Fast Noise Level Estimation from a Single Image Degraded with Gaussian Noise

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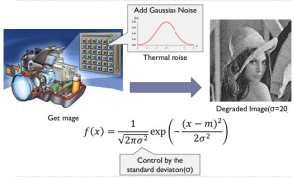
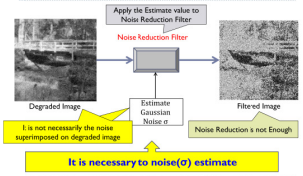
Background : Gaussian Noise



$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(x-m)^2}{2\sigma^2}\right)$$

Control by the standard deviation(σ)

Noise Reduction Filter and Noise Estimation

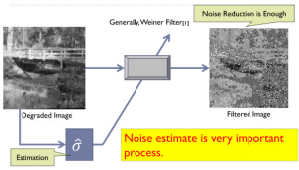


It is not necessarily the noise superimposed on degraded image

Noise Reduction is not Enough

It is necessary to noise(σ) estimate

Wiener Filter



[1] S. Miura, H. Tsuji, T. Kimura, "Enhanced Wiener Filter by fuzzy Rule," IEICE Trans. Fundamentals (Japanese Edition), Vol.J96-A, No.5, pp.283-287, 2013.

Two conventional method

- PCA(Principal Component Analysis) based method [2]
  - It is a good result Gaussian noise's estimate.
    - the error of about 4%
  - It needs many computing time for iteration process.
    - about 0.4 seconds in 256×256 grayscale images
    - 10 times
- MAD(Median Absolute Deviation) based method [3]
  - It is not good estimate to image with many edges and details.
    - the error of about 20%
  - It is little computing time.
    - about 0.03 seconds in 256×256 grayscale images

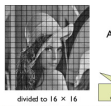
Intel(R) Core(TM)2 Duo CPU E7400 @2.80GHz

[2] Xinhao Liu, Masayuki Tanaka, Masatoshi Okutomi, "Single-Image Noise Level Estimation for Blind Denoising, "IEEE TRANSACTIONS ON IMAGE PROCESSING, Vol.22, No.12,(2013).
[3] S. Miura, H. Tsuji, T. Kimura, S. Tokorozawa, "Gaussian Noise Removal Using TV Filter with Adaptive Parameter Adjustment," IEICE Trans. Fundamentals (Japanese Edition), Vol.J94-A, No.1, pp.37-40, 2011.

Conventional : MAD based method

equation of estimation standard deviation for Gaussian noise

$$\hat{\sigma} = 1483 \cdot med\{|x(n) - med(x(n))|\}_{n\in}$$



Apply the equation to each block.

divided to 16 × 16

estimation standard deviation from flat area.

[4] M. Munegawa, A. Taguchi, Non-Linear Digital Signal Processing, Asakura Publishing Press, 1999. (Japanese)

Conventional : MAD based method

$$\hat{\sigma} = \frac{1}{M}\sum_{i=1}^{M} a_x(B_i)_{in}$$

M: 5% of the total sub-blocks.
$a_x(B_i)$: sub-blocks are sorted in ascending order.

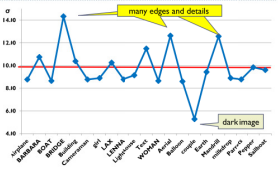
select sub-block of 5% from mininum value of standard deviation.
And, Calculate the average from the selected block.

selected sub-block(5% selected)

It is possible to estimate the standard deviation.

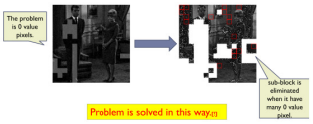
[5] S. Miura, H. Tsuji, T. Kimura, S. Tokorozawa, "Gaussian Noise Removal Using TV Filter with Adaptive Parameter Adjustment," IEICE Trans. Fundamentals (Japanese Edition), Vol.J94-A, No.1, pp.37-40,2011.

Conventional : Result of MAD based method(σ=10)



Problem 1

- the estimate result of the image "couple" is small estimate value.

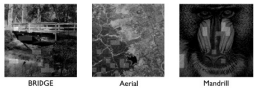


Problem is solved in this way.[5]

[5] T. Suzuki, H. Tsuji, T. Kimura, "An Estimate Method of Standard Deviation for Gaussian Noise in Dark Images," IEICE Gen. Conf. '2014, Fundamentals, pp261, 2014.

Problem 2

- MAD based method calculated high estimate value in "BRIDGE", "Aerial" and "Mandrill".
- These images have many edges and details.



Not good estimation accuracy by image type.

Proposed method

- The proposed method to correct the conventional method's estimated value.
- Correction factor is controlled by image quality.

We proposed estimation method that it estimate the standard deviation for all σ.

Proposed : Application of the Correction Factor

- The proposed method to correct the conventional method's estimated value.

correction

$$\hat{\sigma}^* = \alpha \cdot \frac{\sum_{i=0}^{N} 1.483 * med(|B_i - med(B_i)|)}{N}$$ [4]

Noise level estimation by using conventional method

N: N is number of sub-blocks of $n \times n$. α: correction factor B: region of $n \times n$

[4] T. Suzuki, H. Tsuji, A. Taguchi, T. Kimura, "A Correction method of standard deviation estimation for Gaussian noise," IEICE Technical Report, Vol.113 No.343 SIS2013-54, pp.149-152, 2013.

Proposed : Control of the α

- Correction factor α is controlled by image quality parameter.

$$\alpha = a_1 m + a_0$$

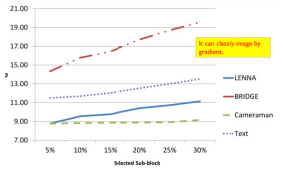
m: image quality parameter(gradient) a_0, a_1: the parameter is dependent on the Gaussian noise in image

Proposed : Calculation of image quality parameter

$$m = \frac{\sigma_{30} - \sigma_5}{0.3 - 0.05}$$

m: image quality parameter(gradient)
σ_x: average value of x% from minimum value of standard deviation.

Proposed : The gradient of 4 type images (σ=10)



Proposed : Calculation of a_i

$\alpha = a_1 m + a_0$ — a_1, a_0 are controlled by Gaussian noise

$a_i = b_{i1}\hat{\sigma} + b_{i0} \quad (i = 0,1)$

Estimation standard deviation by using conventional method. And, calculation of a_1, a_0

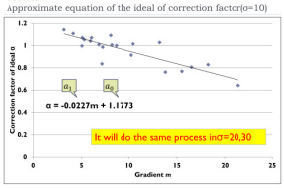
$\hat{\sigma}$: estimate value by conventional method
b_{i0}, b_{i1}: the parameter is calculated experimentally

Results : Derivation of the Correction Factors

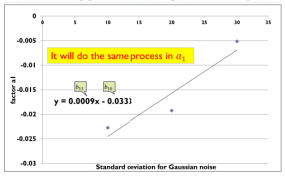
- The four factors are calculated experimentally by using 21 Gaussian noise images(σ=10, 20, 30).
- The ideal correction factor α is calculated from these images by using the estimation value $\hat{\sigma}$.
- The ideal correction factor α and the image quality parameter m are calculated from 21 images by the approximation formula of linear expression.

Results : 21 type standard images

Results : Approximate equation of the ideal of correction factor(σ=10)



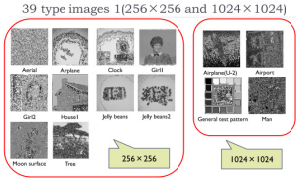
Results : Approximate equation of a_1



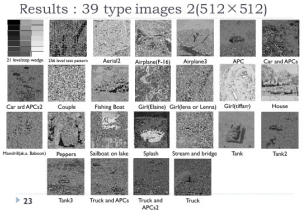
Results : Comparison of the Proposed Method and the Conventional Method

- We compare the conventional method and the proposed method by using the Gaussian noise images (σ=5,10,20,30).
- Gaussian noise images are 39 type images of different sizes.
- Gaussian noise images are 8 bit grayscale images.

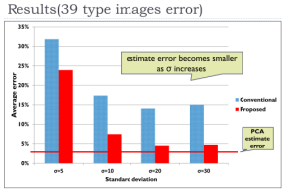
Results : 39 type images 1(256×256 and 1024×1024)



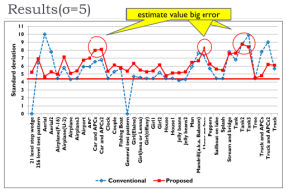
Results : 39 type images 2(512×512)



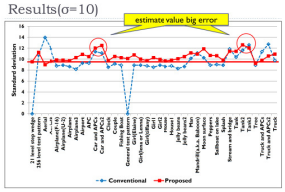
Results(39 type images error)



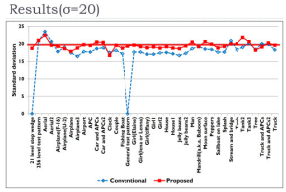
Results(σ=5)



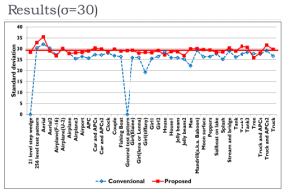
Results(σ=10)



Results(σ=20)



Results(σ=30)



Conclusion

- We proposed new algorithm to estimate the standard deviation for Gaussian noise from the degraded images by Gaussian noise.
- The proposed method corrected the estimation value to estimate the noise level based on the image quality.
- Reduction of estimation result was able to do reduce 10 % .

Future tasks

- The future direction of this study will be improvement in accuracy of the estimate error of the small Gaussian noise images (σ=5).

References

- [1] S. Miura, H. Tsuji, T. Kimura, "Enhanced Wiener Filter by Fuzzy Rule," IEICI Trans. Fundamentals (Japanese Edition), Vol.J96-A, No.5, pp.283-287, 2013.
- [2] Xinhao Liu, Masayuki Tanaka, Masatoshi Okutomi, "Single-Image Noise Level Estimation for Blind Denoising, "IEEE TRANSACTIONS ON IMAGE PROCESSING, Vol.22, No.12, (2013).
- [3] S. Miura, H. Tsuji, T. Kimura, S. Tokorozawa, "Gaussian Noise Removal Using TV Filter with Adaptive Parameter Adjustment," IEICE Trans. Fundamentals (Japanese Edition), Vol.J94-A, No.1, pp.37-40, 2011.
- [4] M. Munegawa, A. Taguchi, Non-Linear Digital Signal Processing, Asakura Publishing Press, 1999. (Japanese)
- [5] T. Suzuki, H. Tsuji, T. Kimura, "An Estimate Method of Standard Deviation for Gaussian Noise in Dark Images," IEICE Gen. Conf. '2014, Fundamentals, pp261, 2014.
- [6] T. Suzuki, H. Tsuji, A. Taguchi, T. Kimura, "A Correction method of standard deviation estimation for Gaussian noise," IEICE Technical Report, Vol.113 No.343 SIS2013-54, pp.149-152, 2013.