A Method of DWT with Bicubic Interpolation for Image Scaling

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Abstract— Image scaling is a technique used to scale down or scale up the pictures or video frames to fit to the application and is very important in image processing applications. In this paper, a new scaling algorithm is proposed for image scaling consisting of a Discrete Wavelet Transform (DWT) based interpolation and bicubic interpolation. A simple Haar wavelet based DWT interpolation is performed to the image to achieve higher Peak Signal to Noise Ratio (PSNR) and then bicubic interpolation is carried out to get higher visual quality. The sub band coding based DWT divides the image into four quadrants according to frequency. To reduce the artifacts, bicubic interpolation is performed to all the four frequency quadrants. This method achieves less Mean Square Error (MSE) and high average Peak Signal to Noise Ratio (PSNR). Thus this work can achieve an image quality by a factor more than 8 dB than the existing interpolation methods. The proposed method greatly reduces the image artifacts like blurring, thus this approach is better than existing methods in visual quality. The simulation of the work is performed in MATLAB R2013a.

Keywords- Image scaling; Discrete Wavelet Transform (DWT); Peak Signal to Noise Ratio (PSNR); Bicubic interpolation; Mean Square Error (MSE)

I. INTRODUCTION

Image scaling is a trade-off between efficiency, sharpness and smoothness. Image scaling has a very important role in many fields such as medical, digital imaging, consumer electronics etc. It is the process of changing the size of an image or resizing an image [1]. An important application of image scaling is to scale down the high-quality pictures or video frames to fit to the application such as the tablet PC or mobile phone etc. Up scaling and down scaling are the two image scaling methods. Up scaling is the process of image enhancement in which the image size is enlarged to fit for the desired application. In this process certain features of image are highlighted. Down scaling is an image compression technique which reduces the amount of data required to represent a digital image. This can be done by removing the redundant data in the image. Image compression decreases the number of bits required to store and transmit image without any measurable loss of information [2].

Common interpolation algorithms are adaptive and non-adaptive. Adaptive methods depends on what they are interpolating such as texture, edge etc. and non-adaptive methods equally treat all pixels. Some of the non adaptive algorithms are nearest neighbor, bilinear, bicubic, spline, etc. The simplest method is the nearest neighbor algorithm in which the scaled images are full of blocking and aliasing effects. Bilinear interpolation algorithm [3], [4] is the most widely used scaling method, in which the target pixel is obtained by the linear interpolation in both horizontal and vertical directions. An extension of cubic model is the bicubic interpolation algorithm [5], [6] is a popular non adaptive method. These are some of the polynomial- based methods.

Some previous studies proposed adaptive image stabilization [7], spatial domain filtering [8] and also area pixel scaling algorithms such as Winscale [9], edge enhanced scaling algorithm [10] and adaptive edge oriented algorithm [11]. These methods enhance the image quality also reduce the image artifacts such as blocking, aliasing and blurring effects but these image scaling algorithms have high complexity and high memory requirement. DWT is an interpolation technique performed with many types of wavelets in the wavelet family [12]-[14]. Haar wavelet based approach for image compression [15] is an efficient and simplest method for image scaling. Inorder to improve the quality of image than the previous works, DWT with bicubic interpolation is proposed in this paper.

II. PROPOSED SCALING METHOD

The proposed scaling algorithm is an area pixel scaling algorithms consisting of an image preprocessor, discrete wavelet transform interpolation, bicubic interpolation and post processor which is shown in Fig. 1. The original image is converted to gray scale values by the preprocessor. To achieve higher visual quality, discrete wavelet transform based interpolation is carried out first to the gray scale values of image and then bicubic interpolation is performed. DWT is based on sub band coding, which divides the image into four frequency quadrants. To reduce the artifacts, bicubic interpolation is carried out to all the four quadrants separately. The resolution of the image is improved by bicubic interpolation, which is an efficient method where the horizontal and vertical interpolation with nearest 16 pixels is done.

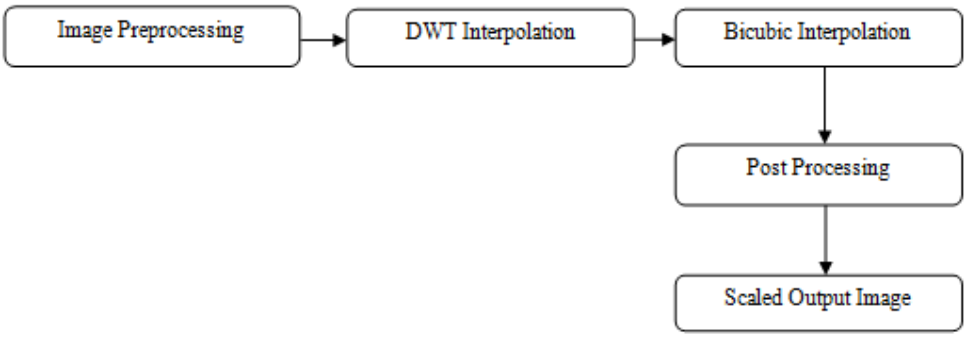

Figure 1. Block diagram of proposed scaling method

A. Image Preprocessor

An image contains descriptive information about the object it represents. Preprocessor converts the original digital image into gray scale values. In a pixel the discrete levels are integers in the interval [0, L-1] where L is the number of discrete gray levels allowed for each pixel. The gray scale values ranges from (0-255). The range of values spanned by the gray scale is called the dynamic range of an image. The image will have high contrast if the dynamic range is high and if the dynamic range is low, the image will have a dull or gray look.

B. DWT Interpolation

Wavelet transform decomposes a signal into a set of basic functions called wavelets which forms the wavelet family. By shifting and dilations, from a single prototype wavelet y (t) called mother wavelet, wavelets are obtained. In DWT, the first level divides the input image into four frequency quadrants. The second level divides each frequency quadrant into sub quadrants and these sub quadrants splits according to frequency in the third level. Thus similar as the expansion of a series function DWT is the process of decomposition of a complex signal in terms of its mother wavelet. The higher accuracy is obtained when more the number of terms are considered. Hence, the series expansion is two-dimensional as the image. To perform DWT Haar wavelet is used which is the oldest, simplest and efficient wavelet in the wavelet family.

C. Bicubic Interpolation

Bicubic interpolation is carried out to all the quadrants separately after DWT interpolation of image. Bicubic interpolation is the default pixel interpolation algorithm and it generates each target pixel by interpolating the nearest sixteen mapped source pixels. The interpolation artifacts like blurring and aliasing can be greatly reduced by bicubic interpolation.

D. Post Processing

Finally, the interpolated gray scale values are converted to original form by post processing and produce the up scaled or down scaled output image. Then the MSE and PSNR are calculated for the scaled output image. These values gives the quality of the scaled image. The peak signal-to-noise ratio (PSNR) is used to quantify a noisy approximation of the output image and the original image. It is the ratio of maximum signal quantity to noise quantity in the image. Since 255 is the maximum value of each pixel, the PSNR in dB is given by:

$$PSNR = 10log_{10}\frac{255^2}{MSE} \quad (1)$$

where, MSE is the mean square error, which is calculated as:

$$\mathrm{MSE} = \frac{1}{uv}\sum_{i=1}^{u}\sum_{j=1}^{v}\left(m_{ij} - n_{ij}\right)^2 \qquad (2)$$

where u and v are the numbers of rows and columns, respectively. m_{ij} and n_{ij} denote the original and reconstructed signals, respectively, where i = 1 : u and j = 1 : v.

III. RESULTS AND DISCUSSION

The simulation results shows the scaled output image of the proposed method better than the existing bilinear interpolation. The performance of the interpolation scheme is evaluated by calculating the MSE and PSNR. The PSNR is expressed in decibel (dB). The average PSNR of the existing bilinear interpolation method is 28.54. In this work different images with three different sizes are verified. From the simulation result, the image "plant" has an average down scaled PSNR of 42.94dB as given in Table 1.

TABLE 1. DOWN SCALED PSNR VALUES OF IMAGE "PLANT" WITH DIFFERENT SIZES

Size	**PSNR (dB)**
120x160	42.11
180x240	45.12
420x560	43.35
Average	**42.94**

The down scaled average PSNR values for image sun, plant and sky are 45.12, 42.94 and 38.48 dB respectively, which are shown in Table 2. From the average PSNR values of different images it is clear that the image quality is improved by a factor of more than 8 dB due to low MSE. The blurring effects in the existing method are greatly reduced in this method. Thus, the proposed DWT with bicubic interpolation is better in image quality than the existing interpolation methods.

TABLE 2. AVERAGE DOWN SCALED PSNR VALUES FOR THREE SAMPLE IMAGES

Image	**Average PSNR (dB)**
Sun	45.12
Plant	42.94
Sky	38.48

Three sample images such as sun, plant and sky tested by this method is listed in Fig. 2. As an example, the interpolated results of image 'plant' are presented in this paper. For different sizes of the image, down scaling is tested and verified by calculating the PSNR values, which are obtained for the down scaled image plant for sizes 120x160, 180x240 and 420x560 are 45.12,42.11 and 43.35 dB respectively.

(a) Sun (b)Plant (c) Sky

Figure 2. Three sample images for test

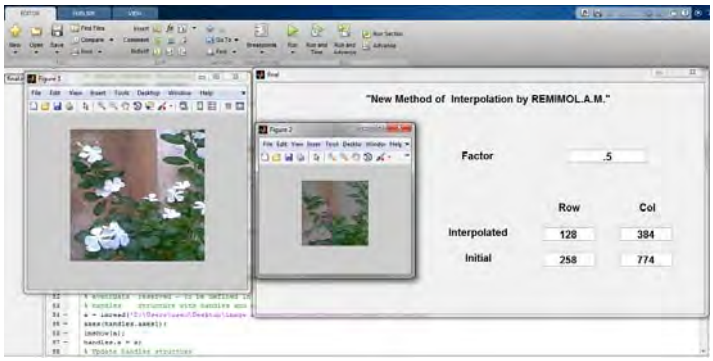

Figure 3. Down scaled result of image plant

The down scaled result of image plant by a factor 0.5 is shown in the Fig. 3., in which, Figure i shows the original image and Figure ii shows the down scaled image. The row and column pixel values of original image are 258 and 774. After interpolation, the row and column values down to 128 and 384 respectively. The PSNR and MSE values of down scaled image plant are obtained as: MSE = 2 and PSNR = 45.11 dB.

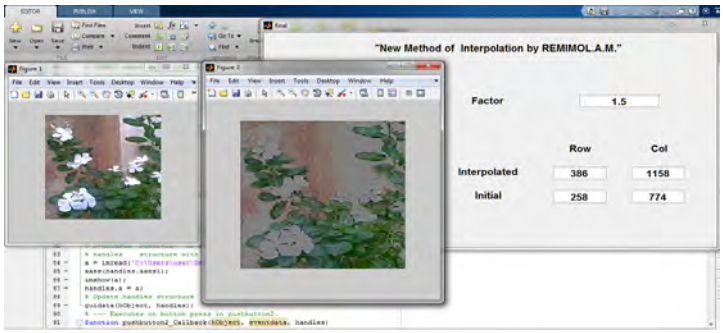

Figure 4. Up scaled result of image plant

The result of up scaling of an image plant by a factor 1.5 is shown in Fig. 4. In the output window, Figure 1 shows the original image and Figure 2 shows the up scaled image. The row and column pixel values of original image are 258 and 774. After interpolation, the corresponding row and column values are scaled to 386 and 1158 respectively. The PSNR and MSE values of up scaled image plant in the proposed method are obtained as: MSE = 598 and PSNR = 19.14 dB.

IV. CONCLUSION

This method tested and verified a new image scaling algorithm combining the discrete wavelet transform with bicubic interpolation. The simple haar wavelet fast computation of wavelet transform and reduction of interpolation artifacts of bicubic interpolation gives better scaled output image quality. The output image of the simulation shows the reduced blurring effects present in existing interpolation methods. The quality of image is measured by calculating the PSNR values. The average PSNR values for three different test images such as, sun, plant, and sky are obtained as 45.12, 42.94 and 38.48 dB in this new method. Thus the quality of the image is improved by a factor more than 8 dB in this method, due to reduced mean square error and high PSNR values than the existing methods. Thus this work can achieve better image quality than the existing scaling methods and gives low visual distortion in the scaled output image. MATLAB R2013a platform is used for the simulation of this work. This work can be enhanced by using another wavelet called Doubechies in the wavelet family to get higher PSNR.

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