International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 5 No. 3 Mar. 2014, pp. 215-221

http://www.issr-journals.org/ijias/

A New Image Interpolation Using Gradient-Orientation and Cubic Spline Interpolation

Said OUSGUINE, Fedwa ESSANNOUNI, Leila ESSANNOUNI, and Driss ABOUTAJDINE

LRIT Laboratory (Unit associated with the CNRST), URAC 29,
Faculty of Science, University Mohammed V, Agdal,
Rabat, Morocco

ABSTRACT: Several factors can interfere in the quality of image such as aliasing, noise, artifact, and blurring, these factors can cause the degradation of image especially in edge regions. In order to reduce the effect of these factors, it is necessary to choose a robust interpolation method which can play important role of the reconstruction of the high-resolution image from its low-resolution counterpart, so as to preserving the edges and textures, increasing the resolution, and improving the image quality.

In this paper, a new image interpolation method is proposed using gradient orientation; in the first step, we estimate the edges directions for a missing pixel location using the gradient-orientation in horizontal and vertical directions. Then, in the second step we interpolate the missing pixels along the detected edge directions using a cubic spline interpolation.

We begin from a gray high-resolution image which is down-sampled by a factor of two, to obtain the low-resolution image, then; this image is reconstructed using the proposed algorithm. Our method is implemented and tested to several gray test images, and compared to other image interpolation methods. The simulation results show the effectiveness of the proposed technique using the PSNR and compared with the traditional interpolation techniques. The results showed that the proposed technique has higher accuracy, and can preserve the sharp edges and textures, and avoid the problems of blurring and the visual artifacts caused by the classical interpolation methods.

KEYWORDS: Image interpolation, gradient orientation, edges direction, cubic spline interpolation, super-resolution.

1 INTRODUCTION

Image interpolation aims to generate a high-resolution image from its low-resolution counterpart. The image interpolation is a technique which estimates a set of unknown pixels from a number of known and discrete pixels, especially the adjacent pixels. The interpolation can be used in image resizing, upscaling, enlargement, and image enhancement. The interpolation can be applied in many fields such as remote sensing, surveillance, medical imaging, computer vision, high definition television, and consumer electronics.

Interpolation methods can be divided into two main classes, the first one is the non-adaptive interpolation, this type of interpolation algorithms treats all images using classical linear interpolation techniques such as nearest neighbor, bilinear, or bi-cubic interpolation [12]. These latter are simple and hence popular, but they all produce images with various artifacts, especially around edges on the image. Nearest neighbor interpolation produces block artifacts and jagged edges, while bilinear and bicubic interpolations usually produce blur edges.

The second class of interpolation methods is the adaptive interpolation, some edge-adaptive interpolation techniques try to explicitly detect the edges on the original image, firstly to generate an edge map and then use it to assist interpolation later. Examples of these techniques are presented in [18], [20]. This class of methods involves multiple steps and is usually complicated and computational costly. Another class of edge-adaptive techniques attempts to have edge information built into the algorithms. These techniques do not require explicit detection of edges. Example of these methods can be found in [4], [5], [19], [21].

Corresponding Author: Said OUSGUINE (saidmadridi.ousguine39@gmail.com)

Several interpolation algorithms have been presented in the literature either in adaptive class or non- adaptive class or by combining the two classes. G.ramponi [1] proposes to use the warped distance to the interpolated pixel instead of a regular one, thus modifying the one-dimensional kernel of a separable interpolation filter. An amelioration of this method was made by Huang and Lee [2] which consists in modifying the two-dimension interpolation Kernel by the characteristics of local gradient.

A method of edge detection was introduced by Jensen and Anastassion [3]; they apply a projection onto orthonormal basis to detect the edge direction, and modify the interpolation process to avoid interpolating across the edges to improve the visual perception of the interpolated image.

An iterative edge-directed scheme was developed in [20]. The authors use an estimate of the edge mapping of the high-resolution image to guide a bilinear interpolation such that interpolation across edges is avoided.

An NEDI interpolation was presented by Li and Orchard in [4].The authors used the local covariance of low-resolution images to estimate the covariance of high-resolution image. Asuni and Giachetti [17] propose INEDI (Improved New Edge-Directed Interpolation) to improve the algorithm of Li and all by adopting circular windows and adaptively selecting the size of windows. However, in the region of fast luminance change, the windows are too small to get a stable solution.

Li and Zhang [6] propose an Edge-guided algorithm via directional filtering and data fusion, they have estimated the missing pixels which can be interpolated, by two sets of observations which are defined in two orthogonal directions, these latter are fused through linear minimum mean-square-error (LMMSE). The authors in [9] propose a regularity-preserving interpolation method which consists in extrapolating a new wavelet sub-bands based on the decay of the finer scale.

Muresan and Park [5] extended this strategy which based on the influence of a full cone sharp edge in the wavelet scale spaces, for estimation the coefficient of scale by an optimal recovery theory. An interpolation scheme was proposed by Giachetti and Asuni [8] , its principle is to interpolate locally the missing pixels in the two diagonal directions, while the second order image derivative is lower, these interpolated pixels value are modified using an iterative refinement to minimizing the differences in second order image derivative. Cha and Kim [7] describe an interpolation method by utilizing a bilinear interpolation and correcting the errors by adopting the interpolation error theorem in an edge-adaptive way. The authors in [11] develop an interpolation approach based on edge-oriented algorithm, they classify the image into two partition, the homogenous zones which its missing pixels are interpolated by a bilinear interpolation, and the edges area, which its missing pixels are interpolated using all neighboring pixels, this neighboring pixels contains the originals pixels and the interpolated pixels in the homogenous area.

Zhou and Shen [10] propose an image zooming using cubic convolution interpolation with detecting the edge-direction, this method is based on the detection of edge-direction of the missing pixels by computing the gradient of horizontal, vertical, 45° diagonal and 135° diagonal directions, then they interpolated the missing pixels utilizing a cubic convolution interpolation.

In our paper, we propose a new approach of image interpolation using gradient-orientation; which the missing pixels are interpolated along the detected edge direction, these latter are estimated by the gradient in the horizontal and vertical directions, a cubic spline interpolation is used to interpolate the missing pixels along the strong edge.

The paper is organized as follows: in section II we recall the principle of the cubic spline interpolation. Section III describes the proposed interpolation method. Simulation and results are shown in section IV. Finally, the conclusion is drawn in section V.

2 CUBIC SPLINE INTERPOLATION

The spline interpolation is based on piecewise polynomial functions. Among the large family of polynomial functions (Lagrange, Hermite…). A polynomial spline is a piecewise polynomial function of degree n with pieces that are patched together such as to guarantee the continuity of the function and its derivatives up to order n-1. The spline interpolation is based on the following principle is that the interpolation interval is divided into small subintervals. Each of these subintervals is interpolated by using the third-degree polynomial. The polynomial coefficients are chosen to satisfy certain conditions. The function must be continuous of higher derivatives and passing through all the given points. Spline interpolation was introduced by Schoenberg [16], and has been described exhaustively by Thévenaz et al. and Unser [13], [14], [15], the main advantages of the spline interpolation are the stability and the calculation simplicity.

Let p be a polynomial piece, the spline interpolation can be defined as ([16]):

$$p(x)=\sum_{k\in Z}c(k)\beta^{n}(x-k)$$

Where the c(k) are the B-spline coefficients, and β(x) is the B-spline basis functions of degree n, all the B-spline bases of degree n can be obtained by the recursive continuous convolution of the box function with the B-spline basis of degree (n−1) ([13], [14], [15]):

$$\beta^{n}(x)=(\beta^{n}*\beta^{0})(x)$$

With

$$\beta^{0}(x)=\begin{cases}1 & |x|<\frac{1}{2}\\ \frac{1}{2} & |x|=\frac{1}{2}\\ 0 & |x|>\frac{1}{2}\end{cases}$$

Therefore, the cubic B-spline can be written as:

$$\beta^{3}(x)=\begin{cases}\frac{2}{3}-\frac{1}{2}|x|^{2}(2-|x|) & 0\le|x|<1\\ \frac{1}{6}(2-|x|)^{3} & 1\le|x|<2\\ 0 & 2\le|x|\end{cases}$$

3 THE PROPOSED METHOD

The known interpolation methods such as spline interpolation, cubic convolution, nearest neighbor interpolation, and linear interpolation method, interpolate the missing pixels in the same direction, and so non-horizontal or non-vertical edges are smoothed. In contrast, edge-directed interpolation methods detect the edge orientations, and then interpolate along the detected edge directions. The frequent problem is that the detected edges are usually imprecise, especially in the regions with composite edges such as textures.

In order to avoid detecting weak edges, we propose a novel interpolation method. By interpolating the missing pixels on the strong edge and then applying the cubic spline interpolation along the estimated edge direction.

An LR image Im can be considered to be a directly downsampled version of the HR image corresponding to Im, where the downsampling factor is 2. The High resolution image Im is restored by copying the LR image Im pixels into an enlarged grid and then filling with the missing pixels. Here we propose an estimation method of the strong edge for a missing pixel location. The proposed method can be described as follows:

Step1: Compute the image gradient of the low-resolution image I_m:

$$[G_x, G_y]=\text{Gradient}(I_m)$$

Let G_r be the complex gradient of the image I_m described by the following equation:

$$G_r=G_x+\text{i}\,G_y$$

Where i is the basic imaginary unit sqrt (-1).

Step 2: For every pixel to be estimated (i, j), in the 7x7 neighbour of this pixel, they are four immediate diagonal pixels to be known, the orientation of the gradient at the central location (i,j) can be determined using the given equations:

$$d_1(i,j)=\sum_{k=3,\pm1}\sum_{l=3,\pm1}\left\|G_r(i+k;j-l)-G_r(i+k-2;j-l+2)\right\|$$

$$d_2(i,j) = \sum_{k=3,\pm1}\sum_{l=3,\pm1}\left\| G_r(i+k;j+l) - G_r(i+k-2;j+l-2) \right\|$$

Where $\|x\|$ denotes the complex modulus (magnitude) of the complex number x.

Using $d_1(i,j)$ and $d_2(i,j)$, the edge direction for a pixel location (i, j), can be estimated as follows:

$$\begin{cases} if\ d_1(i,j) > d_2(i,j) \\ the\ gradient\ is\ greater\ in\ the\ horizontal\ direction \\ else \\ the\ gradient\ is\ greater\ in\ the\ vertical\ direction \\ end \end{cases}$$

Step 3: Compute the intensity value at the missing pixel position using the estimated edge direction. Indeed, the intensity pixel value can be computed using the cubic spline interpolation by interpolating the four neighbour pixels along the strong edge.

4 SIMULATION AND RESULTS

In order to demonstrate the accuracy of the proposed method, a number of simulations are provided to examine the performance of the proposed method, this latter has been implemented in Matlab and tested on several images, and compared with the state of art of interpolation algorithms, cubic spline interpolation [14], directional filtering and data fusion [6], new edge-directed interpolation [4], Accuracy improvements and artifacts removal in edge based image interpolation [17], and fast artifacts-free Image interpolation [8].

CS was implemented by Matlab ‘interp2’ function; the Matlab codes of ICBI, DFDF, INEDI, and NEDI were available from the original authors.

Eight gray test images are used for simulation; Fig.1 represents the eight gray images used for test.

We started from an original high-resolution gray image; this latter was down-sampled by a factor of two to obtain the low resolution image. The LR image was reconstructed by a set of interpolation methods.

Various experimental factors are used to investigate the quality of the interpolated images, the first one is the subjective quality of the output images, Figs. 2–4 compare the results of the six different image interpolation methods on test images Lena, Face, and Monarch, respectively.

The second criterion is the PSNR ratio.

Table 1 indicates the resulting PSNR values on the set of 8 gray images of the compared methods with the proposed one.

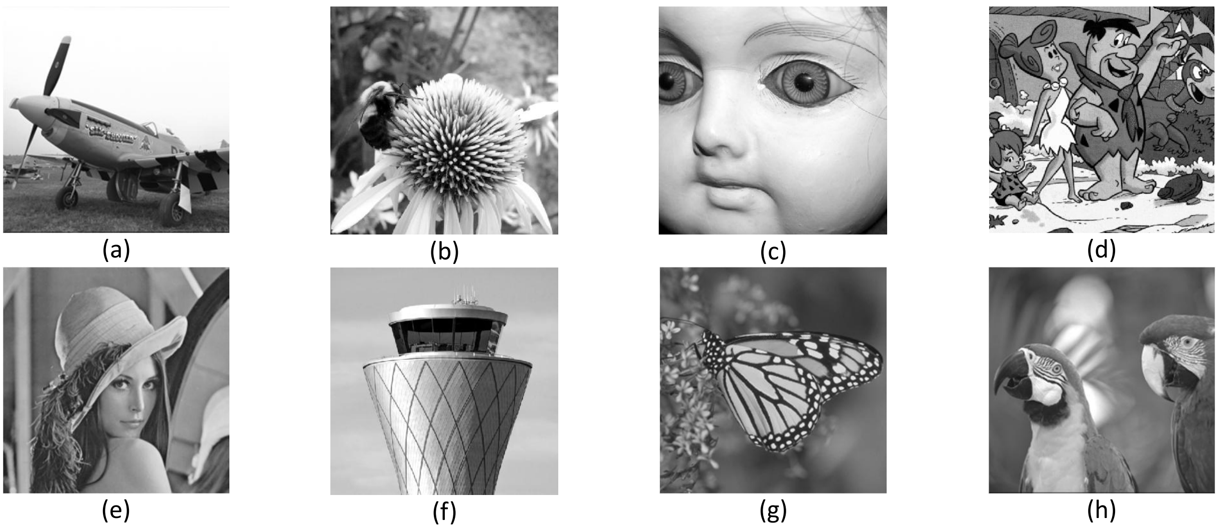

Fig. 1. Set of images test (a) Airplane; (b) Bee; (c) Face; (d) Flinstones; (e) Lena; (f) Lighthouse; (g)Monarch; (h) Parrot

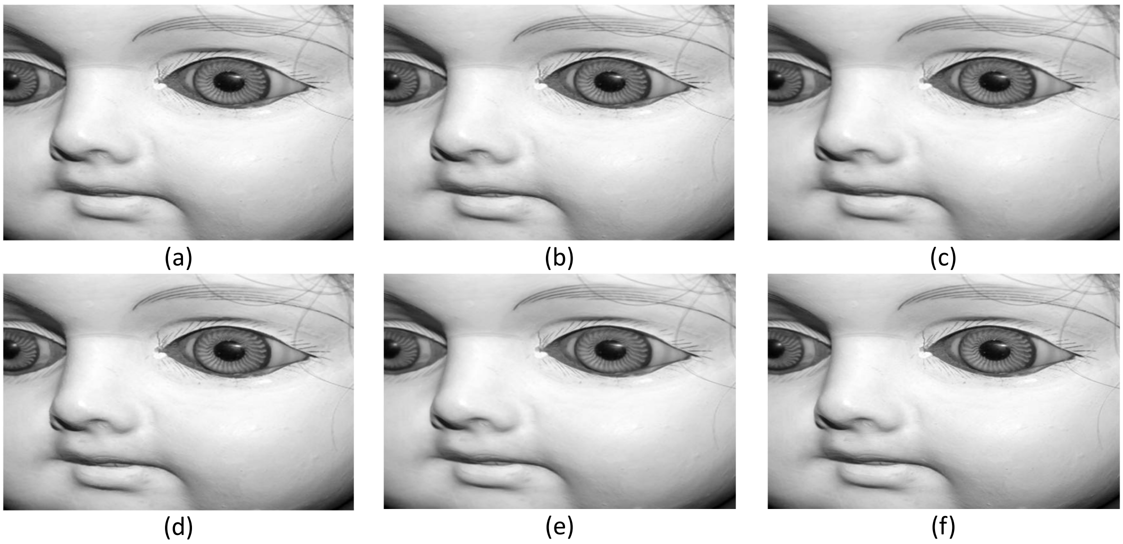

Fig. 2. The interpolated images results of 'Face' (a) Cubic spline; (b) DFDF; (c) ICBI; (d) INEDI; (e) NEDI; (f) Proposed

Fig. 3. The interpolated images results of 'Lena' (a) Cubic spline; (b) DFDF; (c) ICBI; (d) INEDI; (e) NEDI; (f) Proposed

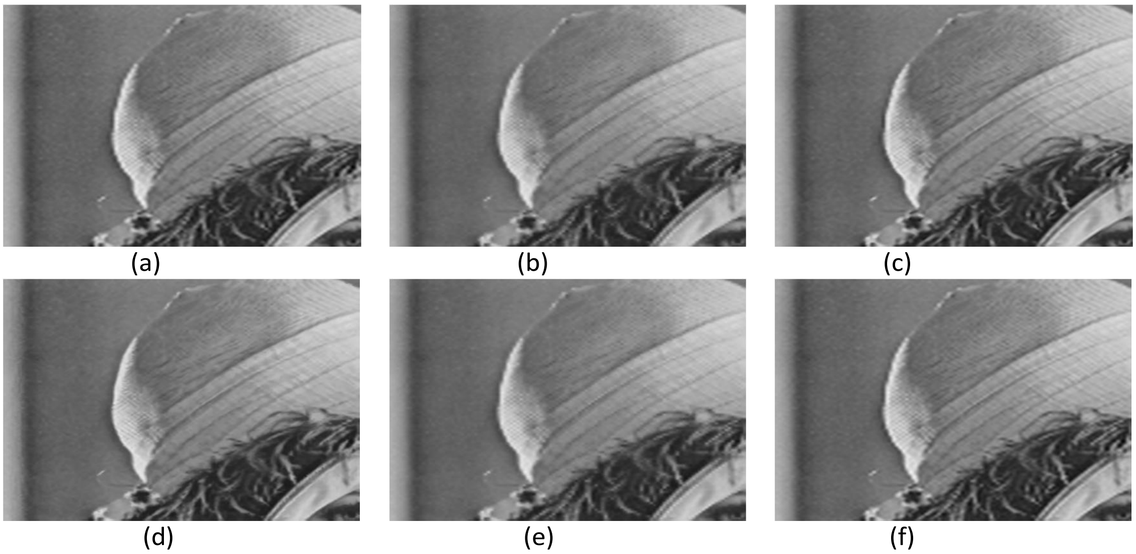

Fig. 4. The interpolated zoomed image results of 'Lena' a) Cubic spline; (b) DFDF; (c) ICBI; (d) INEDI; (e) NEDI; (f) Proposed

The above proposed method was compared to the other interpolation methods; in the part of the subjective appearance of the resulted image, as can be seen in Fig. 2-4, the cubic spline interpolation [14] contains many aliasing artifacts and generates prominent jaggies along sharp edges. This method is in general inferior to the others in visual quality. The NEDI [4] and INEDI [17] are very competitive in terms of visual quality. This is primarily because they preserve long edges well,but these methods are still affected by the ringing effect. DFDF [6] and ICBI [8] interpolation methods take a middle ground between the cubic spline interpolation [14] and edge-directed interpolation NEDI [4] and INEDI [17]. They reproduce sharper large scale edges than the bicubic method, but the reconstruction of these methods is not as good as the method of [4] and [17].

Table 1. Comparison of PSNR results of the reconstructed images(db)

Image	**CS** [14] **(db)**	**DFDF** [6] **(db)**	**ICBI** [8] **(db)**	**NEDI** [4] **(db)**	**INEDI**[17] **(db)**	**Proposed (db)**
Airplane	29,77	30,20	29,65	**30,33**	30,01	30,28
Bee	34,39	35,05	34,31	33,59	33,32	**35,18**
Face	40,53	40,84	40,11	40,21	39,19	**41,27**
Flinstones	26,93	27,03	26,97	26,49	27,03	**27,65**
Lena	33,81	33,77	33,87	33,75	33,20	**34,13**
Lighthouse	32,52	32,61	32,62	33,64	32,82	**33,59**
Monarch	30,16	30,71	30,85	30,21	**31,26**	31,13
Parrot	33,31	33,15	33,10	33,51	33,49	**33,87**
Average	32,68	32,92	32,69	32,71	32,54	**33,39**

The interpolated image of our proposed algorithm can still reconstruct the sharp edges without introducing many artifacts, and the edges and textures reconstructed by our method are much sharper and cleaner than others. Also, more image details are recovered by our method. This proves the strong edge preservation capability of the proposed method.

On the other hand, the highest PSNR value of each row is shown in bold. The PSNR results of the proposed method yields the better performance over the above-mentioned methods for all testing images, and exceeds the average PSNR value of the second best method by 0.47 dB. For the image 'Parrot' with rich textures, the proposed method also has a PSNR improvement of 0.36 dB over the second best method.

5 CONCLUSION

A novel method of image interpolation has been developed; this method consists in interpolating the missing pixel along the detected edge direction by using a cubic spline interpolation. Furthermore, this method has been implemented and tested. From the experimental results, it's clear that the proposed method provided the best improvement than the other interpolation methods, and generated a best high-resolution image, which their PSNR indicates the performance of the proposed method over the afore-mentioned interpolation methods.

Therefore, the proposed method can preserve a number of directional edges in the interpolation process along the estimated edge directions, and can suppress undesirable artifacts such as noise and blurring, caused by the classical interpolation methods.

REFERENCES

[1] G. Ramponi, “Warped distance for space-variant linear image interpolation,” *IEEE Trans. Image Process.*, vol. 62, no. 5, pp. 629 – 639, 1999.

[2] J. W. Hwang and H. S. Lee, “Adaptive image interpolation based on local gradient features,” *IEEE Signal Process. Lett.*, vol. 11, no. 3, pp. 359 – 362, 2004.

[3] K. Jensen and D. Anastassiou, “Subpixel edge localization and the interpolation of still images,” *Image Process. IEEE Trans.*, vol. 4, no. 3, pp. 285 – 295, 1995.

[4] X. Li and M. T. Orchard, “New edge-directed interpolation,” *IEEE Trans. Image Process.*, vol. 10, no. 10, pp. 1521 – 1527, 2001.

[5] D. D. Muresan and T. W. Parks, “Prediction of image detail,” *Process. Int. Conf. Image 2000*, vol. 2, 2000.

[6] L. Zhang and X. Wu, “An edge-guided image interpolation algorithm via directional filtering and data fusion,” *Image Process. IEEE Trans.*, vol. 15, no. 8, pp. 2226 – 2238, 2006.

[7] Y. Cha and S. Kim, “The error-amended sharp edge (EASE) scheme for image zooming,” *Image Process. IEEE Trans.*, vol. 16, no. 6, pp. 1496 – 1505, 2007.

[8] A. Giachetti and N. Asuni, “Fast Artifacts-Free Image Interpolation,” *Br. Mach. Vis. Conf. Leeds UK*, pp. 123–132, 2008.

[9] W. K. Carey and S. S. Hemami, “Regularity-preserving image interpolation,” *IEEE Trans. Image Process.*, vol. 8, no. 9, pp. 1293 – 1297, 1999.

[10] D. Zhou, X. Shen, and W. Dong, “Image zooming using directional cubic convolution interpolation,” *IET Image Process.*, vol. 6, no. 6, pp. 627 – 634, 2012.

[11] M.-J. Chen and W.-L. Lee, “A fast edge-oriented algorithm for image interpolation,” *Image Vis. Comput.*, vol. 23, no. 9, pp. 791 – 798, May 2005.

[12] R. Keys, “Cubic convolution interpolation for digital image processing,” *IEEE Trans. Acoust. Speech Signal Process.*, vol. 29, no. 6, pp. 1153 – 1160, May 1981.

[13] M. Unser, “Splines: A perfect fit for signal and image processing,” *IEEE Signal Process. Mag.*, vol. 16, no. 6, pp. 22 – 38, Nov. 1999.

[14] P. Thevenaz, T. Blu, and M. Unser, “Image Interpolation and Resampling,” *Handb. Med. Imaging Process. Anal. Bankman Ed Acad. Press San Diego Ca USA*, pp. 393 – 420, 2000.

[15] P. Thévenaz and M. Unser, “Interpolation revisited [medical images application,” *IEEE Trans. Med. Imaging*, vol. 19, no. 7, pp. 739 – 758, 2000.

[16] I. J. Schoenberg, “Contribution to the problem of approximation of equidistant data by analytic functions,” *Quart Appl Math*, vol. 4, no. 2, pp. 45 – 99, 1946.

[17] N. Asuni and A. Giachetti, “Accuracy improvements and artifacts removal in edge based image interpolation,” *Proc 3rd Int Conf Comput Vis Theory Appl. VISAPP08*, 2008.

[18] S. Dube and L. Hong, “An adaptive algorithm for image resolution enhancement,” *Signals Syst. Comput. 2000 Conf. Rec. Thirty-Fourth Asilomar Conf.*, vol. 2, 2000.

[19] R. Kimmel, “Demosaicing: Image reconstruction from color CCD samples,” *IEEE Trans. Image Process.*, vol. 8, pp. 1221 – 1228, 1999.

[20] J. Allebach and P. W. Wong, “Edge-directed interpolation,” *Proc. Int. Conf. Image Process. 1996*, vol. 3, pp. 707–710, 1996.

[21] D. R. Cok, “Signal processing method and apparatus for producing interpolated chrominance values in a sampled color image signal,” *US Pat. No 4642678*, 1987.