

A Restrained Neighborhood Analog Median Filter For Image Processing Applications

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ABSTRACT

The implementation of highly parallel median filters for image processing using a reduced interconnection complexity is presented. The performance of the noise removal process is analyzed, and the results are compared with the previously reported. Two analog median filters were used with this technique: a median filter that is based in a transconductance comparator, and a subthreshold operation median filter. Simulation results of a 78 X 89 image corrupted, with 15% salt and pepper noise, was. All the simulations were made using BSIM3 level 49 model and 1.2 μm MOSIS parameters.

1. INTRODUCTION

Median filters are widely accepted to remove impulsive and high frequency noise for signal and image processing. Due they nonlinear characteristics, its efficiency to remove this kind of perturbations is much better than any other known filtering technique [1]. However, when the probability of error occurrence becomes high, the noise removal operation fails [2].

Analog implementations of median filters have been reported in recent research [2-4]. Their simplicity has allowed some parallelism in image processing applications [5]. Most of these applications were based in bipolar transistors or MOS transistors working in the linear or saturation regions, and the total power consumption of that implementations sets a limit in the parallel capabilities of their applications. Other works present a complete MOS

implementation of a median filter, with all the transistors working in the subthreshold region [6]. The very low power consumption and simplicity of MOS transistors implementations allows overcoming the power limitations for massive parallel processing implementations.

Some analog implementations of median filters dedicated to parallel image processing have been described in recent literature [5, 6]. They are simpler than their digital counterparts, have a higher frequency operation and a much lower power consumption, and require much less area to be implemented [5].

Despite the simplicity of the circuits reported, the interconnection problem remains. Each cell requires of eight external connections from its neighborhood, which increases the complexity of the massive interconnection of median filter cells. To overcome that problem, this work describes the use of masks with reduced neighborhood to reduce the number of interconnections to be used. The effect of the proposed neighborhoods on the noise removal process is analyzed. Simulation results of a 78 X 89 image processing corrupted with 15% impulsive noise, using two different analog median filters are shown.

2. - THE RESTRAINED NEIGHBORHOOD

Despite the widely use of the square mask neighborhood in conventional median filtering, the use of different neighborhoods has been proposed to reduce the computation complexity's [7, 8]. The cross and the x-shaped

neighborhoods are two of the alternative options for median filtering. Figure 1 shows both cross and x-shaped neighborhoods of order three.

The use of those neighborhood restricted median filters reduces the input lines required for each cell to four, instead the eight required for the 3 x 3 square mask. Output lines required for other cells are also reduced in the same order. The probability to have an erroneous pixel at the output will be established as follows. The median filter will not correct an error unless at least three elements contain a wrong data. That happens when at least three of the neighborhood has erroneous information or two of the neighborhood elements and the central one are is erroneous. That can be expressed as:

$$P_{(\text{error})} = P_{(\text{erroneous data})} Q_{(\text{ratio of erroneous combinations})} \quad (1)$$

where the ratio of erroneous combination is given by:

$$Q_1 = \frac{\sum_{k=0}^{n-1} \binom{m}{m-k} \binom{n-m}{k}}{\binom{n}{1}} \quad (2)$$

where l is the number of pixels affected by noise, n is the total number of pixels and m is the number of members in the restrained neighborhood.

The probability of having l pixels affected by noise is given by [1]:

$$P_1 = \binom{n}{l} p^{n-l} (1-p)^l \quad (3)$$

where p is the probability of error. The probability of having at least three affected pixels in a reduced neighborhood of five will be given by the formula:

$$P_{(\text{error})} = \sum_{l=3}^n P_1 Q_1 \quad (4)$$

Figure 2 shows a comparison of the error for a neighborhood of 3x3, which is given by [1]:

$$P_{(\text{error})} = 1 - \sum_{k=0}^{\frac{n-1}{2}} \binom{n}{k} p^k (1-p)^{n-k} \quad (5)$$

and the reduced neighborhoods of five elements. The greater incidence of impulsive noise at the output is similar to the case of five elements median filter presented by Justusson.

3.- SIMULATED RESULTS

The restrained neighborhoods were tested using two different topologies. Figure 3.a shows a transconductance comparator [5], which is used to implement the first median filter, shown in figure 3.b. The second median filter is shown in figure 4., where all the transistors work in the subthreshold region [6].

Figure 5.a shows the original image, while figure 5.b shows the same image corrupted with 15% of impulsive noise. The image was corrupted using Matlab®, divided in blocks and stored in ASCII files. All the simulations were made using BSIM3 level 49 model and in a Tanner Spice V6 circuit simulator and the output were stored in a file to be displayed by Matlab®. Figure 5.c shows the reconstruction of a 78 x 89 image using transistor arrays and a mask of 3 x 3.

Figure 6.a shows the results for a transistor array of type II, using a cross-shaped neighborhood mask, while figure 6.b shows the performance of the same transistor array using an x-shaped mask. Figure 6.c shows the results for the image reconstructed using type I (+) OTA array filter, and figure 6.d shows the image reconstructed using type II (X) OTA array filter. Power supplies of ± 2.5 volts were used.

4. - CONCLUSIONS

Restrained neighborhood masks were used for image filtering using two median filter topologies reported for massive and parallel applications. For medium level of noise corruption, the results were similar to the

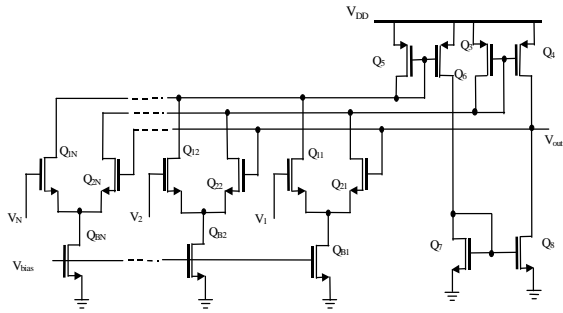


Figure 4. - Wide-range subthreshold median filter.

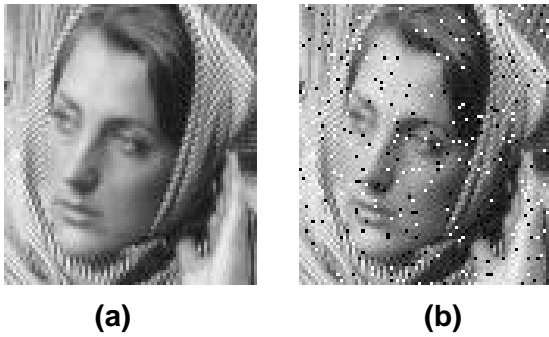


Figure 5. - (a) Original Image. (b) Noisy image. (c) Image reconstructed using a 3 x 3 transistor array.



Figure 6. - (a) Image reconstructed using transistor arrays of type I. (b) Image reconstructed using transistor arrays of type II. (c) Image reconstructed using OTA arrays of type I. (d) Image reconstructed using OTA arrays of type II.