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International Journal of Innovative Research in Technology, Science and Engineering (IJIRTSE)
Volume – 1, Issue – 1. March 2015

Bilater Filter Design For Image Denoising

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***Abstract*—Image processing needs several process to obtain a distortion free and clear image. Here bilateral filter is chosen mainly for preserving the details of the image and to reduce the noise. It is completely based on kernel processing due to changing the clock domain. This provides the processing of entire filter window at one pixel clock cycle, which is composed of global clock and local internal clock. Due to processing the image as set of group, it provides separability and symmetry during processing. By the use of separability and symmetry it made the design to be less complex. On combining these features it is possible to achieve a highly parallelized pipeline structure with the proper utilization of resources. Due to the filter design's modularity, different kernel sizes can be processed. The output image quality is based on the filter parameters which are chosen for processing. The quantization of filter coefficients provides higher detail preservation rate.**

***Keywords*—Image denoising, bilateral filter, image processing, normalization, PSNR.**

I. INTRODUCTION

Bilateral filter is widely used in image processing for its effective reduction of noise. This filter offers detail preservation while removing the noise in image. Bilateral filter consists of three main sub blocks namely Register matrix, Photometric filter and Geometric filter. These three sub-blocks operates in a different way. The photometric filter is an nonlinear filter which selects the pixels of similar intensity and calculates it. Thus it performs an operation of low-pass filter. This noise reduction and detail preserving can be adjusted by two parameters. Bilateral filter also proven that it sharpens the edges [2]. Also the Adaptive bilateral filter used for the low bit rate video coding [4]. This filter concept is used for local tone mapping for noise reduction. The bilateral filter which is applied for reconstruction of images gives much result [6]. Thereby here the image is entered into first block as a noisy image and comes out as a noise free image. These pixels are sorted as a image rows and stored in RAM memory. This pre storage enhances the reduced latency during processing and there is no need of external image buffering. Here the power is reduced by using the global clock and also local internal clock. The processing of an entire filter window is possible in a single pixel clock cycle. The modularity of the filter enhances the processing of all window sizes of the image. The overall process gets completed in one pixel clock cycle. Thereby each blocks operates in a allotted clock cycles. The reconstruction of the image is done by normalization. The overall process achieves proper synchronization.

The three functional block of bilateral filter is depicted in figure 1.

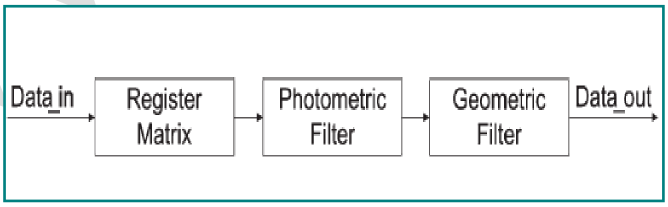

Fig 1. Functional blocks of bilateral filter

A. Bilateral filter

Bilateral filter is a nonlinear, Edge preserving, smoothing filter for image. It is a non iterative scheme for edge preserved smoothing. It used to reduce the noise while preserving the details at the edges. It is composed of three main components. Initially the images get into the register matrix and send to the photometric filter. Later it gets processed into the geometric filter. Finally the resulting image is normalized to retain the original image. The advantages of using the bilateral filter is

1) Effective removal of noise
2) Internal clock frequency is raised according to the data flow
3) External image buffering is not required
4) Reduced usage of power
5) Reduced latency
6) Less complex design

Based on the design, the complexity of the filter is much reduced and it provides a proper usage of resource utilization. Thus the image quality is completely depends on the chosen filter parameters.

II. COMPONENTS

There are three components in bilateral filter which process the data consequently. These components process the data in different manner. The data_in represents the input noisy image. The noisy image flows into these blocks and produces the noise free image data_out.

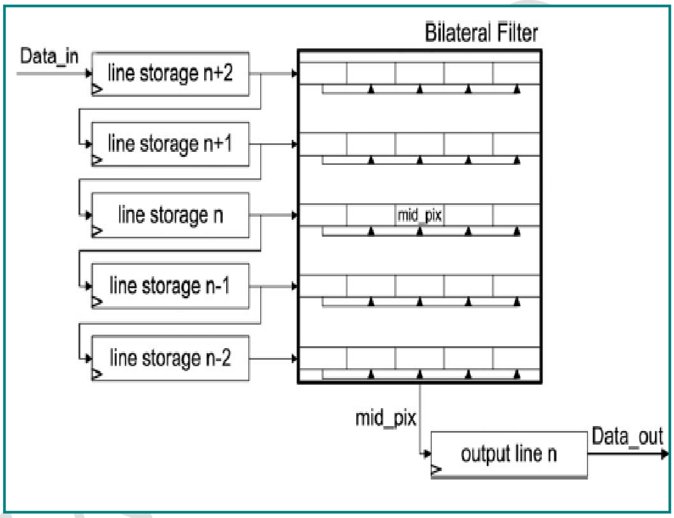

Fig 2. Input data retrieval

The input data is sorted into groups. These groups contains particular amount of pixels called as image rows. The group that is being processed is mentioned as mid_pix. The image rows are entered into the bilateral filter one by one. In order to reduce the latency during processing these image rows are pre stored in RAM memory for further process. Then it can be processed one by one. The processed data is sent out as a output. Then this output undergoes normalization.

B. Register Matrix

The sorted pixels which are stored in the RAM memory are entered into the register matrix. The time taken for filling the register matrix is completely depends on the filter widow size. There is no need of external image buffering. This reduces the latency while processing the data. To reduce the additional latency during access in memory, five input lines are stored in single line storage. After sorting into groups the image rows are entered into the register matrix. The sorting of pixels are done by using multiplexer. The counter at the top of the register matrix produces the select signal for the operation and controls the output of the register matrix. This counter is clocked by internal clocks. This gets enabled whenever the register matrix is filled up by group of pixels. The pixel that is being filtered is depicted as mid_pix. Once the particular row is filtered it moves out of the register matrix and next row enters and get filtered. Every shifting of pixels is done at each clock event. The pixels are processed in parallel manner. Here the quadruplication of pixel clock cycle is done. The pixel at the center is not a part of any group and it is given to the input stage of photometric filter, Once the row gets processed it comes out of the register matrix and next one is processed. It can be done in one pixel clock cycle. The output of the register matrix is sorted into groups i.e. six groups and fed into photometric filter. The sorting of pixels into groups and quadruplicating of pixel clock are in synchronous.

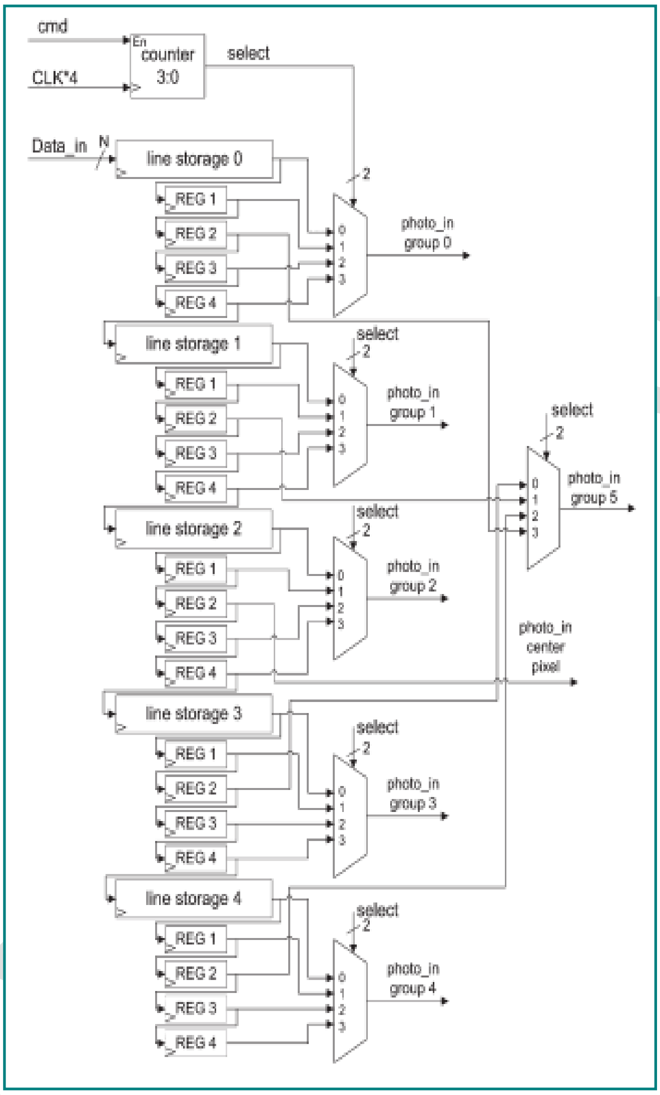

Fig. 3. Design of register matrix

B.Photometric filter

The photometric filter is also referred as Range filter. It is a nonlinear filter. In this the coefficients are changed for every filter position. Here the pixel weights for every pixel in photometric filter have to be calculated. Thus it depends only on the filter window size. After processing in the register matrix the processed data enters into the photometric filter. The photometric filter compares the centered pixel's gray value with the neighborhood pixel and computes the weighted coefficient. Thus it is entirely acts as a low-pass filter.

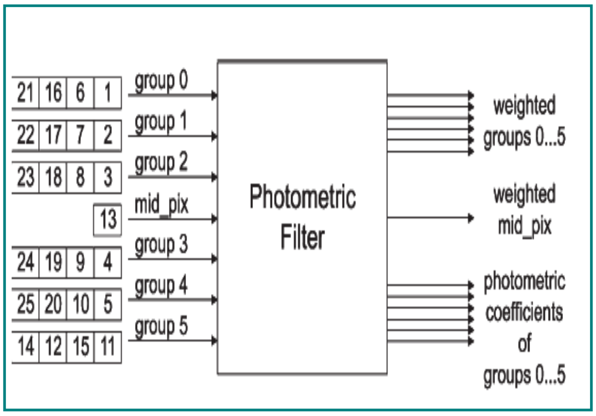

Fig.4. Photometric filter

The output of the photometric filter produces the coefficients for the normalization. The outputs of this filter are still sorted into group. These outputs are normalized by dividing it by normalization factor. Thus the normalization factor is obtained from geometric filter after processing.

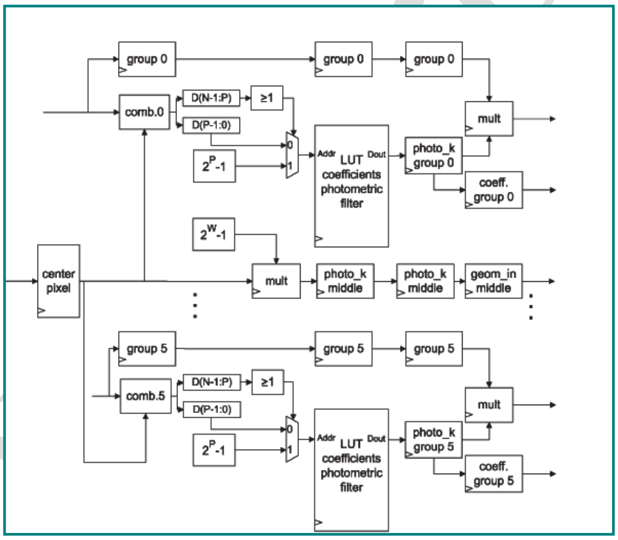

Fig.5. Functional flow of photometric filter

These coefficients are tabulated in LUT. For quantization the numbers of coefficients are limited.

C. Geometric Filter

The feature such as separability and symmetry supports the geometric filter. Here the main advantage is the 1D filtering is achieved. Due to separability the incoming image data are filtered by two components such as vertical component and horizontal component. These two components imply the 1D filtering very efficiently. Here the two components are implemented twice. The input is given as a 2D array of filter window at vertical component and receives output as a 1D vector which is depicted in figure 6. After processing with the two 1D filtering the geometric filter consists of unnormalized values.

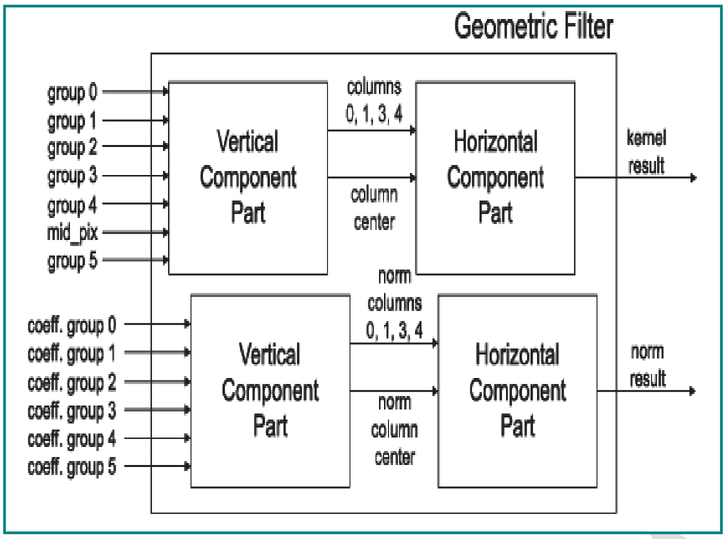

Fig.6. Geometric filter component

Due to the symmetry the pixel order of the multiplication and addition are swapped in both vertical and horizontal parts. Initially the weighted pixels which are located in the same distance from the centered pixel are added. The geometric filter coefficients are calculated in a manner that the sums of coefficient of both components are equal to the normalized one.

These coefficients can be calculated in advance and stored in RAM. Initially smaller groups are allowed for better process. These are sorted into four groups for subsequent processing. Then these pixels are arranged according to their symmetry and multiplied with the coefficient correspondingly. Similarly the horizontal filtering is done. Finally the geometric filter coefficients are calculated as the sum of vertical coefficient and horizontal coefficient which is equal to the normalized one.

After processing in the vertical part the filter window is converted into one row by computing with a single internal clock event. Then it is processed by the horizontal part of the geometric filter as shown in figure 7. Every valid column values are stored in a registers to perform normalization.

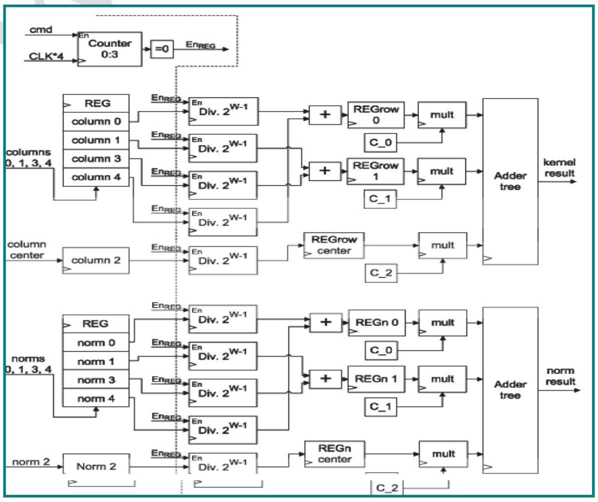

Fig.7. Horizontal component

D. Normalization

Normalization is nothing but a getting back the original details of the image after removal of noise. The values obtained after processing through geometric filter are not normalized. There are two results obtained from the geometric filter. In normalization block the kernel result and norm result are normalized by dividing these results using normalization factor. The weighted gray values and norm values are divided. This process is done in order to retain the image details. The division process is done through a shift operation. Finally after division process the result is forwarded as the output of the bilateral filter.

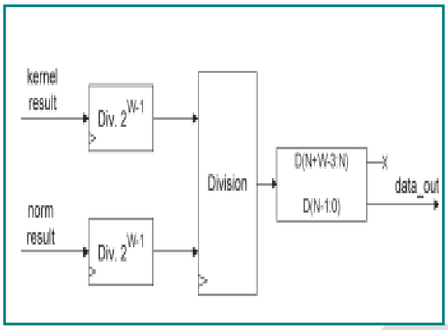

Fig.8. Normalization block

III. IMAGE QUALITY ASSESSMENT

It is necessary to measure the amount of noise reduced and accuracy of detail preserved after filtering. This can be measured by using PSNR AND MSSIM.

$$PSNR = 20.\log 10\ (GV\ max/\sqrt{MSE}) \quad (1)$$

PSNR is an peak signal to noise ratio. It is an ratio between possible value of signal and the distorting noise that effects the quality of its representation. It is measured in decibel. It also measures the quality of reconstruction of lossy compression.

The MSSIM is mean structural index is a method for measuring the quality of the image. It compares the luminance of the pixels. It performs the luminance subtraction after contrast normalization.

$$MSSIM = 1/J \sum_{j=1}^{j} SSIM\ (Vj(\phi ref), V(\phi)) \quad (2)$$

If the value of MSSIM is 1 it means that the two images are identical. This could be easier to find the error pixels. Here the image quality assessment using PSNR and MSSIM shows that the image quality loss is due to coefficient quantization and rounding of internal results in blocks.

IV. SIMULATION RESULT

The result of the function of three functional blocks of bilateral filter could be simulated by using Modelsim. As shown in the figure 9 register matrix the pixels are sorted into groups and then processed separately. Here the RAM represents that memory in which the pixels are sorted and stored. Later the corresponding coefficients are calculated.

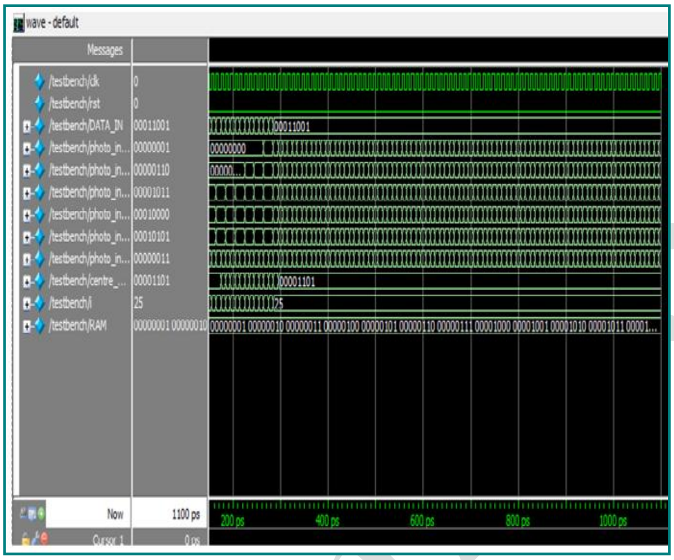

Fig.9. Order of pixels in register matrix

Finally the output of the register matrix which are in groups are sent to the photometric filter .the output of the photometric filter are given below.

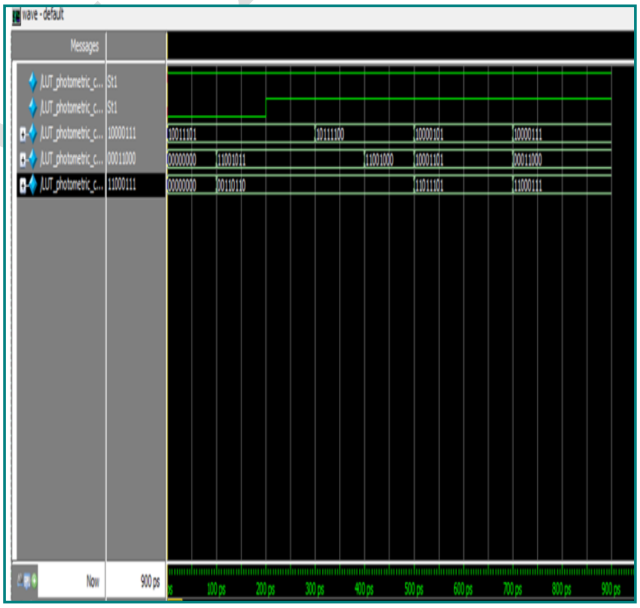

Fig.10. Photometric filter output

The photometric filter output shown in figure 10 represents the coefficients of the processed pixels which is stored in a LUT. These coefficients are further used in geometric filter and normalization.

V. CONCLUSION

In this paper the bilateral filtering technique is used for the removal of noise and to preserve the details. This filtering contributes the effective resource utilization, less power consumption and reduced latency during processing. The clocking strategy performs much efficiently. It also provides processing of all window sizes. The additional contribution of this paper is effective eight direction edge detecting by preserving much details and removing of all type of noise present in the image with less power consumption and reduced latency. At last the original image without any noise is obtained with the help of normalization.

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