# Examination of The Concept of a Row-Column Separated Median Filter

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Abstract - The two-dimensional median filter is not a linear filter and is therefore not separable into a set of smaller one-dimensional filters. Despite this theoretical barrier to simplification, the separation of a two-dimensional median filter into a set of row medians followed by a column median has been reported by others as an effective image processing tool. In this paper, it is shown that the quality of the image output is actually similar for the two implementations. It is further shown that there are situations in which the row/column median filter produces a higher quality image than a two dimensional median for the same Area or Area-Time hardware metric.

## Introduction of Row-Column Separated Median Filter

In modern image processing systems, a median filter cannot be decomposed into one dimensional filters, however, other authors have reported successful use of a filter based upon a row by row one-dimensional median followed by a one-dimensional filters, which is called a row-column median. It offers potential benefits because of the more than linear growth in complexity of an n value sort operation in hardware as n increases.

Comparison between standard median filter and row-column median filter:
In figure 2, a 3x3 window is separated into 3 rows and the median value of each row is found and they form the next one dimensional row which gives the final median value of 3, which is clearly not the same as the median value found in figure 1. However the row-column median filter provides benefits in hardware implementation.

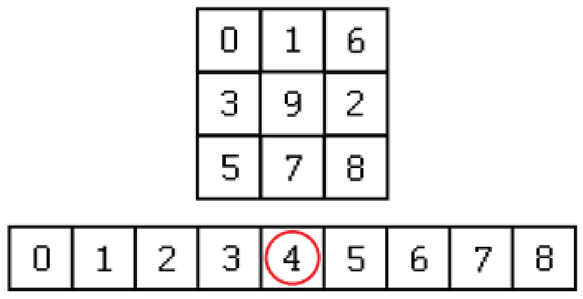


Fig 1. standard median filter

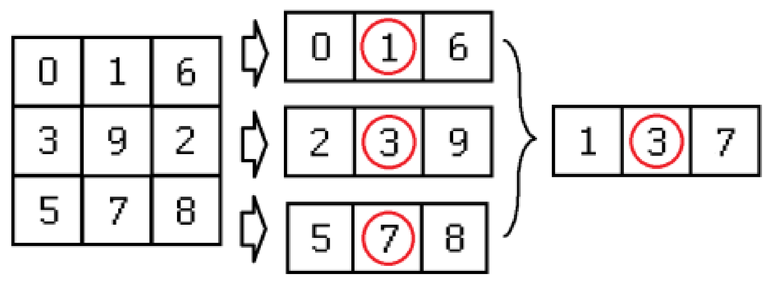


Fig 2. row-column median filter

## Why use Row-Column Median Filter?

Fig 3. Lena image with additive Gaussian Noise

For a image that is corrupted by Gaussian noise, median filter with varies sizes can be applied in order to recover the image, the quality of resultant image is measured using PSNR, a set of results are plotted for different filter sizes and different intensities of noise.

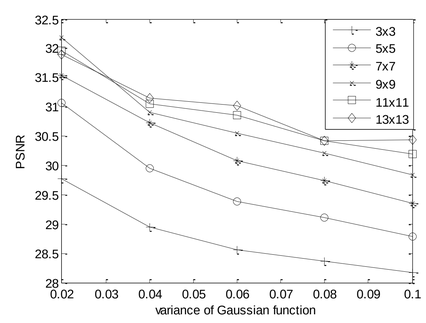


Fig 4. PSNR plot of row-column median

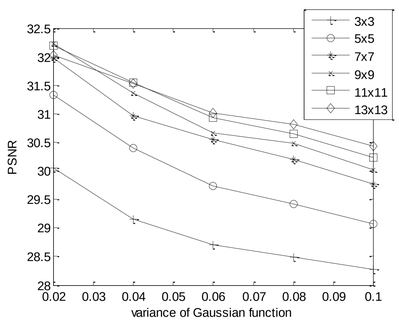


Fig 5. PSNR plot of standard median

Results given by both filters show that larger size median filter is more effective than smaller size filter when handle the Gaussian noise on the image, and therefore scalability of a filtering architecture to large window sizes becomes more important in this noise environment.

## Design Method

The core of the architecture is a simple two (multi-bit) input compare and swap module; it checks the intensity value of two pixels and swaps them if they are in the wrong order. It is possible to run multiple 'compare and swap' processes in parallel. Since normally there will be an odd number of pixel values to be compared, successive sets of swap modules either miss out the top or bottom value in the pixel set. For ease of generation, two sets of pair swapping modules were instantiated within a single "Shift Module" as shown in figure 6.

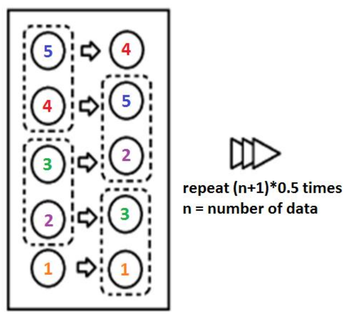


Fig 6. An Example of Shift Module

The Shift Module replicated ($n$+1)*0.5 times (where $n$ is the number of data items to be sorted) to allow for a full sort in the worst case input scenario. For a median filter of size $n$ by $n$ the two-dimensional filter implements $n^4/2$ swap operations in $n^2/2$ pipelined stages; while with the row-column method, $n$ parallel instantiations (the row medians) implement $n^2/2$ swap operations each in $n/2$ pipelined stages and these are combined using a similarly sized sort module instantiation (the column median). The top-level structure consists of the shift module instantiations and an input register. The final output is just a single intensity output that gives the median value.

## Results Analysis

| | Row-column | | Two-dimensional | |
|---|---|---|---|---|
| size | Area | Latency | Area | Latency |
| 3x3 | 204 | 4 | 523 | 5 |
| 5x5 | 954 | 6 | 3959 | 13 |
| 7x7 | 2865 | 8 | 15053 | 25 |
| 9x9 | 5231 | 10 | 40934 | 41 |
| 11x11 | 9349 | 12 | 91103 | 61 |
| 13x13 | 15191 | 14 | 177444 | 85 |

**Table 1.** A comparison of Logic Cell count and cycle Latency for the two filter types

Table 1 lists results obtained from synthesis using the ALTERA Quartus toolset. It can be observed that the 7 by 7 two-dimensional median filter has almost the same cell count as the 13 by 13 row-column median. It is therefore possible to make a fair comparison between these two filters. This comparison is shown in figure 7.

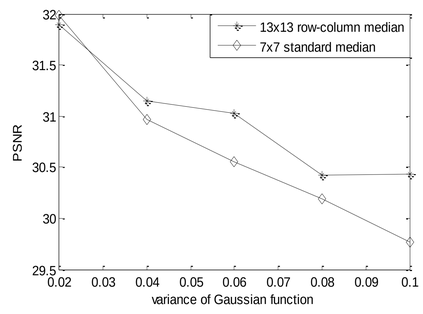


Fig 4. PSNR of 13x13 row-column median and 7x7 standard median

As larger window sizes perform better against additive Gaussian noise. Comparing the performance of the two filters in figure 7 shows that the two filters have very similar PSNR when variance of the Gaussian function is small. However, when the variance increases, the 13 by 13 row-column median achieves a higher PSNR than the two-dimensional filter.

## Conclusions

So in conclusion, it has been shown that the row-column median filter can be more efficient than a two-dimensional filter as it is capable of implementing larger window sizes for the same logic cell resources and the same pixel processing rate. In cases where increasing the median window size or reducing the module latency is beneficial, this modification to the conventional filter provides an effective improvement despite the theoretical non-seperability of a two-dimensional median filter.

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