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FPGA IMPLEMENTATION OF MODIFIED BILATERAL FILTER FOR GAUSSIAN NOISE REMOVAL

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***Abstract*-The real time image processing plays a vital role in many fields such as security system, robotics and in medical images using the techniques like pattern matching, image reconfiguration and denoising . Image denoising is a significant method to retrieve the quality image .This process is done using appropriate filter. Bilateral filter is chosen for the unique characteristics of preserving the edge while reducing the noise and for improving the efficiency the modified edge preserving filter is inbuilt in the system. Here the bilateral filter is realized using the highly synchronized FPGA design. Kernel based design is sustained by means of arranging the input data into groups. Kernel of different size can be implemented. Hardware acceleration can be performed using parallelized and pipelined architecture .The separable and symmetric design of the geometric filter reduces the design complexity. The efficiency of the result is based upon the selection of filter parameter and the convolution mask provided. The quality image can be obtained by reducing the compression artifacts.**

Keywords- Bilateral filter, denoising, kernel, filed-programmable gate array.

I.INTRODUCTION

Filtering is perhaps the most fundamental operation of image processing and computer vision. In the broadest sense of the term "filtering", the value of the filtered image at a given location is a function of the values of the input image in a small neighbourhood of the same location. For example, Gaussian low-pass filtering computes a weighted average of pixel values in the neighbourhood, in which the weights decrease with distance from the neighbourhood centre. Although formal and quantitative explanations of this weight fall-off can be given, the intuition is that images typically vary slowly over space, so near pixels are likely to have similar values, and it is therefore appropriate to average them together. The noise values that corrupt these nearby pixels are mutually less correlated than the signal values, so noise is averaged away while signal is preserved. The assumption of slow spatial variations fails at edges, which are consequently blurred by linear low-pass filtering. Non-linear filters may also be useful when certain "nonlinear" features of the signal are more important than the overall information contents. In digital image processing, for example, one may wish to preserve the sharpness of silhouette edges of objects in photographs, or the connectivity of lines in scanned drawings. A linear noise-removal filter will usually blur those features; a non-linear filter may give more satisfactory results(even if the blurry image may be more "correct" in the information-theoretic sense). Many nonlinear noise-removal filters operate in the time domain. They typically examine the input digital signal within a finite window surrounding each sample, and use some statistical inference model (implicitly or explicitly) to estimate the most likely value for the original signal at that point.To overcome this defect, the bilateral filter is used. Bilateral filtering is a simple, non-iterative scheme for edge-preserving smoothing. The basic idea underlying bilateral filtering is to do in the range of an image what traditional filters do in its domain. Two pixels can be close to one another, that is, occupy nearby spatial location, or they can be similar to one another, that is, have nearby values, possibly in a perceptually meaningful fashion. Combined domain and range filtering will be denoted as bilateral filtering. . In smooth regions, pixel values in a small neighbourhood are similar to each other, and the bilateral filter acts essentially as a standard domain filter, averaging away the small, weakly correlated differences between pixel values caused by noise. The author of [14] is the first to introduce the bilateral filtering which enhance CIE-Lab colour space while smoothing and preserving the edges. Low pass filtering computes the weighted average of the pixel value with the neighbourhood pixel values. Before the bilateral filtering , anisotrophic diffusion method (perona malik diffusion) is used for denoising which does not preserve the edges. The edge consists of bright pixel and dark pixel sides which assumes of the value close to one and zero. When the filter is centered on the bright pixel side the dark side is ignored, the same is followed vice versa in the dark side i.e the bright side is ignored, thus the edges are preserved. Range filtering alone is not useful, because it does only local remapping. Therefore when it is combined with the domain filtering, it provides useful output. Combination of both is called bilateral filtering. The author of [18] shows that the adaptive bilateral filtering provide better result than the previous technique such as unsharp mask and optimal unsharp mask. The unsharp mask is a linear sharpening technique which uses the blurred image to create mask.

The blurred (negative image) combined along with the original (positive image) provide the resultant output which is less blurry than the original image. The optimal unsharp mask sharpens the image but provide artifacts. To overcome this defects the adaptive bilateral filter technique is used ,which adjusts the offset and width of the range filter such that the slope is restored. This is a training based approach. Thus the appropriate output is obtained.

II. BILATERAL FILTER

In real time image processing noise suppression is an important operation. Noise can be supressed by means of filtering but detail preservation play an important role in many applications. The bilateral filter has unique property of noise reduction while preserving the structural information of an image . Christo Ananth et al. [12] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of "ground-truth" reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

The bilateral filter is known to be related to robust estimation. The coordinates of the pixel for the image to be filtered is (m,n). The centred pixel of noisy image is (m_0,n_0) and filtered image is $(\overline{m}_0,\overline{n}_0)$. The range filter which performs edge preservation act as the photometric component, it is denoted as $s(\emptyset(m_0),\emptyset(m))$. The domain filter which performs denoising act as the geometric component , it act as the low pass filter and denoted as $c(m_0,m)$.

$$\bar{\emptyset}(\bar{m_o}) = \frac{1}{k(m_o)} \sum_{m \in F} \emptyset(m).\, s\big(\emptyset(m_o), \emptyset(m)\big).\, c(m_o,m)$$

$$c(m_o,m) = \exp\left(-\frac{1}{2}\left(\frac{||m_o - m||}{\sigma_c}\right)^2\right)$$

$$s\left(\phi(\mathrm{m}_0), \phi(\mathrm{m})\right) = \exp\left(-\frac{1}{2}\left(\frac{\|\phi(\mathrm{m}_0) - \phi(\mathrm{m})\|}{\sigma_{\mathrm{ph}}}\right)^2\right)$$

III. EXISTING SYSTEM

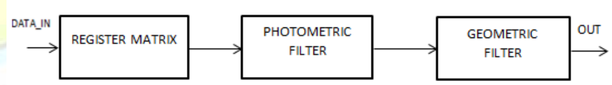

Fig 3.1 Overall design flow of the existing system with separable filter

3.1 REGISTER MATRIX

The registers are responsible for the storing the pixel data. The architecture used for pixel data storage is called as register matrix. 25 pixels are arranged in the 5x5 matrix which is needed to be processed as the filter mask. Each pixel value is available for parallel computation. The pixel data are shifted at each clock cycle. So they are available at the appropriate position filter calculation. The described register matrix implements the first part of the optimised parallel architecture. The pixel data of complete lines are stored to make them available when the next line is needed to be processed.

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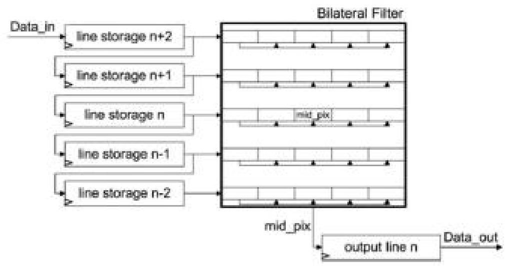

Fig 3.2 Order of the Input data provided to the filter

The register matrix is used as the internal RAM storage block, which is used to store five input lines. The five input lines are called as the image rows which contain the row to be processed, two foregoing rows and two succeeding rows. The pixel being filtered is marked by “mid_pix.” This pixel and its neighbourhood in the solid box represent the kernel of the bilateral filter. The values obtained by the line storage is shifted to the subsequent

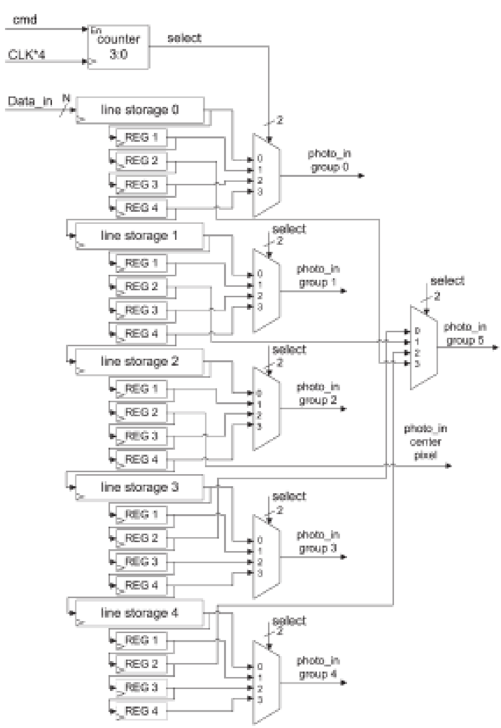

Fig 3.3 Architecture of the kernel based design concept of the register matrix

registers, thus five rows with 25 pixel value is stored .There are five line storage device to store five rows. The groups are obtained by selecting the particular pixel and multiplexing the values. The order of selecting the pixel to form the group is given in fig no.4.4. The quadruplication of the filter processing clock is implemented by setting the select signal of the multiplexers four times in one pixel clock. The N bit data is given as the input(N=8). The centre pixel is processed separately.

3.2 PHOTOMETRIC COMPONENT

A photometric system (filter system) provide coarse spectral information about the source. The photometric filter act as the range filter which helps in edge preservation. The edge preserving is performed in order to avoid the blurring effects in the image. The blurring effect is produced due to the absence of the neighbour values in the boundary, such that the averaging of the nearby pixel value cannot be performed . To avoid this effect and to provide good perceptual view of the images with sharp boundary, the photometric filter is used.

The photometers is used in the field of digital photography. When used in photography, the main task of a photometer is to determine the right amount of exposure. Since light is never even, obtaining an ideal photograph means taking light into account. Photometers that are built into digital cameras measure the amount of light within an area in order to produce the best possible photograph. While photometers are widely used within the field of photography, there are other uses for photometers as well. When a photometer is operated, some spatial restriction is imposed on the radiation flux.

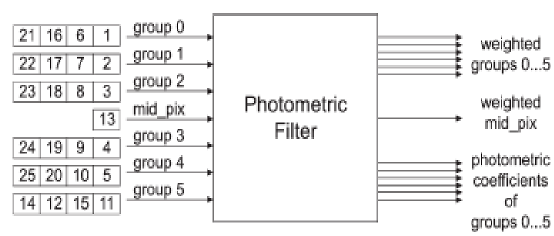

Fig 3.4 Illustration of the photometric component with order of processing

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10	10	10	14	14
10	10	10	14	14
17	17	17	1	1
17	17	17	1	1
21	21	21	16	16

10	10	14	14

10	10	14	14

17	17	1	1

17	17	1	1

21	21	16	16

10	10	17	21

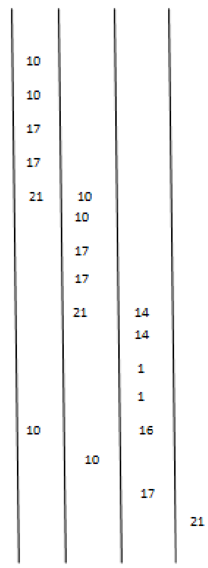

Fig 3.5 Order of processing of the input data in the photometric component

The groups obtained from the register matrix is fed into the photometric filter in order to obtain the weighted values . Additionally the photometric coefficient of the groups are obtained. The nearby pixel values are added to get the weighted average values. . Due to weighted average filtering, we can control the blurring of image. The groups obtained from the register matrix is processed separately and the coefficient of the groups are obtained by the difference value between the centre pixel and the remaining pixel inside the pixel window. Each group contains four pixels. A separate pipeline belonging to each group makes it possible to process the entire neighbourhood of "mid_pix" at one pixel clock signal. All six pipelines are designed identically. In order to keep the design synchronous, the gray values of each pipeline are registered during the difference calculation. So that the parallelized and synchronised design can be obtained. To avoid the calculation of the expensive exponential, all possible values of the function are precalculated and stored in the lookup table (LUT). The absolute difference of the gray values itself is directly interpreted as the address of the corresponding weight coefficient in the LUT. Due to the quantization, the number of the weight coefficients is limited.

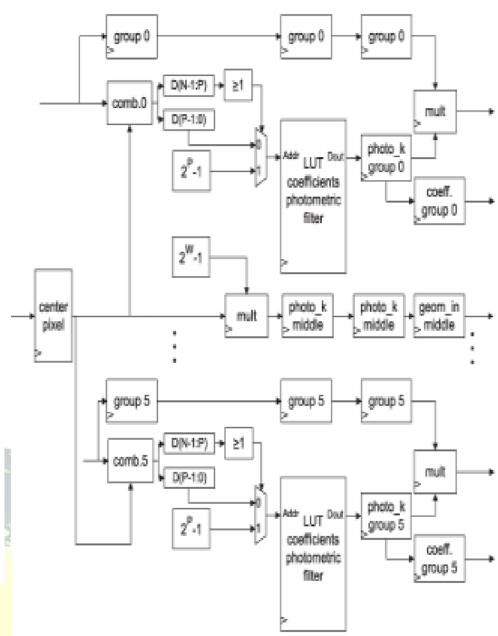

Fig 3.6 Architecture of the Photometric System for edge preservation

3.3 GEOMETRIC COMPONENT

The geometric mean filter is better at removing Gaussian type noise and preserving edge features than the arithmetic mean filter. The geometric mean filter is very susceptible to negative outliers.

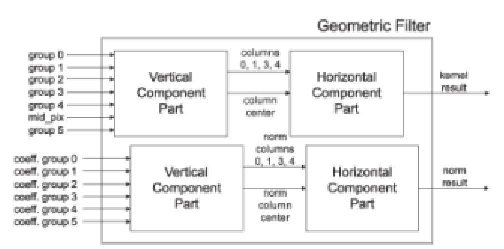

Fig 3.7 Illustration of the Geometric filter component

The 2-D filtering is done by consecutive 1-D filtering in horizontal and vertical direction. This type of design is preferred because 1-D filtering can be implemented more efficiently. The horizontal and vertical parts are implemented twice to evalulate the weighted groups and the photometric coefficients of the groups. The input provided for the vertical component is 2-D and the outputs obtained are said to be 1-D. The output obtained consists of kerel result(unnormalised) and

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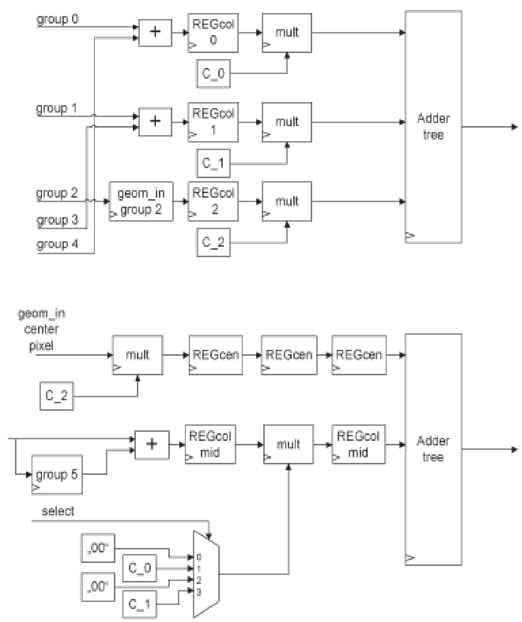

Fig 3.8 Vertical part of geometric component that converts the dimension of filtering

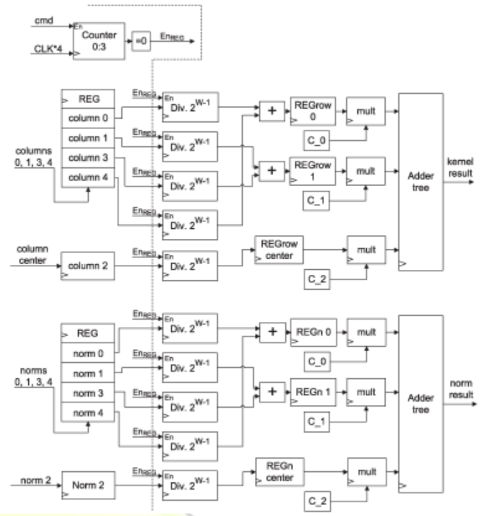

Fig 3.9 Horizontal part of geometric component that performs the domain filtering

coefficients to get the weighted value. The kernel result and the normalised result are obtained.

norm result. The weight coefficients are symmetric in nature , therefore the order of multiplication and addition can be interchanged. The gray values with same distance are added and weighted with the same coefficient .

3.3.1 VERTICAL COMPONENT PART

The groups with similar distance are summed up and multiplied with the photometric coefficient. The REGcol 0,1,2 are the registers used to maintain the synchronicity of the design by means of delaying the weighted groups. The centre pixel is processed separately. After the multiplication, the weighted values are summed up by the adder tree and processed at each internal clock event. The centre pixel and the group 5 are processed in the lower part . The centre pixel is delayed by the REGcen . The processed values are given as input to the adder tree.

3.3.2 HORIZONTAL COMPONENT PART

The horizontal section consists of counter with quadruple pixel clock, which is used to maintain the synchronicity of the design. The groups are converted into columns of single dimension. The divider is used to reduce the number of bits transferred. The registers are used for delaying purpose and are multiplied with the coefficients to get the weighted value. The kernel result and the normalised result are obtained.

3.3.3 NORMALIZATION

At the last stage, the unnormalised result is normalised and divided by the appropriate number of bits to reduce number of bits equivalent to the input data. And the bilateral ouput is onbtained.

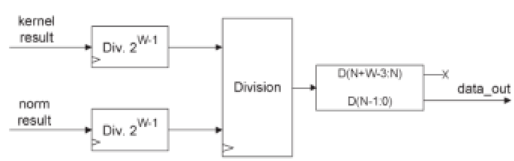

Fig 3.10 Normalisation of the filtered result

Table 3.1 Synthesis result of the amount of utilization of the resources

LOGIC UTILIZATION	USED	AVAILABLE	UTILIZATION
Number of slice flipflop	1.548	13.824	11%
Total number of input LUTs	2.374	13.824	17%
Number of block RAMs	6	72	8%
Total equivalent gate count for design	136.297		

IV. PROPOSED SYSTEM

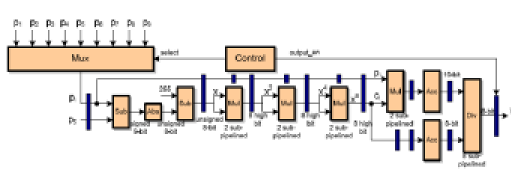

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Fig 4.1 Structure shared architecture for modified edge preserving filter

The modified edge preserving filter is implemented instead photometric filter for better edge preservation. The serial type of processing is designed. The structured architecture is used for less amount of resource utilization. This filter can smooth along edge and thus enhance the details of the images. The intensity of the distance from the centre pixel is determined as

$$d_1=p_1-p_2$$

The convolution mask provide smooth effect along the edges and thus can remove noise while not blurring the edges. The coefficient for the convolution mask of the filter is extracted as

$$c_i=(255-d_i)_p$$

The factor p controls the amount of edge smoothing around the centre pixel.

V.IMAGE QUALITY ASSESSMENT

To evaluate the efficiency of image denoising the PSNR value is calculated.

Peak signal to Noise ratio (PSNR): PSNR is the ratio between maximum possible power of a signal and the power of distorting noise which affects the quality of its representation. It is defined by:

$$PSNR_{db} = 20.log_{10}(\frac{GV_{max}}{\sqrt{MSE}})$$

Table 5.1 PSNR calculation for various level of noise added

Noise level	Original image	Bilateral image	Edge preserved image
10	66.24	67.20	68.93
30	59.27	59.44	59.69
40	57.18	57.22	57.41

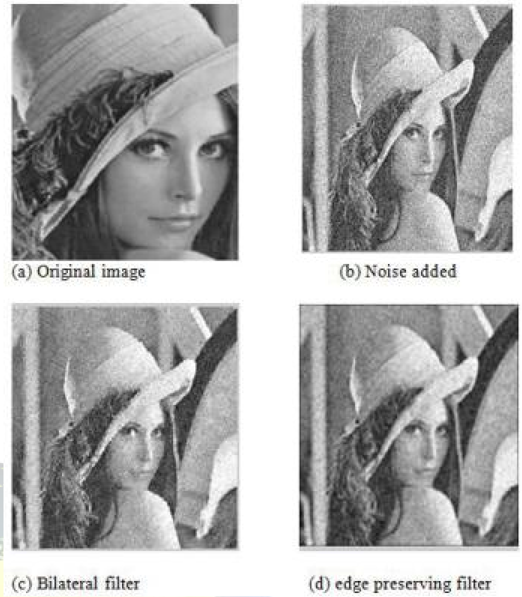

Fig 5.1 Retrieved images using bilateral and edge preserving filter

V. CONCLUSION AND FUTURE WORK

The existing bilateral filter for real-time image processing is implemented using FPGA design. The effective utilization of the dedicated resources is calculated. The PSNR calculation of the image with various noise levels is calculated. The highly structured architecture that is capable of producing better efficient edge preservation is proposed. The filtered image is retrieved and the PSNR calculation for various levels for the proposed system is analysed. The resource utilisation calculation of the proposed system is in realisation process.

REFERENCE

[1] L. Costas, P. Colodrón, J. J. Rodríguez-Andina, J. Fariña, and M.-Y. Chow, “Analysis of two FPGA design methodologies applied to an image processing system,” in Proc. IEEE ISIE, 2010, pp. 3040–3044.

[2] Y. Chen and V. Dinavahi, “Digital hardware emulation of universal machine and universal line models for real-time electromagnetic transient

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ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 1, March 2016

simulation," IEEE Trans. Ind. Electron., vol. 59, no. 2, pp. 1300–1309, Feb. 2012.

[3] C. Charoensak and F. Sattar, "FPGA design of a real-time implementation of dynamic range compression for improving television picture," in Proc. IEEE ICICS, 2007, pp. 1–5.

[4] M. de-Frutos-López, H. Medina-Chanca, S. Sanz-Rodríguez, C. Peláez- Moreno, and F. Díaz- de-María, "Perceptually-aware bilateral filter for quality improvement in low bit rate video coding," in Proc. IEEE PCS, 2012, pp. 477 480.

[5] Christo Ananth, H. Anusuya Baby, "S-Box using AES Technique", International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 3, March – 2014, pp 285-290

[6] H. Dutta, F. Hannig, J. Teich, B. Heigl, and H. Hornegger, "A design methodology for hardware acceleration of adaptive filter algorithms in image processing," in Proc. IEEE ASAP, 2006, pp. 331–340.

[7] A. Gabiger, R. Weigel, S. Oeckl, and P. Schmitt, "Enhancement of CT image quality via bilateral filtering of projections," in Proc. 1st Int. Conf. Image Formation X-ray Comput. Tomography, 2010, pp. 140–143.

[8] A. Gabiger-Rose, R. Rose, M. Kube, P. Schmitt, and R. Weigel, "Noise adaptive bilateral filtering of projections for computed tomography," in Proc. 11th Int. Meet. Fully Three-Dimens. Image Reconstruction Radiol. Nucl. Med., 2011, pp. 306–309.

[9] A. Gabiger, M. Kube, and R. Weigel, "A synchronous FPGA design of a bilateral filter for image processing," in Proc. IEEE IECON, 2009, pp. 1990–1995.

[10] A. Gabiger-Rose, M. Kube, P. Schmitt, R. Weigel, and R. Rose, "Image denoising using bilateral filter with noise-adaptive parameter tuning," in Proc. IEEE IECON, 2011, pp. 4515– 4520.

[11] F. Hannig, M. Schmid, J. Teich, and H. Hornegger, "A deeply pipelined and parallel architecture for denoising medical images," in Proc. IEEE FPT, 2010, pp. 485–490.

[12] Christo Ananth, Vivek.T, Selvakumar.S., Sakthi Kannan.S., Sankara Narayanan.D, "Impulse Noise Removal using Improved Particle Swarm Optimization", International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), Volume 3, Issue 4, April 2014,pp 366-370

[13] A. Rosado-Muñoz, M. Bataller-Mompeán, E. Soria-Olivas, C. Scarante, and J. F. Guerrero- Martínez, "FPGA implementation of an adaptive filter robust to impulsive noise: Two approaches," IEEE Trans. Ind. Electron., vol. 58, no. 3, pp. 860– 870, Mar. 2011.

[14] C. Tomasi and P. Manduchi, "Bilateral filtering for gray and color images," in Proc. IEEE ICCV, 1998, pp. 839–846.

[15] J. Won Lee, R.-H. Park, and S. Chang, "Noise reduction and adaptive contrast enhancement for local tone mapping," IEEE Trans. Consum. Electron., vol. 58, no. 2, pp. 578–586, May 2012.

[16] L. Yu, A. Manduca, J. Trzasko, N. Khaylova, J. Kofler, C. McCollough, and J. Fletcher, "Sinogram smoothing with bilateral filtering for lowdose CT," in Proc. SPIE Med. Imag.: Phys. Med. Imag., 2008, vol. 6913, pp. 691329-1– 691329-8.

[17] M. Zhang and B. K. Gunturk, "Multiresolution bilateral filter for image denoising," IEEE Trans. Image Process., vol. 17, no. 12, pp. 2324–2333, Dec. 2008.

[18] B. Zhang and J. P. Allebach, "Adaptive bilateral filter for sharpness enhancement and noise removal," IEEE Trans. Image Process., vol. 17, no. 5, pp. 664–678, May 2008.