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Image Denoising using Median Filter Having SDC Comparator

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Abstract

Images are often received in defective conditions due to poor scanning and transmitting devices. Consequently, it creates problems for the subsequent process to read and understand such images. This paper presents a intelligent approach using scalable digital CMOS comparator having parallel prefix tree in filtering to denoise an image even in the presence of very high ratio of noise. The proposed idea exhibits promising results from quantitatively and qualitatively points of view.
Keywords: Image Denoising, CMOS, VLSI, Noise

I. INTRODUCTION

Digital images play an important role both in daily life applications such as satellite television, magnetic resonance imaging, computer tomography as well as in areas of research and technology such as geographical information systems and astronomy. Data sets collected by image sensors are generally contaminated by noise. Imperfect instruments, problems with the data acquisition process, and interfering natural phenomena can all degrade the data of interest. Furthermore, noise can be introduced by transmission errors and compression. Thus, denoising is often a necessary and the first step to be taken before the images data is analyzed. It is necessary to apply an efficient denoising technique to compensate for such data corruption. Image denoising still remains a challenge for researchers because noise removal introduces artifacts and causes blurring of the images. This paper describes methodology for noise reduction (or denoising). Most of the natural images are assumed to have additive random noise which is modeled as a Gaussian. Speckle noise [1] is observed in ultrasound images whereas Rician noise [2] affects MRI images. The scope of the paper is to focus on noise removal techniques for natural images using median filter having SDC comparator.

II. CLASSIFICATION OF IMAGE DENOISING TECHNIQUE

There are two categories for image denoising
- Spatial filtering methods
- Transform domain filtering methods.

A. Spatial Filtering:

This can be divided into Linear and Non-Linear filters and this is the traditional method to remove the noise from images.

1) *Non-Linear Filters:*

In Non-Linear filters, noise can be removed without identifying it exclusively. It employs a low-pass filtering on the assumption that noise always occupies a higher region of spectrum frequency. It removes the noise to very large extent but at the cost of blurring of images. Rank conditioned selection [9], weighted median [8], relaxed median [10] have been developed over recent years to cover up some of the drawbacks.

2) *Linear Filters:*

The optimal linear filter for gaussian noise is the mean filter in terms of mean square error. It also tends to destroy the edges which are sharp, destroy lines and other details of image. It does not perform well in case of signal-dependent noise. The filtering of Weiner method [11] requires the details of the spectrum of original signal and noise and it will give the good results if the underlying signal is smooth. Donoho and Johnstone proposed wavelet based denoising scheme in [12,13].

B. Transform Domain Filtering:

These methods can be subdivided according to the basis functions. This can be further classified into data adaptive and non-adaptive.

1) *Spatial Frequency Filtering:*

It refers the use of low pass filters using Fast Fourier Transform(FFT) .The removal of noise is done by adapting a frequency domain filter and deciding a cut-off frequency when the component of noise are decorrelated from the useful signal. These methods are time consuming and dependent on cut-off frequency. Furthermore, in the processed image they create artificial frequencies.

2) *Wavelet Domain:*

In wavelet domain filtering methods are divided into linear and non-linear methods.

a) Linear Filter:

If the signal corruption can be modelled as Gaussian process, Linear filters such as Weiner filter can give the optimal result and mean square error (MSE) [14,15] is the accuracy criterion. However, if we design a filter on this assumption, this results in a filtered image which is very displeasant than the original noisy signal even though it considerably reduces the MSE. In [16] a wavelet domain spatially adaptive Weiner Filtering is proposed in which intrascale filtering is not allowed in any case.

b) Non Linear Threshold Filtering:

The most researched domain in denoising using wavelet transform is the non-linear coefficient thresholding based method. This exploits the fact of the sparsity problem of wavelet transform and maps white noise in the signal domain to white noise in the transform domain. Thus, white signal energy is more concentrated into transform domain, noise energy cannot be accumulated. So, this is the very effective method of noise removal from signal. The method which removes the small coefficients while others are untouched, is known as Hard Thresholding [5].In this process, certain blips occurred which are also known as Artifacts which shows the unsuccessful attempts to remove moderately large noise coefficients. To cover the demerits of Hard Thresholding, Wavelet transform soft thresholding was also introduced in [5].In this, the coefficients greater than threshold are limited by the absolute value of threshold itself. Techniques other than soft thresholding are semi-soft thresholding and Garrot Thresholding [6].

III. IMAGE DENOISING USING NONLINEAR MEDIAN FILTER HAVING SDC COMPARATOR

A. Scalable Digital CMOS Comparator Using Parallel Prefix Tree:

In this comparator design standard CMOS cells are leveraged to architect fast, scalable, wide-range and power-efficient algorithmic comparators [17] with the following key features:

1) Use of reconfigurable arithmetic algorithms, with total (input-to-output) hardware realization for both fully custom and standard-cell approaches, improves the longevity of our design and makes our design ideal for technology scaling and short time to market.
2) A novel MSB-to-LSB parallel-prefix tree structure, based on a reduced switching paradigm and using parallelism at each level (as opposed to a sequential approach), contributes to the speed and energy efficiency of our design.
3) Use of components built from simple single-gate-level logic, with maximum fan-in and fan-out of five and four, respectively, regardless of the comparator bitwidth, makes it easy to characterize and accurately model our comparator for arbitrary bitwidths.
4) Use of combinatorial logic, with neither clock gating nor latency delay, enables global partitioning into two main pipelined stages or locally into several pipelined stages based on the number of levels. This flexibility provides area versus performance tradeoffs.

1) *Comparator Architectural Overview:*

The comparison resolution module in Fig. 1 (which depicts the high-level architecture of our proposed design) is a novel MSB-to-LSB parallel-prefix tree structure that performs bitwise comparison of two N-bit operands A and B, the subscripts range from N–1 for the MSB to 0 for the LSB. The comparison resolution module performs the bitwise comparison asynchronously from left to right, such that the comparison logic's computation is triggered only if all bits of greater significance are equal. The parallel structure encodes the bitwise comparison results into two N-bit buses, the left bus and the right bus, each of which store the partial comparison result as each bit position is evaluated, such that

$$\begin{cases} \text{if } A_k > B_k, & \text{then left}_k = 1 \text{ and right}_k = 0 \\ \text{if } A_k < B_k, & \text{then left}_k = 0 \text{ and right}_k = 1 \\ \text{if } A_k = B_k, & \text{then left}_k = 0 \text{ and right}_k = 0. \end{cases}$$

In addition, to reduce switching activities, as soon as a bitwise comparison is not equal, the bitwise comparison of every bit of lower significance is terminated and all such positions are set to zero on both buses, thus, there is never more than one high bit on either bus.

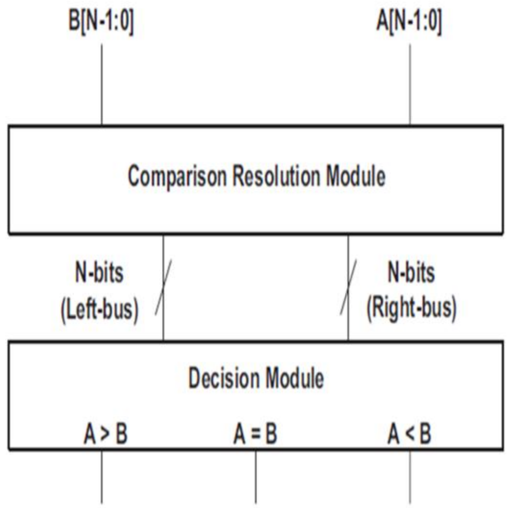

Fig. 1: Block diagram of comparator architecture

The decision module uses two OR-networks to output the final comparison decision based on separate OR-scans of all of the bits on the left bus (producing the L bit) and all of the bits on the right bus (producing the R bit).

- If LR = 00, then A = B,
- If LR= 10 then A > B,
- If LR= 01 then A < B,
- and LR = 11 is not possible.

An 8-b comparison of input operands A = 01011101 and B = 01101001 is illustrated in Fig. 2.

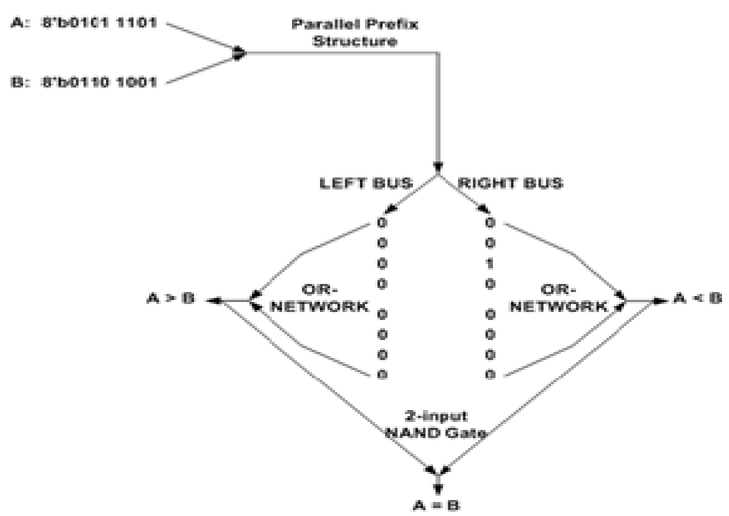

Fig. 2: Example 8-b comparison

2) *Comparator Design Detail:*

In this section, we detail our comparator's design (Fig. 4), which is based on using a novel parallel prefix tree. Each set or group of cells produces outputs that serve as inputs to the next set in the hierarchy, with the exception of set 1, whose outputs serve as inputs to several sets.

- **Set 1 Equation**

$$\Psi : \quad D_k = \qquad \oplus \; B_k$$

- **Set 2 Equation**

$$\Sigma_2 : \quad C_2 = (\textstyle\sum_{i=4m}^{4m+3} D_i)$$

- **Set 3 Equation**

$$\Sigma_3 : \quad C_3 = \mathrm{COMP} (\textstyle\sum_{i=0}^{m} C_{2,i})$$

- **Set 4 Equation**

$$\Omega : \quad Y_k = C_{3,\left[\frac{k}{4}\right]-1} \; D_k \; \textstyle\prod_{i=4\left[\frac{k}{4}\right]-1}^{k-1} \; \overline{D}_i$$

- **Set 5 Equation**

$$\Phi : \quad F_k = Y_k * M_k + \overline{Y}_k * (00)$$

B. Image Denoising:

Image denoising is an important image processing task, both as a process itself, and as a component in other processes. Very many ways to denoise an image or a set of data exists. The main properties of a good image denoising model is that it will remove noise while preserving edges. Traditionally, linear models have been used. One common approach is to use a Gaussian filter, or equivalently solving the heat-equation with the noisy image as input-data, i.e. a linear, 2nd order PDE-model. For some purposes this kind of denoising is adequate. One big advantage of linear noise removal models is the speed. But a backdraw of the linear models is that they are not able to preserve edges in a good manner: edges, which are recognized as discontinuities in the image, are smeared out. Nonlinear models on the other hand can handle edges in a much better way than linear models can. One popular model for nonlinear image denoising is the median filter. This filter is very good at preserving edges, but smoothly varying regions in the input image are transformed into piecewise constant regions in the output image.

1) *Median Filter:*

In signal processing, it is often desirable to be able to perform some kind of noise reduction on an image or signal. The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise.

A median filter operates over a window by selecting the median intensity in the window.

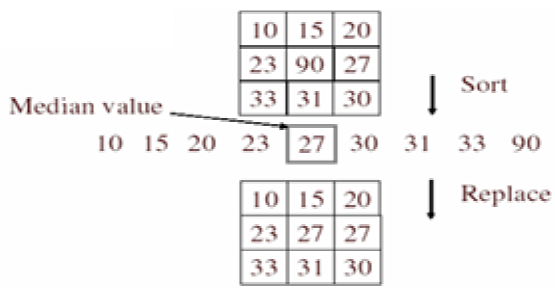

Fig. 3: How Median Filter Works?

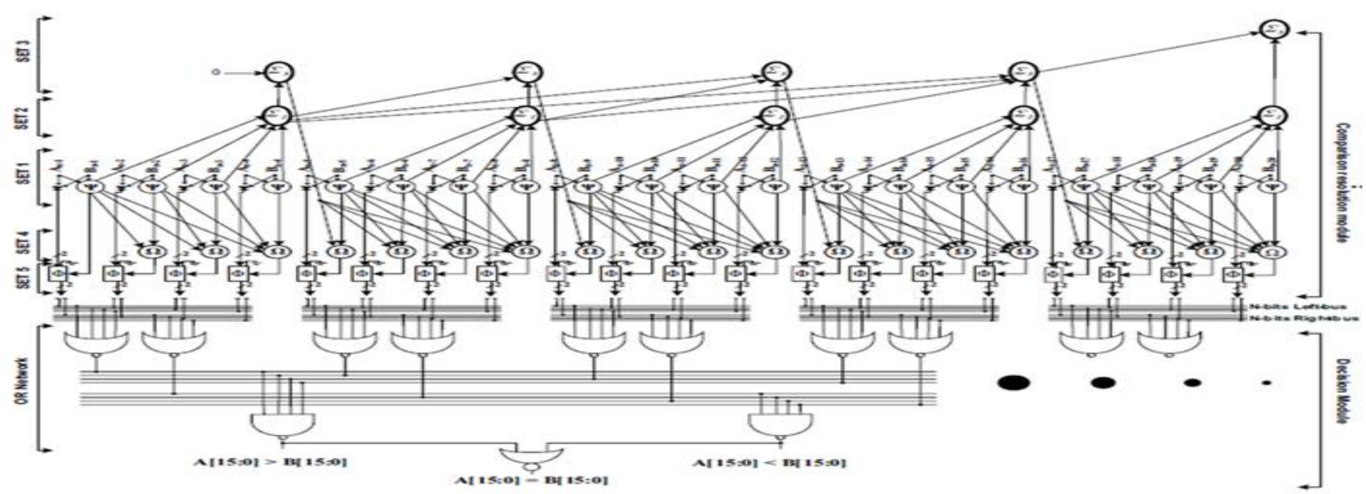

Fig. 4: Implementation Details for the Comparison Resolution Module

2) *Algorithm Description for Median Filter:*

The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighboring entries. The pattern of neighbors is called the "window", which slides, entry by entry, over the entire signal. For 1D signals, the most obvious window is just the first few preceding and following entries, whereas for 2D (or higher-dimensional) signals such as images, more complex window patterns are possible (such as "box" or "cross" patterns). Note that if the window has an odd number of entries, then the median is simple to define: it is just the middle value after all the entries in the window are sorted numerically. For an even number of entries, there is more than one possible median.

3) *Approach Used For Image Denoising:*

The process used for Image Denoising has been divided into 3 parts: a) Preprocessing of Image b) Image Denoising c) Post Processing of Image

a) Preprocessing of Image:

In preprocessing, 2 main functions are performed. a) Adding of noise (salt & pepper) in the image for further image denoising process, which will be performed using Median filter. b) Change the noisy picture into text file, which can be taken by median filter as input.

b) Image Denoising:

Under this process,the image will go through median filter , where the SDC comparator design has been used. This will give the denoised image as output in text form and the text form of denoised image is taken converted again to output image in normal form (Post processing).

c) Post Processing:

In past processing text file of image is converted to picture form. This will be the final smoothened output image (Fig 5).

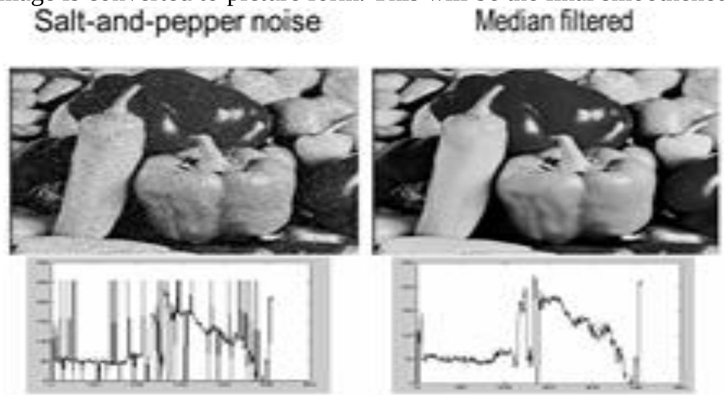

Fig. 5: Final Output Image after Image Denoising

IV. Conclusion

In this paper, new approach of Image Denoising Technique is discussed. The selection of Denoising technique depends on what kind of denoising is required. Further, it depends on what kind of information is required. Median filter model with SDC comparator will be a good choice to represent the region boundaries which is ambiguity free. Furthermore it can be put into use for neural models in artificial intelligence. As the future perspective can be seen, the mentioned method can be implemented that to look how it can be used on different images. With different spatial resolution, different behaviours of same image would be quite interesting. Addition of existing quantative analysis of recent denoising techniques would be quite helpful.

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