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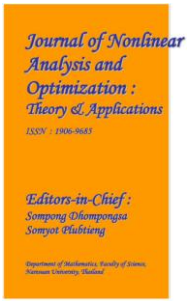

VLSI IMPLEMENTATION OF ADAPTIVE WIENER FILTER FOR IMAGE SCALING APPLICATIONS

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Abstract
Filters are used to remove the different types of noises including salt and pepper, gaussian, and random noises from image. Therefore, the VLSI oriented hardware implementation of filters plays the crucial role in real time applications. However, the conventional hardware-based filters are failed to reduce the look-up-table (LUT)s, path delays, and power consumption. Therefore, this work is focused on implementation of Hybrid Adaptive Wiener Filter (HAWF) using Decision-based multiplexer logic. Initially, the multiplexer selection logic-based decision-based multiplexer is used to identify the high and low values from two numbers. Then, decision-based multiplexer is repeated for multiple number of times for nine pixels combinations, which identifies the Wiener value from nine pixels. The subjective and objective evaluation shows that the proposed HAWF resulted in superior performance in terms reduced noise, hardware metrics like LUTs, delay, and power consumption as compared to state of art approaches.

Keywords:
Hybrid Wiener Filter, Decision-based multiplexer, multiplexer selection logic, look-up-tables, power consumption.

1. Introduction

Noise is undesirable information which degrades image quality [1]. The image can be noisy because of dust present on the lens, electronic noise in camera, imperfection present in the image sensor or can be introduced when image data is transmitted over communication channel. The motive of image processing is to get rid of noise from a digital image while keeping its features unaltered. Image filter is the key blog of Image processing system. An impulsive noise can be added when image data transmitted over an insecure communication channel. [2]. It causes small size dots or dark/black spot on an image. Impulse noise is uniformly distributed and the most often mentioned noise in digital images. Further, Impulse noise can be divided into two parts. The first one is salt and pepper noise which is a type of impulse noise having noisy pixel intensity either 0 (minimum) or 255 (maximum) in the case of gray scale images. It appears as randomly scattered black or white dots over the images [3]. The second one is the random-valued shot noise which has arbitrary valued noisy pixels. To remove these noises, it is necessary that the acquired image must pass through an image pre-processing stage defined as a filter [4]. Spatial and frequency domain are two categories of the filtering operation. Generally, filters are implemented by MATLAB, OCTAVE software's in real time systems [5]. As it is a well-known fact that software implementation offers less processing speed in comparison to hardware implementation [6]. Hardware implementation has become better alternative after the boost in the VLSI technology. To reduce the power consumption in the systems, more cooling devices have to be incorporated results in the costly system. Keeping the same functional capabilities with the reduction in power factors are heavily demanding. Yet in that context, battery and power optimizing technology have not matured up to that target. Most of these products include embedded microprocessors, DSPs and ASICs [7]. It is a provoking undertaking to accomplish low force plan of

any VLSI circuit. There are various degrees of advancement in VLSI configuration measure for low force applications. For battery operated portable products [8], power has been the main concern. As System-on-Chip (SoC) developing with more power transistors, it requires less power consumption. Power consumption reduction in highly integrated SoC cut down the heating problem. It reduces the cost of expensive packing and cooling mechanism [9]. In this work, VLSI architecture for noise reduction in different imaging applications is proposed to deal with the above issues of power and cost reduction, respectively. To achieve low resources, this work mainly focusing on Verilog based coding mechanisms with FPGA prototype [10]. Then, the subjective and objective image statistics are measured by using MATLAB environment. The major contributions of this work are as follows:

- Implementation of decision-based multiplexer for identifying the high, low values using multiplexer selection logic.
- Implementation of multi-level network for selection of Wiener value from nine pixels in a window.
- Implementation of HAWF for removal of different types of noises from image using hybrid switching of data blocks.

Rest of the article is organized as follows: section 2 delas with literature survey, section 3 delas with the proposed HAWF implementation, section 4 delas with analysis of results with performance comparison, section 5 concludes the article with possible future directions.

2. Literature survey

In spatial domain filtering, the image pixel values are directly manipulated to achieve the desired result. Available spatial domain filters are mean, order statistics and Adaptive filters [11]. Image filters have wide applications in the domain of image processing, satellite, and remote sensing, medical and microscopic imaging, geographic image surveillance and seismographic analysis. In [12] authors proposed a new method of Wiener filter by sharing Common Boolean Logic (CBL) which replaces RCA-XOR gate and inverter are used for the sum generation. AND gate and OR gate is used for carry generation [13]. Based on the specific carry input given to the multiplexer both the required sum and carry output are generated. An efficient design is proposed by partial sharing of the circuit and by logical simplification. This design leads to a decrease in the transistor count with minimum power dissipation. In [14] authors proposed the efficient Frequency Domain Denoising Filters by using a newly proposed new type of basic full adder. In [15] authors discussed about the implementation of Wiener filter using basic logic gates. The main advantage of using the basic gates is its zero-power dissipation under ideal conditions. Design modifications are performed in the basic gates to reduce the garbage bits and constant inputs.

In [16] authors proposed a proficient Efficient Wiener Filter which replaces a BEC with normal Boolean logic in conventional CSLA. This work utilizes an effective CSLA by sharing the Common Boolean logic term [17]. One OR gate and one inverter are used for carry and sum generation. Multiplexer is used for selecting the required output based on appropriate carry. Power and delay are reduced with increase in area. In [18] authors proposed a low-cost image denoising standard Wiener filter (SMF**)** methodology using CSLA without multiplexers. First carry input zero operation is performed followed by BEC adder operation. The circuit is designed such that BEC adder replaces the last MUX arrange utilized in customary methodology. Replacing the MUX stage will lessen the area and delay to give considerably higher execution for the adder. In [19] authors implemented parallel pipeline Wiener finder using ultra low power design in near threshold region. Sub threshold operation is similar to minimum energy operation. This work deals with the energy delay modeling framework that develops in the weak, moderate and strong inversion regions. The operation below the minimum energy point is also discussed [20]. The experimental results show that there is a 20% increase in energy which leads to better performance. This concept is used for comparing adders based on their energy delay characteristics and presents the results for our estimation technique. In [21] authors discuss area, power and delay performances of hybrid sorting-based dynamic Wiener filtering (DMF) by using different CMOS logic styles. A new hybrid style is proposed for designing full adder. Though full adders are used in tree structured arithmetic circuits [22], new hybrid logic is used for simulation which is used in the application environment. A full swing and balanced output are achieved using this logic. An area efficient layout is achieved by this methodology.

In [23] authors designed low power Wiener filter based on the variation in supply voltage for impulse noise suppression. Based on input vector pattern, supp.ly voltage is selected. This method will drastically reduce the power consumption [24]. This methodology is explained with respect to the prototype of 32-bit RCA. Simulation results show that there is a 29% reduction in power requirement when compared with conventional RCA In [25] authors designed Adaptive Wiener filter (AMF) with thresholding methods for low power applications. Designing the structure with single supp.ly voltage or comparison based on the gate count is not a suitable method for finding the optimal structures. Therefore, high performance structures should be combined with the supp.ly voltage scaling for obtaining a reduced energy. These technology outlooks the traditional design for low power operation.

3. Proposed methodology

Commotion is signal-subordinate and is hard to be eliminated without disabling image subtleties. Various sorts of error influence the image, like Gaussian, drive, dot and Rician commotions. In the image denoising measure, data about the sort of error present in the original image assumes a huge part. The image error can be delegated either added substance or multiplicative. The image is a 2-D function $f(x, y)$ of light intensities, where f is amplitude at any spatial coordinate x and y. The beam of light falls on an object and reflected light reaches to eyes. It makes humans see the object. The smallest element of the image is pixels. Each pixel represents intensity value at a particular location. Mathematically, image can be represented as Equation (1).

$$F(x, y) = I(x, y).R(x, y) \quad (1)$$

Here, $I\ (x, y)$ is intensity of incident light on object, $R\ (x, y)$ is reflected light from object in intensity and $F(x, y)$ is intensity of resultant image. The image restoration is the process to denoise a image, which has been distorted by prior knowledge of degradation model. Once the degradation model is known, by applying inverse process to recover the desired imagery. image restoration is different than traditional image enhancement techniques. It is a subjective process, which produces more effective results to an observer with and without using degradation model. The image degradation process is shown in Figure 1. image degradation model in the spatial domain is achieved by performing the convolution between $f\ (x, y)$ and model function ($h(x, y)$).

$$F(x, y) = h(x, y) * f\ (x, y) + \eta\ (x, y) \quad (2)$$

Here, $\eta\ (x, y)$ represents the speckle noise. Further, degradation model in the frequency domain is achieved by applying the Fourier transform as follows:

$$F\ (u, v) = h\ (u, v) * f\ (u, v) + \eta(u, v) \quad (3)$$

Here, u, v represents the frequency domain coefficients.

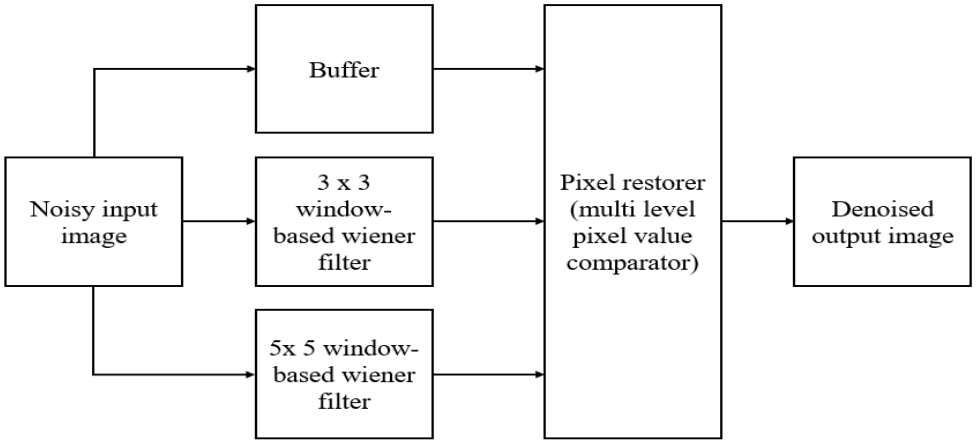

Figure 1: Proposed Image degradation model.

The HAWF is a digital non-linear method used to eliminate noise, similar to that of the medium filter. However, by keeping valuable details in the image, it typically does better than the mean filter. This filter class belongs to the class of filter that preserves the edge. These filters smooth down the data while maintaining the details. The Wiener is only the average of all the pixel values in the area. It doesn't correspond to the mean (or average), but the Wiener is half bigger and half smaller in the neighborhood. The Wiener is a "centre indication" stronger than the average. Like the medium, every pixel in the image is considered by the HAWF and its close neighbors are examined to determine if it is typical of their surroundings. It replaces the Wiener value with those values instead of just replacing the pixel value by the means of the next pixel value. Particularly better than the typical filter is to take away impulsive noise. The HAWF eliminates the noise as well as the fine details as the difference between them cannot be identified. Anything that is comparatively tiny in size with the area size will minimize and filter out the Wiener value. In other words, the HAWF can differentiate between fine detail and noise.

3.1 Decision-based multiplexer

Figure 2 shows the block diagram of decision-based multiplexer, which is used to perform the selection of highest and lowest values from the given two input data. Further, the decision-based multiplexer block contains inputs as A, B and outputs are High (H) and Low (L).

Step 1: Initially, A < B condition is verified, if condition is satisfied selection line of multiplexer becomes one, else condition failed selection line becomes zero.

Step 2: Input-A is applied as Data-input-0 and Input-B is applied as Data-input-1 to 2to1 multiplexer. If A value is smaller than B, then selection line becomes one and multiplexer generates H as input-B through selection switching. If A value is higher than B, then selection line becomes zero and multiplexer generates H as input-A through selection switching.

Step 3: Input-B is applied as Data-input-0 and Input-A is applied as Data-input-1 to 2to1 multiplexer. If A value is smaller than B, then selection line becomes one and multiplexer generates L as input-A through selection switching. If A value is higher than B, then selection line becomes zero and multiplexer generates L as input-B through selection switching.

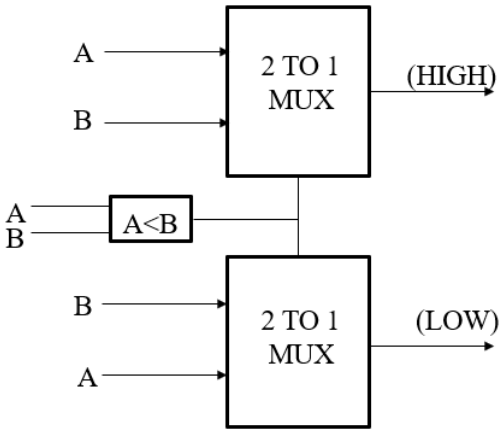

Figure 2. Block diagram of decision-based multiplexer.

3.2 Hardware architecture of HAMF

Figure 3 shows the hardware architecture of HAWF, which contains the fourteen number of hardware resource blocks. Here, inputs P0, P1, P2, P3, P4, P5, P6, P7, and P8 are applied to HAWF, which generates the Wiener value as M. Here, DC-1, DC-2, DC-3 are grouped together and performs the selection of high (H1), low (L1) and Wiener (M1) values. Similarly, DC-6, DC-7, DC-8 and DC-15, DC-16, DC-17 performs the generation of high, low and Wiener values. Further, DC-4 is used to select the lowest value from H1, H2, H3 outcomes. Furthermore, DC-18 is used to select the highest value from L1, L2, L3 outcomes. Similarly, DC-9, DC-10, DC-11 are grouped together and performs the selection of high, low and Wiener values. Like this, the process will continue and generates the Wiener value (M) from DC-14 low outcome.

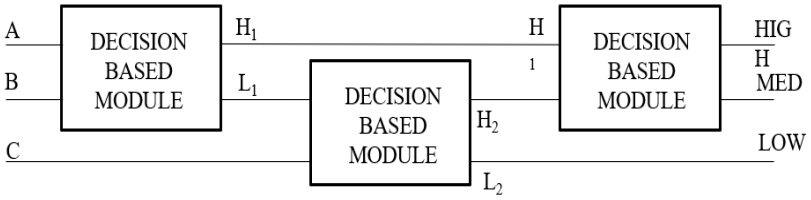

Figure 3. Hardware architecture of HAWF.

4. Results and discussion

Xilinx ISE software was used to create all of the HAWF designs. This software programmed gives two types of outputs: simulation and synthesis. The simulation results provide a thorough examination of the HAWF architecture in terms of input and output byte level combinations. Decoding procedure approximated simply by applying numerous combinations of inputs and monitoring various outputs through simulated study of encoding correctness. The use of area in relation to the LUT count will be accomplished as a result of the synthesis findings. In addition, a time summary will be obtained with regard to various path delays, and a power summary will be prepared utilizing the static and dynamic power consumption. Further, MatlabR2020a software is used to evaluate the subjective performance of HAWF.

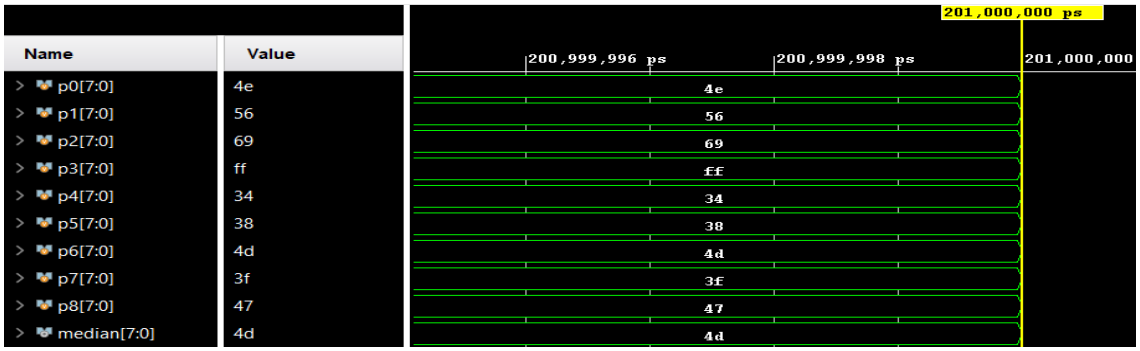

Figure 4. Simulation outcome of HAWF.

Figure 4 presents the simulation outcome of HAWF. Here, P0, P1, P2, P3, P4, P5, P6, P7, P8 are the inputs to HAWF and Wiener is the output value.

Resource	Utilization	Available	Utilization %
LUT	393	41000	0.96
IO	81	300	27.00

Figure 5. Design summary.

Name	Slack	Levels	Routes	High Fanout	From	To	Total Delay	Logic Delay	Net Delay	R
Path 1	∞	5	4	11	p4[4]	median[4]	3.250	1.528	1.722	
Path 2	∞	6	5	7	p5[1]	median[1]	3.252	1.580	1.673	
Path 3	∞	5	4	11	p5[0]	median[0]	3.282	1.530	1.752	
Path 4	∞	6	5	7	p5[5]	median[5]	3.411	1.589	1.821	
Path 5	∞	6	5	9	p4[7]	median[7]	3.419	1.664	1.755	
Path 6	∞	6	5	11	p5[2]	median[2]	3.422	1.569	1.853	
Path 7	∞	5	4	11	p5[6]	median[6]	3.422	1.547	1.875	
Path 8	∞	6	5	9	p4[3]	median[3]	3.503	1.585	1.917	
Path 9	∞	8	6	10	p5[2]	error	4.089	1.689	2.400	

Figure 6. Time summary.

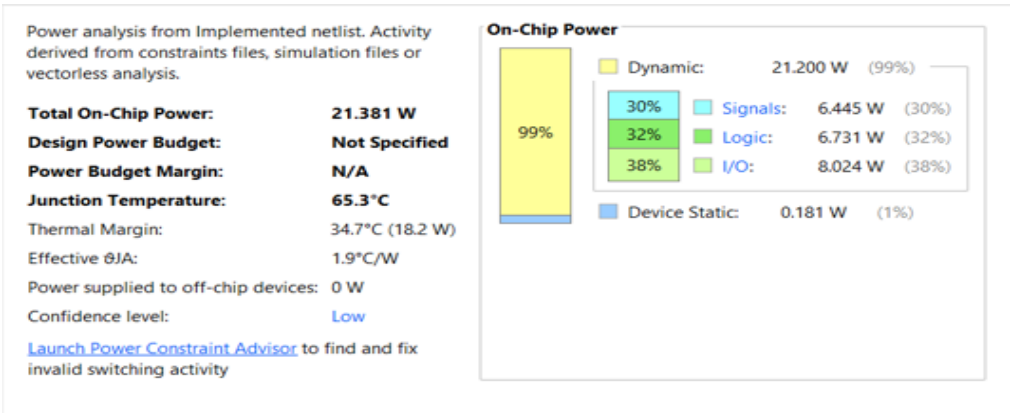

Figure 7. Power summary.

Figure 8. Visuval performmace of HAWF. (a) original image, (b) noisy image, (c) proposed HAWF.

5. Conclusion

The development of a Hybrid Wiener Filter by making use of Decision-based multiplexer logic is the primary emphasis of this study. In the beginning, a multiplexer selection logic-based decision-based multiplexer is used in order to determine which of two numbers have high and low values. After then, the decision-based multiplexer is carried out a number of times for the nine different possible combinations of pixels, which determines the Wiener value for all nine of those values. The subjective and objective evaluations both reveal that the suggested HAWF resulted in greater performance when compared to the state-of-the-art techniques in terms of decreased noise, latency, and power consumption. Hardware metrics such as LUTs were also reduced and software metrics such as PSNR, SSIM are improved using the proposed HAWF approach. Further, this work can be extended with the hybrid Adaptive filters for improved PSNR performance.

References

[1]. Liao, Jan-Ray, Kun-Feng Lin, and Yen-Cheng Chang. "Residual dense network with non-residual guidance for blind image denoising." Digital Signal Processing 137 (2023): 104052.
[2]. Song, Lingfei, and Hua Huang. "Simultaneous Destriping and Image Denoising Using a Nonparametric Model with the EM Algorithm." IEEE Transactions on Image Processing 32 (2023): 1065-1077.
[3]. Zhang, Xiaobo. "Two-step non-local means method for image denoising." Multidimensional Systems and Signal Processing 33.2 (2022): 341-366.
[4]. Sam, B. Baron, Kanthavelkumaran Natesan, and P. V. Prasanth. "Denoising and Restoration of Degraded Images Using Gray Wolf Optimization Algorithm Based on Mean Absolute Difference (Mad) and Extended Kalman Filter." (2022).
[5]. Yang, Ying, and Yusen Wei. "An Adaptive Shrinkage Function for Image Denoising Based on Neighborhood Characteristics." Image Analysis & Stereology 41.2 (2022): 121-131.
[6]. Chang, Shih Yu, and Hsiao-Chun Wu. "Tensor wiener filter." IEEE Transactions on Signal Processing 70 (2022): 410-422.
[7]. Regunathan, Rajeshkannan, et al. "Image Denoising Using a Combination of Spatial Domain Filters and Convolutional Neural Networks."
[8]. Sun, Jialong, et al. "Image edge extraction algorithm based on adaptive Wiener filtering." International Journal of Information and Communication Technology 20.4 (2022): 391-410.

[9]. Hemanand, D., et al. "An Image Denoising Scheme Remove Unwanted Pixel Using NLM with Sprint Deep Learning Network." International Journal of Intelligent Systems and Applications in Engineering 10.4 (2022): 130-137.
[10]. Chyophel Lepcha, Dawa, Bhawna Goyal, and Ayush Dogra. "Low-dose CT image denoising using sparse 3d transformation with probabilistic non-local means for clinical applications." The Imaging Science Journal 71.2 (2023): 97-109.
[11]. Habeeb, Nada Jasim. "Medical Image Denoising with Wiener Filter and High Boost Filtering." Iraqi Journal of Science (2023): 4023-4035.
[12]. Liu, Xuya, et al. "Windowed variation kernel Wiener filter model for image denoising with edge preservation." Optics & Laser Technology 167 (2023): 109688.
[13]. Naimi, Hilal. "Performance and quality assurance of medical image using hybrid thresholding wavelet transform with Wiener filter." Australian Journal of Electrical and Electronics Engineering 19.3 (2022): 294-299.
[14]. He, Xingkun, et al. "GPR image denoising with NSST-UNET and an improved BM3D." Digital Signal Processing 123 (2022): 103402.
[15]. Göreke, Volkan. "A novel method based on Wiener filter for denoising Poisson noise from medical X-Ray images." Biomedical Signal Processing and Control 79 (2023): 104031.
[16]. Lee, Dohwa, et al. "Performance evaluation of 3D median modified Wiener filter in brain T1-weighted magnetic resonance imaging." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 1047 (2023): 167779.
[17]. Jia, Hongbin, Qingbo Yin, and Mingyu Lu. "Blind-noise image denoising with block-matching domain transformation filtering and improved guided filtering." Scientific Reports 12.1 (2022): 16195.
[18]. Gupta, Himanshu, et al. "Variational mode decomposition-based image denoising using semi-adaptive conductance function inspired diffusion filtering." Multimedia Tools and Applications (2023): 1-24.
[19]. Juneja, Mamta, et al. "Autoencoder-based dense denoiser and block-based wiener filter for noise reduction of optical coherence tomography." Computers and Electrical Engineering 108 (2023): 108708.
[20]. He, Wanning, Xin-Lin Huang, and Pengfei Li. "The wiener filter-based adaptive denoising for pseudo analogy video transmission." IEEE Access 10 (2022): 52760-52770.