60.5959 _63.5549 _64.4181 _ _Image 5 _MSE _0.0055 _0.0123 _0.0053 _0.004 _ _ _PSNR _70.7050 _67.2474 _70.9133 _72.0813 _ _ _MSE 1 _0.0096 _0.0176 _0.0092 _0.007 _ _ _PSNR 1 _68.3119 _65.677 _68.4872 _69.698 _ _Comparison Table Pagoda Image __ (a) Original 1 (b) Original 2 (c) Original 3 (d) Original 4 (e) Original 5 _Median _Average _Gaussian _Wiener _ _Image 1 _MSE _0.0098 _0.0141 _0.0093 _0.0055 _ _ _PSNR _68.2117 _66.6490 _68.4598 _70.7544 _ _ _MSE 1 _0.013 _0.0168 _0.0115 _0.0068 _ _ _PSNR 1 _66.9999 _65.8739 _67.5091 _69.7993 _ _Image 2 _MSE _0.0098 _0.0145 _0.0088 _0.0053 _ _ _PSNR _68.2338 _66.5220 _68.6970 _70.9009 _ _ _MSE 1 _0.0138 _0.0189 _0.0122 _0.0076 _ _ _PSNR 1 _66.7404 _65.3739 _67.2818 _69.3011 _ _Image 3 _MSE _0.0114 _0.0177 _0.0102 _0.0065 _ _ _PSNR _67.5543 _65.6549 _68.0291 _70.0034 _ _ _MSE 1 _0.0150 _0.0215

_0.0131 _0.0081 _ _ _PSNR 1 _66.3743 _64.8131 _66.9631 _69.0515 _ _Image 4 _MSE _0.0080 _0.0188 _0.0072 _0.0047 _ _ _PSNR _69.1060 _65.3952 _69.5399 _71.4029 _ _ _MSE 1 _0.0116 _0.0229 _0.0106 _0.0069 _ _ _PSNR 1 _67.4972 _64.5418 _67.8751 _69.7300 _ _Image 5 _MSE _0.0104 _0.0179 _0.0087 _0.0062 _ _ _PSNR _67.9741 _65.6092 _68.7310 _70.2064 _ _ _MSE 1 _0.0141 _0.0230 _0.0125 _0.0086 _ _ _PSNR 1 _66.6335 _64.5060 _67.1643 _68.8033 _ _Comparison Table Pond Image _ (a) Original 1 (b) Original 2 (c) Original 3 (d) Original 4 (e) Original 5 _Median _Average _Gaussian _Wiener _ _Image 1 _MSE _0.0071 _0.0267 _0.0071 _0.0057 _ _ _PSNR _69.6156 _63.8625 _69.6193 _70.5647 _ _ _MSE 1 _0.0151 _0.0374 _0.0148 _0.0116 _ _ _PSNR 1 _66.3488 _62.4067 _66.4381 _69.5

_ _Image 2 _MSE _0.0049 _0.0118 _0.0049 _0.0037 _ _ _PSNR _71.1950 _67.4075 _71.1985 _72.4594 _ _ _MSE 1 _0.009 _0.0161 _0.087 _0.0066 _ _ _PSNR 1 _68.5651 _66.0539 _68.7473 _69.9595 _ _Image 3 _MSE _0.0063 _0.0136 _0.0059 _0.0045 _ _ _PSNR _70.1294 _66.7905 _70.4278 _71.5971 _ _ _MSE 1 _0.0103 _0.0181 _0.0095 _0.0071 _ _ _PSNR 1 _68.0057 _65.5457 _68.3309 _69.5910 _ _Image 4 _MSE _0.0044 _0.0103 _0.0045 _0.0034 _ _ _PSNR _71.7345 _67.9993 _71.5601 _72.7996 _ _ _MSE 1 _0.0085 _0.0148 _0.0082 _0.0062 _ _ _PSNR 1 _68.8176 _66.4207 _68.9979 _70.1919 _ _Image 5 _MSE _0.0076 _0.0149 _0.0065 _0.0044 _ _ _PSNR _69.3244 _66.4011 _70.0243 _71.7026 _ _ _MSE 1 _0.0111 _0.0191 _0.0098 _0.0068 _ _ _PSNR 1 _67.6856 _65.3228 _68.2256 _69.7923 _ _Comparison Table Normally paper in the chapter 2 as we see, they usually use PSNR or MSE to quality comparison of image after denoise.

But in this report, we used 2 methods to obtain best result and showed best noise removal method. With 4 images class, value comparison by MSE and PSNR.Moreover, we used MSE 1 and PSNR 1 to evaluate 4 method which remove noise in this report. MSE 1 and PSNR1 were created by image add gaussian noise and original. According comparison table, MSE 1 is bigger than MSE and PSNR 1 is smaller than PSNR .

From this, we conclusion 4 method to remove noise is correct We have best of results Gaussian filter with MSE is minimum mean square error and it is maximum PSNR. Chapter 5 Conclusion Problematic of internship is images noise and denoise. Because all of image noise will be the main cause of image degradation. Denoise solution is very popular to remove noise. In this report we propose main method : median filter, average filter, gaussian filter and wiener filter.

MSE and PSNR are 2 quality evaluation method for image when image was remove noise. With values of comparison table, we obtain gaussian filter is the best method. In the future, we will research and improve new methods to solve noise problems in better images.

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Priya Image Enhancement with Noise Reduction in Spatial Domain DIGITAL CAMERA IMAGE NOISE - PART 1 http://www.cambridgeincolour.com/tutorials/image-noise.htm The Wiener filter http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/VELDHUIZEN/node15.html

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