

AN IMAGE INTERPOLATOR WITH IMAGE IMPROVEMENT FOR LCD CONTROLLER

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Abstract

An image interpolator with image improvement is proposed and implemented for FPD(Flat Panel Display) in this paper. We propose the adaptive pseudomedian filter for the interpolation of images and the real-time contrast controller for image improvement. The proposed interpolation algorithm is based on a pseudomedian filter and uses transposed sub-windows according to the correlation of pixels in the image. The proposed contrast controller uses improved histogram stretching methods and does not require field and frame memory for processing the pixels. The operation of the proposed method has been verified and designed using computer simulation and VHDL. The proposed method achieves better performance than the others from the point of view of the edge and local characteristics.

1. Introduction

Recently, multimedia electronic systems have been quickly changed with the rapid progress of the information industry. The role of display systems that connect humans with variable electronic devices is getting more important. FPD(Flat Panel Display) like LCD (Liquid Crystal Display) is the most suitable device to replace the existing CRT(Cathode Ray Tube) monitors, which are bulky and dissipates larger power than an LCD does. The main advantages of LCD include lightweight, thinness, high-resolution, and low-power operation. In addition, FPD systems employ digital driving methods, which have more strong noise immunity. Moreover, it can represent high quality images when the length of digital

data is increased [1].

However, as the size of FPD panels increase and need higher resolution, FPD systems require full screen displays like CRT monitors which are independent of input resolution, where an interpolation process is executed. Many interpolation algorithms have been proposed for digital image enlargement. However, existing interpolators have a tendency to employ the same method on all pixels in the frame. For example, conventional pseudomedian filtering methods use fixed sub-windows regardless of the correlation of pixels. These methods can cause a reduction in image quality. To overcome these problems, we have proposed an adaptive pseudomedian filtering method considering the correlation of pixels in the image. In addition, we can use image enhancement techniques to improve the image.

Usually, image enhancement is achieved by such methods as utilized contrast control, edge enhancement, noise reduction, and so on. However, these methods do not increase the inherent information contents of image data[2,3]. For example, contrast indicates the distribution from bright color range to dark color range. As the contrast of an image is improved, the image quality will be improved. In addition, human sight is very sensitive to the contrast of luminance. Therefore, we can improve image quality by means of modifying the image histogram[2,4]. Conventional digital contrast control methods have been implemented by using lookup tables, histogram sliding, and histogram stretching. However, these methods have several disadvantages such as extra costs, hardware components and so on. Some of them also have the disadvantages for real-time processing because of their complex hardware architecture.

In this paper, we describe an interpolation filter and contrast control method for improving image quality and show how it is applied to the digital display controller.

2. Interpolation Algorithms

2.1 The conventional interpolation algorithms

Conventional interpolation methods are divided into the linear interpolation method and the nonlinear interpolation method that is based on median filters. There are some typical conventional linear interpolation methods such as ZOI (zero order interpolation)[7], FOI (first order interpolation)[7] and SWAI (spatio-weighted adaptive interpolation)[8]. The nonlinear interpolation methods are the Median method [9], ELA (edge based line average)[10] and PMED (pseudomedian) filter.

2.1.1 ZOI

The ZOI method repeats the pixels of the previous line to create new pixels. It can be very simply realized but it is applied to a limited field[7]. Fig. 1 shows the principle of ZOI. It is suitable for still images and it has been used in still parts in an image.

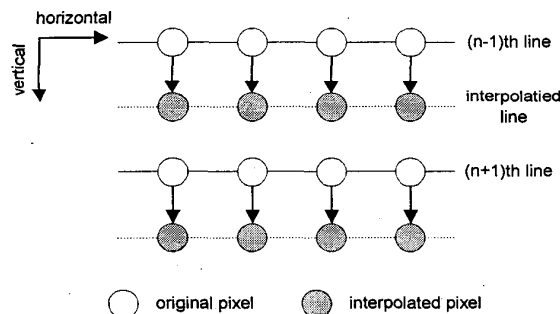


Figure 1. The principle of ZOI

2.1.2 FOI

The FOI method averages neighboring two pixels in the $(n-1)th$ line and $(n)th$ line of the interpolated line. It is suitable for a moving image[8]. Although we can't have a high image quality, we use the FOI method because it can be realized simply with low cost. Figure 2 shows the principle of FOI method.

2.1.3 SWAI

The interpolated pixel is obtained by multiplying weight in proportion to correlation of vertical and diagonal directions. However, this method is difficult to apply to the interpolation of TV scanning lines because this method requires a large amount of computation[8].

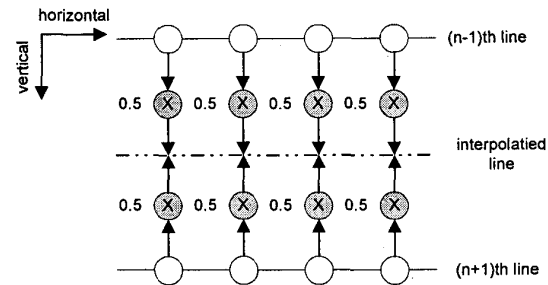


Figure 2. The principle of FOI

2.1.4 Median Filtering

Median filtering is one of the most general nonlinear methods being used for signal processing. Its principle is not complex but it requires many computations[9]. The output of the filter is the median in the windows. This method is particularly effective when the noise pattern consists of strong, spikelike components[11].

Interpolated pixel g is given by equation (1). Figure 3 shows the pixels using median filtering.

$$g = MED(a, b, c, d, e, f, h) \quad (1)$$

$$h = (b + e) / 2.$$

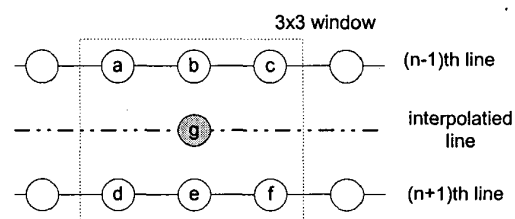


Figure 3. The pixels using median filtering

2.1.5 ELA

ELA interpolation algorithms are used in signal processing like TV. It is superior in rejecting impulse noises but it tends to blur an image. Interpolated pixel $x(i, j)$ is obtained by figure 5. Figure 4 shows the pixels using the ELA algorithm.

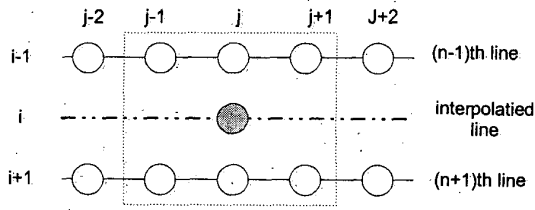


Figure 4. The pixels using the ELA algorithm

$$\begin{aligned}
 a &= \text{abs}(x(i-1, j-1) - x(i+1, j+1)) \\
 b &= \text{abs}(x(i-1, j) - x(i+1, j)) \\
 c &= \text{abs}(x(i-1, j+1) - x(i+1, j-1)) \\
 \text{if } \min(a, b, c) &= b \\
 x(i, j) &= 0.5 * (x(i-1, j) + x(i+1, j)) \\
 \text{elseif } \min(a, b, c) &= a \\
 x(i, j) &= 0.5 * (x(i-1, j-1) + x(i+1, j+1)) \\
 \text{else} \\
 x(i, j) &= 0.5 * (x(i-1, j+1) + x(i+1, j-1))
 \end{aligned}$$

Figure 5. The principle of the ELA algorithm

2.1.6 PMED(Pseudomedian filtering)

PMED is proposed for an effective computation of median filter. The definition of PMED is represented in equation (2) and (3) when N each is 1 and 2.

$$\begin{aligned}
 \text{PMED}\{a, b, c\} & \\
 &= 0.5 \times \max[\min\{a, b\}, \min\{b, c\}] \\
 &+ 0.5 \times \min[\max\{a, b\}, \max\{b, c\}]
 \end{aligned} \quad (2)$$

$$\begin{aligned}
 \text{PMED}\{a, b, c, d, e\} & \\
 &= 0.5 \times \max[\min\{a, b, c\}, \min\{b, c, d\}, \min\{c, d, e\}] \\
 &+ 0.5 \times \min[\max\{a, b, c\}, \max\{b, c, d\}, \max\{c, d, e\}]
 \end{aligned} \quad (3)$$

Since the pseudomedian filter uses the N+1 sub-windows different from a median filter, it adds stronger weight to the middle value. It also has better edge and impulse response characteristics than median filter[10]. Typically, Pseudomedian filter is named according to a shape of the sub-windows. One of them is an H-shaped PMED (pseudomedian) and the other is an Asterisk-shaped PMED(pseudomedian)[12].

H-shaped PMED : H-shaped PMED converts an interlaced scanning line to a progressive scanning line. Figure 6 shows the pixels using H-shaped PMED algorithm. Pixels a, b and c are pixels in the $(n-1)$ th line and d, e and f are pixels in the $(n+1)$ th. Here, g is an interpolated pixel and the line that g is located in is an interpolated line. In Fig. 6, sub-windows are $\{a, b, c\}$, $\{d, e, f\}$ and $\{b, e\}$. Interpolated pixel g is obtained by equation (4). In Eq. (4) “min” means the function calculating the minimum value among the pixels in the sub-windows and “max” means the function calculating the maximum value among the pixels in the sub-windows.

$$\begin{aligned}
 g &= \text{PMED}\{a, b, c, d, e, f\} \\
 &= 0.5 \times \max[\min\{a, b, c\}, \min\{d, e, f\}, \min\{b, e\}] \\
 &+ 0.5 \times \min[\max\{a, b, c\}, \max\{d, e, f\}, \max\{b, e\}]
 \end{aligned} \quad (4)$$

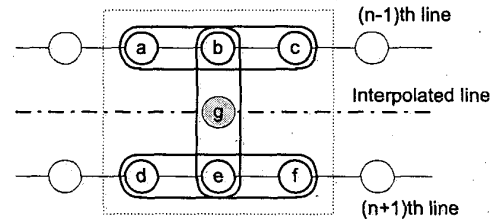


Figure 6. H-shaped PMED filter

As we can see in the Eq. (4), interpolated pixel g is obtained by linear and nonlinear operations using neighbored pixels through both vertical and horizontal directions.

Asterisk-shaped PMED : Pixels in an image have large correlations through diagonal directions as well as horizontal and vertical directions. Asterisk-shaped PMED(below A-PMED) is the method considering both diagonal and vertical directions. In this method, sub-windows are $\{a, f\}$, $\{c, d\}$ and $\{b, e\}$. Therefore, Interpolated pixel g is obtained by equation (5).

$$\begin{aligned}
 g &= \text{PMED}\{a, b, c, d, e, f\} \\
 &= 0.5 \times \max[\min\{a, f\}, \min\{c, d\}, \min\{b, e\}] \\
 &+ 0.5 \times \min[\max\{a, f\}, \max\{c, d\}, \max\{b, e\}]
 \end{aligned} \quad (5)$$

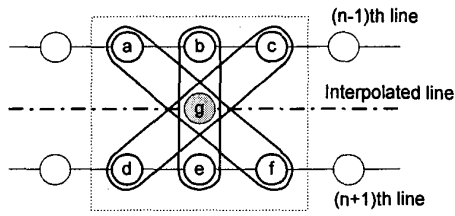


Figure 7. Asterisk-shaped PMED

2.2 The proposed process

The proposed adaptive window algorithm executes interpolation by converting a settlement of sub-windows according to the correlation among neighbored pixels of an arbitrary pixel. Generally, it was known that the H-shaped PMED method shows a superior performance in the vertical edge, that is, in the case where the correlation of horizontal pixels is larger. We have used the original sub-window of the H-shaped PMED in the vertical edge and newly proposed a sub-window in the horizontal edge.

2.2.1 Correlation Decision

Eq. (6) is the equations to decide correlation among neighbored pixels. Here, SH is defined as the sum of the pixel difference in the horizontal direction and SV is defined as the sum of the pixel difference in the vertical direction.

$$\begin{aligned} SH &= |a - c| + |d - f| \\ SV &= |a - d| + |c - f| \end{aligned} \quad (6)$$

The smaller one between these two values has a stronger correlation. That is, if SH is larger than SV , the correlation is stronger in the vertical direction, otherwise, it is in the horizontal direction. Figure 8 shows the group of pixels that is used in the correlation decision.

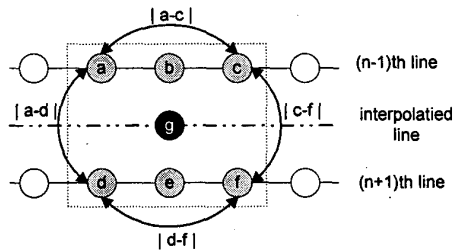


Figure 8. The group of pixels for correlation decision

2.2.2 The proposed new sub-windows of PMED

If the correlation in the vertical direction is stronger, the sub-window is transposed, as in Figure 9. The previously mentioned sub-windows of the H-shaped PMED are $\{a, b, c\}$, $\{d, e, f\}$ and $\{b, e\}$. However, the proposed new sub-windows are transposed into $\{a, b, d\}$, $\{c, e, f\}$ and $\{b, e\}$. The reason for the establishment of the sub-windows like this is to use the closest pixels for an interpolation. Therefore, the interpolated pixel g is obtained by Eq. (7).

$$\begin{aligned} g &= PMED\{a, b, c, d, e, f\} \\ &= 0.5 \times \max[\min\{a, b, d\}, \min\{c, e, f\}, \min\{b, e\}] \\ &\quad + 0.5 \times \min[\max\{a, b, d\}, \max\{c, e, f\}, \max\{b, e\}] \end{aligned} \quad (7)$$

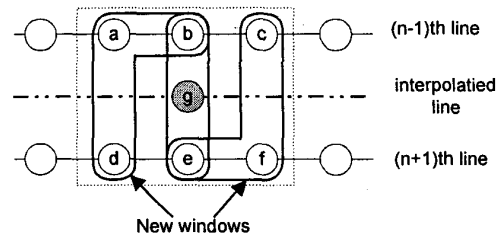


Figure 9. New sub-windows structure

2.3 The proposed adaptive pseudomedian filter

The proposed adaptive window algorithm is performed as in Figure 10. Firstly, the algorithm decides the correlation of pixels and then executes interpolation with the selected sub-window as the correlation of pixels. Only two pixels are exchanged in the correlation.

$$\begin{aligned} SH &= abs(a - c) + abs(d - f) \\ SV &= abs(a - d) + abs(c - f) \\ \text{if } (SH < SV) \text{ then} \\ \quad \text{newpixel} &= \\ &\quad 0.5 \times \max[\min\{a, b, c\}, \min\{d, e, f\}, \min\{b, e\}] \\ &\quad + 0.5 \times \min[\max\{a, b, c\}, \max\{d, e, f\}, \max\{b, e\}] \\ \text{else} \\ \quad \text{newpixel} &= \\ &\quad 0.5 \times \max[\min\{a, b, d\}, \min\{c, e, f\}, \min\{b, e\}] \\ &\quad + 0.5 \times \min[\max\{a, b, d\}, \max\{c, e, f\}, \max\{b, e\}] \end{aligned}$$

Figure 10. The proposed adaptive pseudomedian algorithm.

3 CONTRAST CONTROLLER

3.1 Conventional Methods

3.1.1 Look-up table method

The lookup table is used to contrast control. The present pixel value becomes the corresponding address of the look-up table and its content becomes a new pixel. This method is represented by Eq. (8).

$$\text{New pixel} = \text{DATA}[\text{Add}(\text{Input pixel})] \quad (8)$$

Here, $\text{Add}(\ast)$ is the address of $\ast$. The additional circuits and memory are needed for computation of LUT(Look-Up Table) and storage of the computed values.

3.1.2 Histogram sliding method

The histogram sliding method uses the relationship between the input pixel and the output pixel. Since this method requires extra circuits to calculate weight values, its circuit size is larger[5,6]. The new pixel is calculated by Eq. (9).

$$\text{New Pixel} = \text{Input Pixel} \times \text{Weight} \quad (9)$$

3.1.3 Histogram stretching method

This method is the typical method to improve contrast. It is suitable for an image where the contrast is centralized toward the middle. The new pixel is obtained by Eq. (10).

$$\text{New Pixel} = \frac{\text{Input pixel} - \text{Low pixel}}{\text{High pixel} - \text{Low pixel}} \times 255 \quad (10)$$

This method can occur with some under or overflow and it isn't suitable for a real time processing like FPD driving systems.

3.2 The proposed Contrast Control Method

The proposed method can provide image improvement regardless of the input gray level. In addition, we propose that a contrast control can be easily applied to the FPD for real-time processing because of its lower hardware complexity than that of the conventional methods. The proposed method is given by considering the following equation.

$$\text{New Pixel} \quad (11)$$

$$= (\text{Input Pixel} - \text{Low Pixel}) \times (M + US)$$

In Equation (11), if we subtract an input pixel from its lowest pixel value in the image, the histogram is shifted to the left. In order to prevent overflow and expand the range of the histogram including the overall histogram, the proposed algorithm calculates the weight value $(M+US)$. A user can control the contrast of an image using the US (user select). The values of M (multiple) in weight value are given by Eq. (12).

$$\text{If}(\text{MSB Value} = 1) \text{ then} \quad (12)$$

$$M = 1 + 2^{-n}$$

else

$$M = 2^m + 2^{-n}$$

For decision of index (m, n) , where the index value is an integer, the integer value is determined by the decision algorithm in Figure 11. The value of M is the MSB(Most Significant Bit) in the difference of maximum and minimum pixel value. Therefore, this can be easily implemented by using a priority encoder.

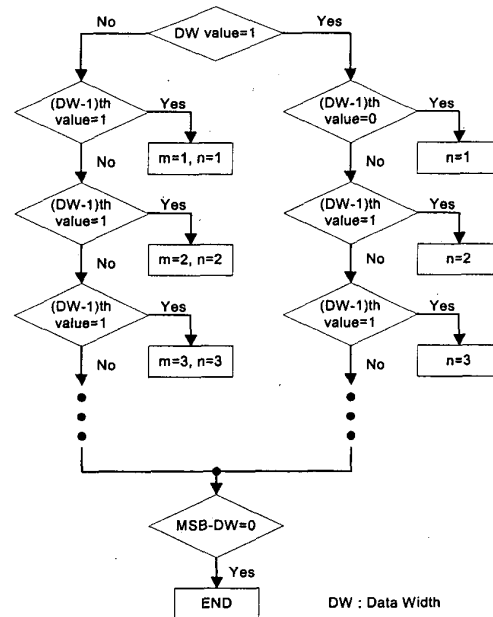


Figure 11. The decision algorithm for index m and n

The US(user select), which acts as an optional function, can control the range of contrast like Eq. (13).

$$\text{If } (16 \leq DR \leq MED) \text{ then} \quad (13)$$

$$US = \{n\}$$

else

$$US = \{2^{-n}\}$$

If DR (Difference Range) is larger than the MED (The middle of input gray level), the US is smaller than 1.

4. Architecture

4.1 The proposed adaptive pseudomedian filter

Figure 12 shows the block diagram of the proposed filter. It is composed of subtractor, comparator, adder, SORT blocks and multiplexer. CSH calculates the sum of the pixel difference through horizontal directions and CSV calculates the sum of pixel difference through vertical directions. COMP block decides the correlation of the pixels. Also, SORT blocks and AVG block perform the operation of a pseudomedian filter.

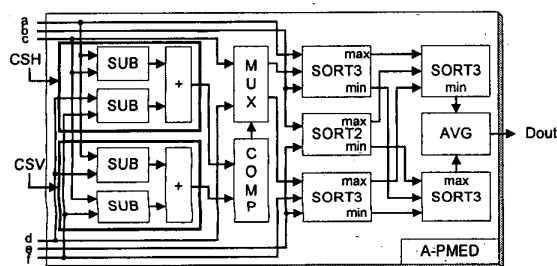


Figure 12. Block diagram of the proposed interpolation filter

4.2 The proposed contrast controller

The architecture of the proposed contrast control is shown in figure 13. This contrast control consists of MM(Max and Min determination) Block, WD(Weight Determination) Block, WE(Weight Expansion) Block, and four pipeline stages. MM block subtracts an input pixel from its lowest pixel value in the image. WD block determines the weight value of an image. Finally, WE block expands the range of the histogram including the overall histogram by using a barrel shifter and adder circuits.

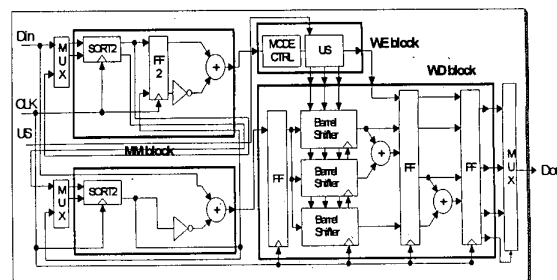


Figure 13. Block diagram of contrast controller

Figure 14 shows the image processor using the proposed image scaler and contrast control circuit. The image processor consists of ADCs, memory banks, interpolation scaler blocks, video processing blocks, and a timing control block. The processor has a block diagram of the proposed driving control. It is possible to reduce the clock speed to a quarter of the main clock. The required input signals are R, G, B, MODE, HSYNC, and VSYNC. The controller employs dual-port memory for the purpose of reading and writing data simultaneously. The controller can detect automatically variable video modes such as NTSC, VGA, SVGA, XGA, SXGA, and UXGA. In addition, it includes the video processing techniques for real-time image improvement[7].

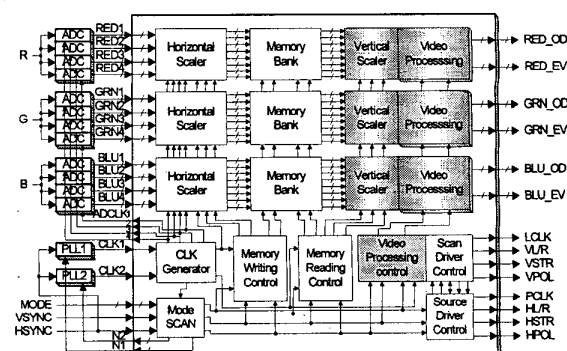


Figure 14. Image processor with the proposed image scaler and contrast controller

5. Simulation Results

5.1 Computer simulation results

5.1.1 Interpolation algorithm

The simulations are executed by the following methods. By elimination of lows and columns of sample images,

we reduce the sample images to one-four. Sample images are “*salesman*(512x480)” and “*lena*(512x480)”. The eliminated columns are interpolated by ZOI and lines are interpolated by the existing interpolation algorithms(FOI, ZOI, H-PMED etc.) and the proposed algorithm. Then, we compared and analyzed the interpolated image and the original image by placing the focus on PSNR(Peak Signal Noise Ratio), which is the objective method of image comparison relatively, and making a subjective assessment of the image quality.

Table 1. Comparisons of PSNR for sample images (*lena* and several frames of *salesman*)

Image Method	Salesman			lena
	Frame1	Frame9	Frame13	
Proposed	25.4820	25.6250	25.6337	24.1476
HPMED	25.4577	25.5886	25.6026	24.1582
APMED	25.4652	25.6233	25.6465	24.0306
MED	25.4393	25.6076	25.6285	24.1072
FOI	25.3664	25.5095	25.5107	24.0690
ELA	24.9034	25.0662	25.0805	23.6449
ZOI	23.6812	23.8574	23.8303	22.5541

Table 1 shows the PSNR results of the sample images. The results show that the proposed algorithm a similar result to as the H-shaped PMED and the proposed algorithm in the case of *lena*(still image), and the proposed algorithm is better than the H-shaped PMED in case of *salesman*(semi moving image). Figure 15 shows the results of the enlarged images that are interpolated by the interpolation algorithms with a *lena* image. The proposed algorithm shows excellent results in edge characteristic. Also, we have confirmed the fact that the proposed method can minimize blurring of the image.

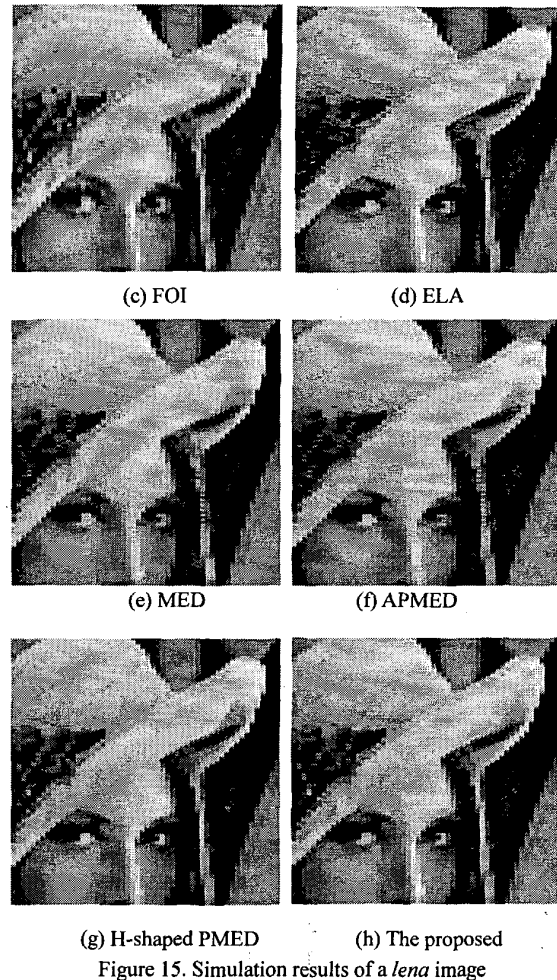
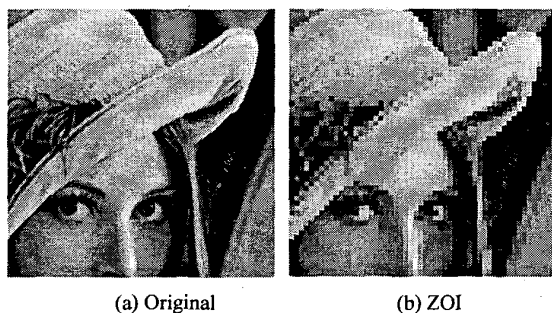
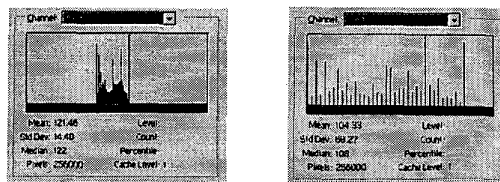


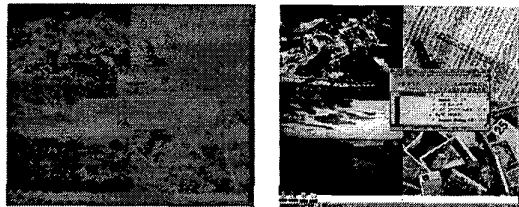
Figure 15. Simulation results of a *lena* image

5.1.2 Contrast control algorithm

In order to compare the processed image using the proposed method with the original image, we examined the SD(standard deviation) of their histograms. Figure 16 shows two histogram distributions according to each weight where the histogram range of the maximum and minimum pixel value is from 104 to 140. In Figure 17, we can find that its histogram distribution has an equal interval as weight value increases. Figure 17 shows an original image and its processed image.

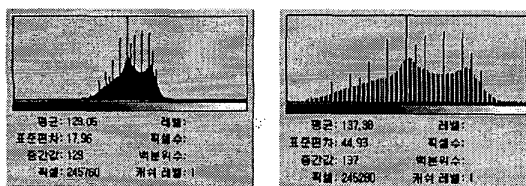


(a) Original histogram (b) Processed histogram
Figure 16. Histogram distribution where the difference in the maximum pixel value is from 140 to 104.

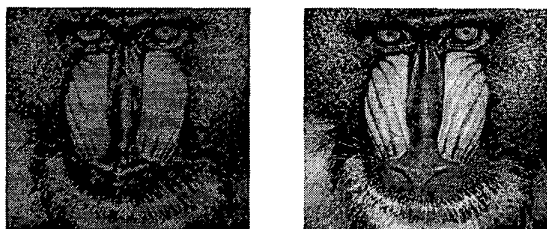


(a) Original image (b) Processed image
Figure 17. Comparison between simulated and original.

Figure 18 shows two histogram distributions according to each weight where the histogram range of the maximum and minimum pixel value is from 92 to 159. In Figure 19, we find that the histogram distribution has equal interval as weight value increases. Figure 19 shows an original image and its processed image.



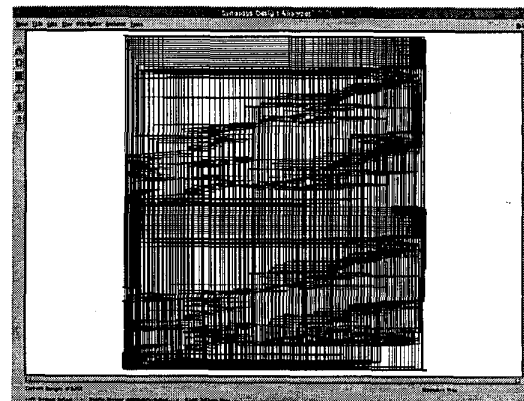
(a) Original histogram (b) Processed histogram
Figure 18. Histogram distribution where the difference the maximum pixel value is from 92 to 159.



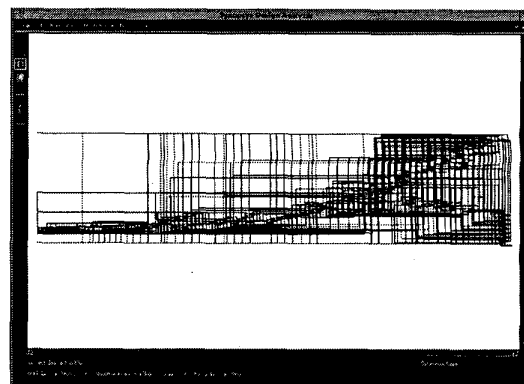
(a) Original image (b) Processed histogram
Figure 19. Comparison between simulated and original.

5.2 Synthesis results

We have designed the proposed contrast controller by using a VHDL tool and we verified it through functional simulation. Figure 20 shows the synthesis results of the proposed circuits using an ANAM 0.25 μ m CMOS process. Result (a) is the result of an adaptive image scaler for vertical interpolation and (b) is the result of the contrast controller. The synthesis results show that the adaptive image scaler has occupied with 2,337 gates and the contrast controller consists of 2,317 gates.



(a) Adaptive pseudomedian filter



(b) Contrast Controller
Figure 20. Synthesis Results

6. Conclusions

In this paper, we proposed an adaptive pseudomedian filter and contrast controller. The conventional pseudomedian filtering methods can partially cause reduction of the image quality because those methods use fixed sub-windows regardless of the correlations of pixels.

However, the proposed interpolation algorithms can overcome those disadvantages because the proposed method adaptively performs interpolation through the correlation of neighbored pixels. Also, the proposed contrast control method has some advantages different from the conventional method. The conventional contrast control methods require field and frame memory to save, a large amount of computation data and their circuit sizes are usually very large. However, the proposed contrast control method requires smaller hardware components and can be easily applied to the FPD for real-time processing because this method can substitute complex multiplier and divider circuits for MD and barrel shifter circuits. In addition to, the proposed method can flexibly control the contrast of the input image by varying the weight values that control the contrast range. Therefore, we have concluded that the proposed interpolator and contrast controller can be effectively applied to digital display systems like LCD without reduction of the image quality.

7. Acknowledgment

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