Abstract- In digital image processing, the necessity for a sharp and clean image has been gradually increased. Accordingly, the demand of the technology to effectively remove the noise from the noisy image has also been increased. It is important to remove the degradation factors of the image and improve the quality close to the original image. In this paper, we propose the method using direction which uses a novel Gaussian weight value, and we adjust the intensity Gaussian weight to remove the noise in flat region. In conclusion, the experimental results show that the proposed method can preserve the edge components of the image and remove the noise.

Index Terms- De-noising, Bilateral filtering, Detection direction, Novel Gaussian weight.

I. INTRODUCTION

In recent years, high-quality display devices such as, UHD-TV, smart phone, and tablet PC are widely used in everyday life such as digital television, and mobile phone. Watching the deteriorated image can cause discomfort to users, so noise in the image should be removed. Noise can be generated on various occasions; when analog signal is converted to digital signal, and image is transmitted. Among various noise models, we deal with additive white Gaussian noise (AWGN) in this paper. AWGN has the following characteristics: it has a normal distribution in the time domain, it has uniform power in the frequency domain, and it is added to the original signal. The image containing a white Gaussian noise is defined by the equation (1) as follows:

\[ e(m, n) = f(m, n) + n(m, n) \]  

where \( m \) and \( n \) mean the horizontal and vertical size of image, respectively. \( e(m, n) \) is an image including white Gaussian noise, \( f(m, n) \) is the original image, and \( n(m, n) \) is a white Gaussian noise. The intensity of the noise is defined by standard deviation value of the normal Gaussian distribution.

In order to remove the AWGN, many methods are studied [1]-[9]. Among these, the bilateral filter is effective and has a great performance. Bilateral filter[1] is a nonlinear filter to remove noise during preserving the edges of the image. It eliminates the noises using two weights; one related to distance and the other related to pixel intensity. However, the weights of the user parameters must always be set when we use the bilateral filter. In addition, depending on the intensity of noise, excessive blurring or remarkable phenomenon of noise can be represented.

In order to remove noise effectively, there are methods of using the wavelet transform with bilateral filter[2], [3]. These methods divide several sub-band images through wavelet transform. For each such sub-band images, bilateral filter or wavelet thresholding is performed. In this paper, we propose the noise reduction method to supplement the above mentioned drawbacks. The proposed method is composed of two steps. First, a novel Gaussian weight in bilateral filter is added by considering the four edge directions: \( \angle 0, \angle 45, \angle 90, \angle 135 \). Second, the intensity Gaussian weight is increased to remove the noise in flat region that is undirected or non-complex. By using these two methods, we remove the noise and preserve the edge effectively.

II. PROPOSED METHOD

Figure1 shows the overall flowchart of the proposed de-noising method. First, each block is determined whether it has a direction in 8x8 size; this method is explained in section A. If the current block is determined as directional block, we apply the bilateral filter by using novel Gaussian weight considering the direction. This method is described in section B. Next, blocks without directivity are determined if it is a flat regions or not; this method is explained in section C. Finally, we apply the conventional bilateral filter [1] in the non-flat and directionless region.

A. Detection of direction

As shown in Figure 2, the each block is determined using sum of absolute differences (SAD) about four directions, i.e. horizontal, vertical, diagonal up, and diagonal down, but minimum SAD does not assure its direction. In order to increase the reliability of detection, we compare each SAD values like equation (2):

\[ \frac{SAD(1)}{SAD(2)} < T \]


where SAD(1) means the smallest SAD value, SAD(2) is the second smallest SAD value, and threshold value is represented as $T$. If the ratio of SAD(1) and SAD(2) is smaller than $T$, this region is determined as directional area. Otherwise, we decide it as non-directional area. Based on the intensity of the noise, threshold value is determined using regression analysis; Least Mean Squares (LMS) method [10] is used as regression analysis, and the equation is simplified. Figure 3 shows the threshold values in accordance with the noise variance.

**B. Novel Gaussian weight**

In the image, existing bilateral filter preserves the edge by removing the noise. Bilateral filter removes the noise using the two weights those are distance and intensity values. The equation of bilateral filter is defined as (3):

$$f'(x) = \frac{1}{k(x)} \sum_{y \in N(x)} f(y) c(y, x)s(f(y), f(x))$$  \hspace{1cm} (3)

where $X$ is the position of the current pixel for removing the noise, $N(x)$ is the region about neighboring pixels of the current processing pixel $x$, $y$ is located within the $N(x)$, and $k(x)$ is a normalizing factor. Normalizing factor is defined as equation (4):

$$k(x) = \sum_{y \in N(x)} c(y, x)s(f(y), f(x))$$  \hspace{1cm} (4)

In equation (5) and (6):

$$c(y, x) = e^{-\frac{(y-x)^2}{2\sigma^2}}$$  \hspace{1cm} (5)

$$s(f(y), f(x)) = e^{-\frac{(f(y)-f(x))^2}{2\sigma^2}}$$  \hspace{1cm} (6)
where \( c(y, x) \) is a weight value corresponding to the distance between current pixel and neighboring pixels within the \( N(x) \), and \( s(f(y), f(x)) \) is a weight value corresponding to the intensity between current pixel and neighboring pixels within the \( N(x) \). \( \sigma_d \) is the parameter for the distance and \( \sigma_v \) is the parameter for the intensity values. We determine the intensity of filter by using these factors.

A new weight is proposed for the conventional bilateral filter to consider local characteristic. This weight is a novel Gaussian weight and defined as follows:

\[
\hat{f}(x) = \frac{1}{k(x)} \sum_{y \in N(x)} c(y, x)s(f(y), f(x))d(y, x)
\]

\[
k(x) = \sum_{y \in N(x)} c(y, x)s(f(y), f(x))d(y, x)
\]

\[
d(y, x) = 20e^{-\log_{10} \sigma_v}
\]

where \( d(y, x) \) is a new weight for directional area. This weight is obtained through the experimental results as shown in Figure 4. \( \sigma_v \) is a parameter value about direction at pixel location, and it is determined by according to the accuracy of the direction. In order to set the value of \( d(y, x) \), as shown in Figure 5, we divide the region according to the direction that is determined in the region of SAD(1). Even in the region that has direction, intensities of pixels can be greatly different for each divided region. \( \sigma_v \) set a variance value for each divided area by the direction as shown by Figure 5.

**C. Flat region decision**

In the flat region, we increase the intensity weight of existing bilateral filter because information of the edge is relatively small. Flat regions are determined by the each value of SAD as following equation (10):

\[
\frac{SAD(1)}{SAD(4)} > T
\]

If the value, i.e. \( SAD(1) \) is divided by \( SAD(4) \), is larger than threshold \( T \), this region is determined as the flat region. We increase \( \sigma_v \) value of bilateral filter by up to 50% in flat region. For the remaining regions except A, B, and C sections, conventional bilateral filtering is used.

### III. EXPERIMENTAL RESULTS

In this paper, proposed method is compared with other methods through Peak Signal-to-Noise Ratio (PSNR). It is defined as equation (11):

\[
PSNR = 20 \log_{10} \frac{MAX}{\sqrt{MSE}}
\]

where \( MAX \) means the maximum value of pixel, \( MSE \) is the mean squared error, \( I(i, j) \) and \( K(i, j) \) represent input image and de-noised image, respectively.

We set the variance of the AWGN as 10, 20, 30, and 40 for the objective evaluation. Actually, the parameter of intensity Gaussian weight should be changed according to the noise. This parameter set the value obtained by twice the noise variance. High definition (HD) test sequences, which include Kimono(178th), ParkScene(1th), Cactus(172th), and BQTerrace(235th) are used for the experiment.

In Figure 6, white points are influenced by the proposed novel Gaussian weight at position that has a respective directionality.

Table 1 shows PSNR results about conventional bilateral filter, reference methods [2], [3], and proposed method. In most of the sequence, PSNR values of proposed method are higher than the other methods. As shown in Figure 7, edge regions are blurred excessively in (c) and (e), and there remains still a lot of noise in (d).

In conclusion, proposed method can prevent blurring artifacts at edge regions and reduce noise effectively at flat regions compared with the reference method.
CONCLUSION

Digital images are likely to have various noise, and it is hard to reduce the noise similarly with original image. When bilateral filter removes the noise, it appears blurring phenomenon. In order to solve this problem, we proposed the new bilateral filtering method using novel Gaussian weight based on the edge directions. As a result, our proposed method shows more clear images because it reduces noise while preserving edges and removes noise strongly at flat regions compared with other de-noising methods.

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REFERENCES

Table 1
PSNR of experimental results

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AWGN variance: 20, σr: 40

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AWGN variance: 30, σr: 60

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AWGN variance: 40, σr: 80

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Figure 7: Result of prevention about blurred edge

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