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Image Scaling Algorithm for Multimedia Applications

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Abstract: ***This paper contains an adaptive edge enhancement algorithm proposed for two-dimensional (2-D) image scaling application. The proposed image scaling algorithm consists of an edge detector, bilinear interpolation and low complexity spatial filter. The bilinear interpolation defines the intensity of the scaled pixel with the weighted average of the four nearest neighboring pixels, interpolated images become smooth and loss of edge information. The adaptive edge enhancement technique is used to protect the edge features effectively, to achieve better image quality and to avoid the loss of edge information. The filter attempts to reduce the noise, in blurred and distorted edges which are produced by bilinear interpolation. The analysis shows that edges are well preserved and interpolation artifacts (blurring) are reduced. Compared with the previous low-complexity techniques, this proposed method produces better quality required output images. To show the advantages of this system the PSNR values produced by different algorithms are compared.***

Keywords: Simplified Bilinear interpolation, Edge detector, Spatial sharpening filter

1. Introduction

Image scaling technique is widely used in the field of digital image processing. In common applications, such as medical image processing, image zooming, computer graphic, online videos etc. Image scaling plays a more and more important role. Nowadays, the image scalar is widely adopted in electric devices such as portable healthcare device, electronic measurement equipment, digital apparatus, digital camera, digital photo frame, mobile phone, touch panel computers. It has become a significant trend to design a low-cost, high quality, and high performance image scalar for multimedia electronic products. Among various proposed interpolation algorithms for image scaling, the simplest one is the nearest neighbor algorithm.

The image scaling algorithms can be split into two types: polynomial-based and non-polynomial-base methods. The polynomial- based methods are nearest neighbor interpolation, bicubic interpolation, and bilinear interpolation. One of the simplest methods is nearest neighbor interpolation, where each interpolated output pixel is assigned to the value of nearest sample point in the input image. The resulting images of this method are full of blocking and aliasing artifacts. So it is unable to use in high quality imaging applications. The advantages of this method are easy to implement and computationally fast, but it does not give good quality of images. Another method is bicubic interpolation; it is based on extended cubic model to scaled images in 2-D regular grid. This algorithm has benefit to produce of high quality images. However, it is computationally expensive due to the complexity in its computation and memory requirements.

Bilinear interpolation method which uses linear interpolation can be performed in both horizontal and vertical directions. This method is most widely-used because it reduces the blocking and aliasing effects.

Recently, many popular non-polynomial based methods have been proposed such as bilateral filter [1], blending kernels [2], adaptive 2-D autoregressive model [11], HVS-directed neural network [12] and orientation adaptive interpolation [13].

These algorithms improve image quality and also reduce aliasing and blurring effects but it has memory requirement, high complexity so it is not easy to be realized in VLSI technique. Low complexity methods are necessary for VLSI implementation.

One of the re-sampling methods is winscale algorithm [14]; it uses area coverage of original pixels for measuring new pixels of a scaled image. However, this method requires more time to calculate area coverage. Hardware cost is low but resulting images are undesirable block and blurring effects. A fuzzy image interpolation [10] combined a fuzzy inference system and an image interpolation technique. An adaptive low-cost and high quality image scalar [4], uses a filter combining and hardware sharing technique are used to reduce chip area and memory requirement. A clamp and sharpening spatial filter are used to decrease the blurring effects produced by the bilinear interpolation. The proposed algorithm consists of a Sharpening spatial filter, edge detector, and bilinear interpolation. The sharpening spatial filter and edge detector are used to enhance the edges of the source images and decrease the blurring effects caused by the bilinear interpolation. The experimental results show that this design improves image quality. The proposed scaling algorithm is designed by Verilog HDL.

2. Proposed Scaling Algorithm

Figure 1 shows the block diagram of an adaptive edge enhanced scalar architecture. It consists of a sharpening spatial filter, edge detector and bilinear interpolation.

In block diagram 1, the input gray scale image is converted into text using MATLAB. The text image is given to register bank on FPGA. The pixels are feed to the sharp filter and edge detector. The edge detector identifies the horizontal and vertical gradient. The gradient gets added to form the edges in the image. The sharp filter which is actually a mask of weights arranged in a rectangular

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pattern. It is mainly used for smoothing and sharpening. The multiplexer combines the pixels coming from register bank directly and pixels passing through sharp filter. The output of edge detector controls the multiplexer input according to the asymmetric parameter (A) of the image.

$$A = P(m+1) - P(m-1) - P(m+2) - P(m) \quad (1)$$

Where P(m+1), P(m-1), P(m+2), P(m) four nearest neighboring Pixels.

The multiplexed output is given to the bilinear interpolation block. The bilinear interpolation is used to up scaling or image zooming. Finally the image is zoomed by bilinear interpolation. The image text is converter to image using MATLAB. Finally output Image is obtained. In real-time multimedia applications, it is necessary to develop low computational complexity, low-memory requirement, high performance, and high quality scaling algorithms. The proposed adaptive edge-enhanced scaling algorithm provides a favorable base for VLSI implementation.

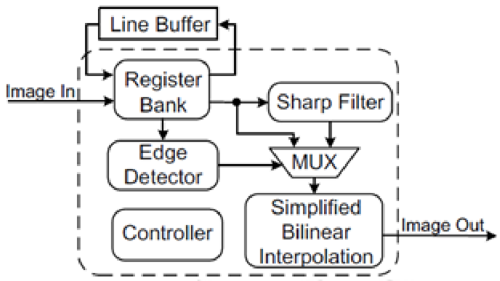

Figure 1: Block Diagram of an adaptive edge enhancement algorithm

A. Bilinear Interpolation

Bilinear Interpolation is an operation that determines the intensity from the weighted average of the four closest pixels to the specified input coordinates, and then assigns that value to the output coordinates. The key point of this idea is to perform linear interpolation first in one direction, and then again in the other direction.

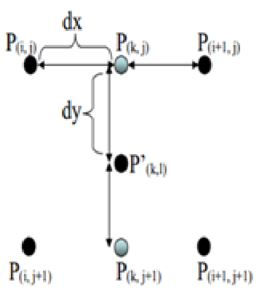

Figure 2: Bilinear Interpolation

Above figure 2 depicts a block which includes four input pixels $P_{(i,j)}$, $P_{(i+1,j)}$, $P_{(i,j+1)}$, $P_{(i+1,j+1)}$ where i=[0…..M] and j=[0……N]. The M and N are the width and height of the original image. The temporary pixel $P_{(k,j)}$ is calculated by linear interpolation in X direction with $P_{(i,j)}$ and$P_{(i+1,j)}$where $I \leq k \leq i+1$. Also, the temporary pixel $P_{(k,j+1)}$ can be calculated with $P_{(i,j+1)}$ and $P_{(i+1,j+1)}$. The temporary pixel $P_{(k,j)}$ and $P_{(k,j+1)}$ can be obtained by,

$$P_{(k,j)} = (1-dx) \times P_{(i,j)} + dx \times P_{(i+1,j)} \quad (2)$$

$$P_{(k,j+1)} = (1-dx) \times P_{(i,j+1)} + dx \times P_{(i+1+1,j)} \quad (3)$$

Where dx is the scale parameter in horizontal direction. After interpolating in horizontal direction, the output pixel $P'_{(k,l)}$ can be calculated by linear interpolation in Y direction with $P_{(k,j)}$ and $P_{(k,j+1)}$ as

$$P'_{(k,l)} = (1-dy) \times P_{(k,j)} + dy \times P_{(k,j+1)} \quad (4)$$

Where dy is the scale parameter in vertical direction.

In image zooming applications, the dx and dy are zooming ratios of the horizontal and vertical directions, and both of them can be set by users. By trading-off the complexity and quality, the bilinear interpolation algorithm is selected as the proposed interpolation base algorithm due to its computational efficiency and qualitative stability. It is also efficient for VLSI implementation because of its low complexity and simple architecture.

B. Edge-Detecting Technique

The edge detecting technique uses a sigmoidal edge detecting method [8]. The interpolated pixel P(k)can be calculated as four closest pixels as P(i-1), P(i), P(i+1), P(i+2) placed at i-1, i, i+1, i+2 respectively.

In this work, a linear space-variant sigmoidal edge detecting model [12]-[13] is selected as the proposed edge detecting algorithm due to its low complexity and memory requirement.

The local characteristics of neighboring around the target interpolated pixel P(k) can be evaluated by the four nearest neighboring pixels P(m-1), P(m), P(m+1), P(m+2). The coordinates of the interpolated pixel P(k) and four neighboring around pixels are located at k, m-1, m, m+1, and m+2, respectively. By using sigmoidal edge detecting model, the asymmetry of the local characteristics neighboring around P(k) can be evaluated by

$$A=|P(m+1) - P(m-1)| - |P(m+2) - P(m)| \quad (5)$$

where A is asymmetry parameter defined to evaluate the asymmetry of the data in the neighborhood of P(k).

By using sigmoidal functions, the asymmetry of the edges can be summarized as

1. A=0, edges are symmetry on the left side and right side.
2. A>0, edges are more homogeneous on the right side
3. A<0, edges are more homogeneous on the left side

The edge detecting method is used to obtain the local characteristics of edges. The interpolated images become smooth and there is a loss of edge information. To protect edge information an adaptive edge enhancement technique is used. For example, the edge detector is used to search

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edges on the left side, if more homogeneous of the left side (E<0). To exclude the loss of edge information after bilinear interpolation, right side of two pixels is adaptively enhanced by the Sharpening Spatial filter.

C. Sharpening Spatial Filter

The sharpening spatial filter [14], which is a kind of high-pass filters, can be used to not only enhance the edges as well as details of the objects but also shut associated low-frequency noise for image processing. It is defined by a kernel designed to increase the intensity of the center pixel relative to neighboring pixels. Convolution filter is a kind of linear filters, which modifies or enhances images by linear combination (for example addition and multiplication). It is called neighborhood-like operation, in which the value of any output pixel is determined by the weighted sum of neighboring input pixels.

D. Register Bank

In this work, the edge detector and sharp spatial filter are filtering and edge catching by using the source pixels P(m-1, n), P(m, n), P(m+1, n), P(m+2, n), P(m-1, n+1), P(m, n+1), P(m+1, n+1), and P(m, n+2). These eight pixels are distributed in two lines of the original image. However, in order to limit the memory requirement for the proposed image scalar, the register bank is designed to provide those eight neighboring pixels with only a one-line-buffer memory. Figure 3 shows the architecture of the register bank which consists of eight shift-registers and connects with a one-line-buffer memory. The shift registers are used to store the values of eight neighboring pixels, and the line buffer is used to store the values of one-row pixels in the source image.

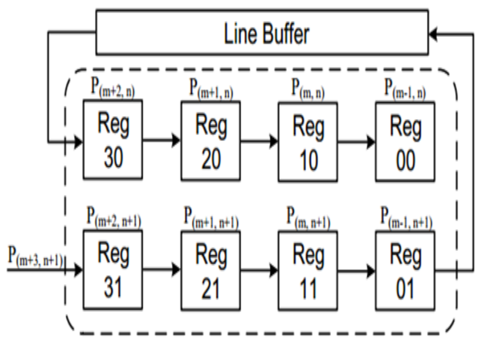

Figure 3: Architecture of the register bank[1]

The register bank design can receive only one value of pixel in each time and provide eight values of neighboring pixels as inputs of edge detector and sharp spatial filter. The details of operating procedures for the register bank will be described as followed. When the shift command is issued from the controller, a new value of the source pixel is read into Reg31. Simultaneously, each value stored in the register is shifted and stored into the right side register. The value in Reg01 is written into the line buffer and the value in the left most location of the line buffer is written into Reg30 immediately. By this register bank design, the input pixels, P(m-1, n), P(m, n), P(m+1, n), P(m+2, n), P(m-1, n+1), P(m, n+1), P(m+1, n+1), and P(m, n+2), of the edge detector and sharp spatial filter can be obtained by the values of Reg00, Reg10, Reg20, Reg30, Reg01, Reg11, Reg21, and Reg31 in the register bank design. By adding the proposed register bank design, one of a two-line-buffer memory can be successfully reduced.

3. Simulation Results

To evaluate the performance of the proposed adaptive edge enhanced scaling algorithm, different 8 test images (256×256) are used in the simulation. First perform up-scaling an image, and then down-scaling an image, finally get the same size of the original image. The Peak-Signal to Noise Ratio (PSNR) is commonly used to measure the quality of a noisy approximation of the m × n refined image and the original image.

The Mean Squared Error defines the cumulative squared error between the refined image and the original image. The low value of the MSE is considered as low error. The MSE defined as;

$$\text{MSE} = \sum_{i=1}^{x} \sum_{j=1}^{y} \frac{(Aij - Bij)^2}{x \times y} \tag{6}$$

Where x and y represents the number of rows and columns of the pixels of the original image.
The PSNR is defined as

$$\text{PSNR} = 10 \log_{10} \frac{R^2}{\text{MSE}} \tag{7}$$

The pixels are represented by eight bits per sample, so the maximum value of each pixel(R) is 255. The quality of the scaled image expressed in decibel (dB).

The input image and corresponding output from the algorithm that has been developed.

Table 1: Comparison of PSNR for image zooming algorithms from the size of 256×256 to 512×512

Input Images	Different Scaling Algorithms			
	BL	Win	Edge – Oriented	**Adaptive edge enhancement**
	PSNR VALUES			
Lena	29.64	26.87	27.06	49.767
Peppers	28.03	25.55	25.73	50.365
Airplane	27.98	25.41	25.83	49.779
Mandrill	21.73	20.82	20.95	50.589
Girl	29.20	27.61	27.71	50.589
Sailboat	25.57	23.38	23.59	52.814
Splash	30.74	27.99	28.06	48.466
House	25.93	23.77	23.98	50.615
Camera man	27.35	25.18	25.36	49.742

By using different algorithm such as bilinear algorithm, winscale algorithm, edge oriented scaling algorithm etc. PSNR values of different input images are calculated using MATLAB.

Table I lists the PSNR (peak signal to noise ratio) values of different test images. The experimental results show

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that the proposed adaptive edge enhanced technique achieves better image quality.

Figure 4 shows the observed waveforms on Modelsim simulator. The proposed adaptive edge enhanced algorithm is simulated using the Modelsim simulator to get the required scaled output image. All the modules of adaptive edge enhanced algorithm works simultaneously on each and every pixel of the input image. Input modules like bilinear interpolation, sharpening spatial filter, edge detector and register bank operates on each pixel of input image. Output matrix of the required pixel size would be obtained.

Following figure shows the step by step change of input pixel values extracted from text file of input image generated by MATLAB transformation. This change is obtained after every 3 pico Seconds.

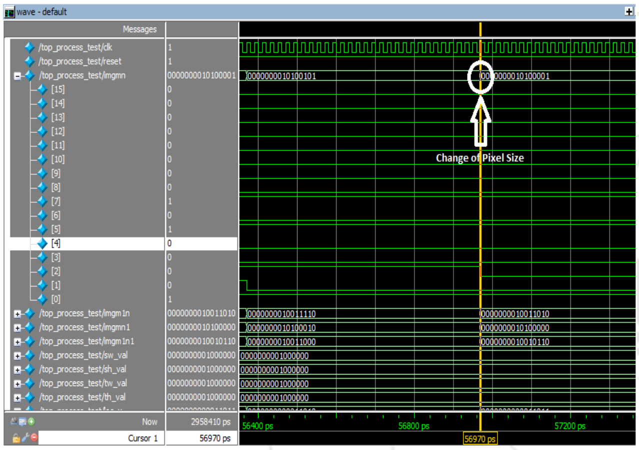

Figure 4: Modelsim waveforms of implemented algorithm

4. Conclusion

This paper proposed an adaptive edge enhancement technique for image scaling application. The sharpening spatial filter solved the blurring and aliasing artifacts caused by bilinear interpolation. The adaptive edge enhanced technique is effectively enhanced the edge features of scaled images. An algebraic manipulation and hardware sharing technique in this design greatly reduces the computing resources costs. Comparing results of the proposed method with all other method it shows that this method improves the image quality.

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