Improvement of Image Zooming Using Least Directional Differences based on Linear and Cubic Interpolation

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***Abstract*—There are many interpolation methods, among them, bilinear (BL) and bicubic (BC) are more popular. However, these methods suffer from low quality edge blurring and aliasing effect. In the other hand, if high resolution images are not available, it is impossible to produce high quality display images and prints. To overcome this drawback, in this paper, we proposed a new method that uses least directional differences of neighbor pixels, based on preceding bilinear and bicubic interpolation methods for images. The qualitative and quantitative results of proposed technique show that this method improves bilinear and bicubic interpolations. The proposed algorithm can also be applied both to RGB and gray level images.**

***Index Terms*— Cubic interpolation, direction difference, linear interpolation, Image zooming, qualitative and quantitative analysis.**

I. INTRODUCTION

In the today's world graphic arts, with no doubt, most people count with the problem of low resolution images because of poor hardware capability of cameras used to take photos especially ones mounted on cell phones. In return, this low resolution effects leads to low quality in image processing procedures such as image scaling enhancement and etc. To solve this problem, i.e. converting low resolution image to higher ones, various zooming methods and algorithms have been proposed [1], [2], yet there are some basically drawbacks in all of them. Some of the most common zooming methods are pixel replication [3], bilinear interpolation (BL) [4], [5] and bicubic interpolation (BC) [6]. Pixel replication method is a technique of nearest neighbor interpolation, which is simple to implement thus replicating the original pixels. This method is usually capable to the undesirable defect of blocking effects. Bilinear and bicubic interpolation, achieve more pleasing affect. Usually in these commonly used interpolation techniques, there exists a problem where the low order interpolation method degrades the zoomed image quality, despite that lower order interpolation method requires less computation as well as that higher order interpolation method which yields better results requires more computations [13]. These popular methods cause undesired effects during zooming procedure, e.g. low quality edge blurring or making jagged or synthetic edges. The averaging has an anti-aliasing effect and therefore produces relatively smooth edges with hardly any jaggies. Our proposed method in this paper is more sophisticated and produces smoother edges than both bilinear and bicubic interpolations. The advantage of this approach is that fine details can be retrieved when producing high-resolution images.

The organization of this paper is as follows. In section II, the basis of linear and cubic interpolations is described. In section III, the proposed method is presented. Section IV gives the experimental results of competitive methods discussed in this paper and also shows the significant improvement of zooming procedure. Finally, section V includes a summery of our development and the proposed method preferences to BL and BC interpolations.

II. PREVIOUS INTERPOLATION METODS

In this section, linear and cubic interpolation methods are reviewed.

A. *Linear Interpolation Method*

If I is a 1D discrete signal, then for magnifying k times or in another words, to zoom the signal, it is usual to use linear interpolation[4], [5]. Fig. 1(a), illustrates initial signal I. for magnifying k times, $k-1$ points have to be padded between two I's points. The new padded signal is named Z, which is shown in Fig. 1(b). symbol ● stands for I's points and symbol □ stands for points of signal Z. To find out pixel value $Z(ki-n)$, the following formula is used:

$$Z(ki-n) = a\frac{n}{k} + b(1-\frac{n}{k}) \tag{1}$$

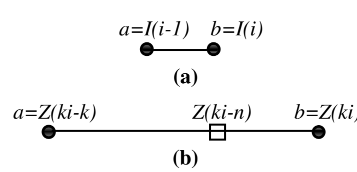
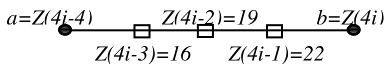


Fig. 1. (a) The solid circular dots indicate points from the initial signal *I*, **(b)** points of zooming signal *Z*

In (1), *k* is an integer zooming factor, *i* is determine the point position, *a* and *b* are initial signal *I* values and finally *n* is the position of resulting pixel in magnified signal (*n=1, 2,…, k-1*). For instance, if *a*, *b* and *k* takes the values *13*, *25* and *4*, respectively, then according to (1), the magnified signal *Z* values are as follows:



B. Cubic Interpolation Method

Same as previous subsection, suppose *I* as a 1D discrete signal. In this subsection, signal *I* is to be zoomed by using cubic interpolation method [5]. Fig. 2(a) shows initial signal *I*.

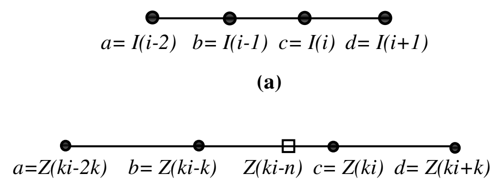


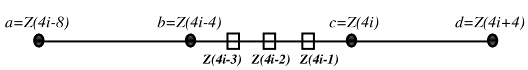
Fig. 2. (a) Initial points of signal *I*, **(b)** points of zoomed signal *Z*

For zooming *I*, *k* times using cubic interpolation method, it is necessary to pad *k*-1 points between each two points of signal *I*. The resulting signal is named as *Z* and is shown in fig. 2(b). For finding *Z(ki-n)*, the following formula is used:

$$n = 1,2,\ldots,k-1$$
$$t = -\frac{n}{k} + 1$$
$$Z(ki-n) = 0.5 \times \begin{bmatrix} 1 & t & t^2 & t^3 \end{bmatrix} \times \begin{bmatrix} 0 & 2 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 2 & -5 & 4 & -1 \\ -1 & 3 & -3 & 1 \end{bmatrix} \times \begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix} \quad (2)$$

Where *a*, *b*, *c* and *d* are initial signal value, *k* is an integer zooming factor, *i* determines the original points position and *n,* the computed points position (*n=1,2,…,k-1*).

As an example, suppose that *a=5*, *b=20*, *c=20*, *d=8* and *k=4*, then results are as follows:



Z(4i-1) = 21.19, Z(4i-2) = 21.68, Z(4i-3) = 21.33

III. THE PROPOSED METHOD

In this section, the proposed algorithm is described for gray level image. This algorithm includes two stages and the second stage is divided into multiple substages.

A. First Stage

In this stage, it is supposed that input image *I* has *M*×*N* pixels and the zoomed image, *Z* has been magnified with zooming factor *k*, at the beginning of the proposed algorithm, pixels value shown with symbol □ in Fig .3(b) have been calculated using linear interpolation. In the next step, for computing pixels value *Z(ki-k,kj-n)*, *n=1,2,…,k-1*, it is necessary to apply linear interpolation method by using pixels *a* and *b*. At the same step, pixels value *Z(ki-m,kj-k)*, *m=1,2,…,k-1*, are to be calculated using pixels *a* and *c* in linear interpolation. Also, for computing pixels value *Z(ki-m,kj)*, *m=1,2,…,k-1*, interpolation of pixels value *b* and *d* have to be used. At last, for calculating pixel value *Z(ki,kj-n)*, *n=1,2,…,k-1*, it is necessary to use pixel value c and d for interpolation.

For example, if *k=3*, *a=12*, *b=21*, *c=18* and *d=6*, then the result of calculating pixel values Z, as mentioned above, are as follows:

I

12	**21**
18	**6**

Z

12	15	18	**21**
14	-	-	16
16	-	-	11
18	14	10	**6**

It is important to mention that in this stage, cubic interpolation can also be applied for calculating *Z* pixels (□s). We name our proposed method according to the first stage; LDDL for linear interpolation and LDDC for cubic interpolation.

B. Second Stage

This stage computes *Z(ki-m,kj-n)* pixels *for m=1,2,…,k-1*, *n=1,2,…,k-1*. At first, let *X=Z(ki-m,kj-n)*. According to Fig. 4, computed pixels value in the previous stage, i.e., *A, B, C, D, E, F, G* and *H* are employed to calculate *d(1), d(2), d(3)* and *d(4)* using the following formulas:

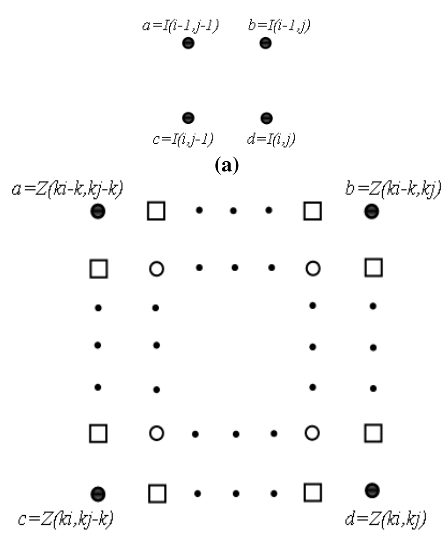
$$\begin{cases} d(1) = |A - B| \\ d(2) = |C - D| \\ d(3) = |E - F| \\ d(4) = |G - H| \end{cases} \quad (3)$$

After computing *d(1), d(2), d(3)* and *d(4)* from (3), the minimum of them is chosen as follows:

$$md = \underset{i}{Min}\left(d(i)\right) \quad i = 1,2,3,4 \quad (4)$$

If *md=d(1)*, then pixel value *X* is computed by using linear interpolation between pixels *A* and *B*.

If *md=d(2)*, then pixel value *X* is calculated by using linear interpolation between pixels *C* and *D*.



(b)

Fig. 3. (a)) The solid circular dots are Pixels of initial image, (b) Pixels of zooming image with zooming factor k

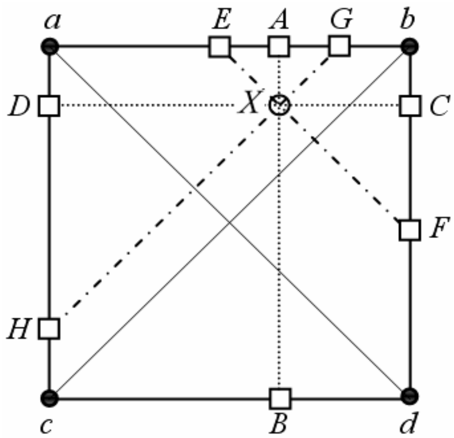


Fig. 4. pixels of zooming image with directional pixels

If $md=d(3)$, then pixel value X is computed by using linear interpolation between pixels E and F. At last, if $md=d(4)$, then pixel value X is calculated by using linear interpolation between pixels G and H. The result of these computations is shown below:

I

12	21
18	6

Z

12	15	18	21
14	14.66	15.33	16
16	14.33	15	11
18	14	10	6

As a matter of fact, it may not possible to interpolate using other orientations except for those used in our method (i.e. o°, 45°, 90° and 135°). This is because the neighbor pixels for other orientations may not exist.

An important advantage of the proposed method to *BL* and *BC* interpolation methods is its better edge blurring specially for edges oriented in 45º and 135º, as shown in Fig. 5.

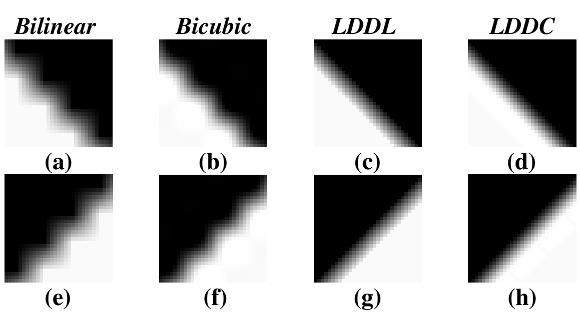


Fig. 5. Visual comparison between interpolations with directional edges 45° and 135°

IV. EXPERIMENTAL RESULTS

To evaluate the proposed method in comparing with bilinear (*BL*) and bicubic (*BC*) zooming methods, several experimental factors are set up to examine quality of zoomed images. The first factor is visualization as a subjective one. The other factors are *mean square error* (*MSE*), *mean absolute error* (*MAE*) and *cross correlation coefficient* (*C*) which are statistical criteria. The proposed method is compared with mentioned methods in this paper, using above factors. The results of quantitative analysis of zoomed images using the proposed method are shown in Fig 7 and 8. In the Lena's zoomed image with original size of 90×90 pixels, the better edge blurring results are obvious on the hat edges of the proposed method, in comparison with the other two images zoomed by *BL* and *BC* methods. Fig. 6(b), is an image produced synthetically. The original size of this image is 50×50 pixels. Fig. 8 shows its zoomed images using *BL*, *BC* and the proposed interpolation method. Again, zooming by the proposed method shows better edge blurring results than the other two methods. To rate image zooming techniques statistically according to human vision, three more criteria are introduced as the following:

$$MSE = \frac{\sum_{x=1,y=1}^{M,N}\left(\hat{I}(x,y)-I(x,y)\right)^2}{MN} \tag{5}$$

$$MAE = \frac{\sum_{x=1,y=1}^{M,N}\left|\hat{I}(x,y)-I(x,y)\right|}{MN} \tag{6}$$

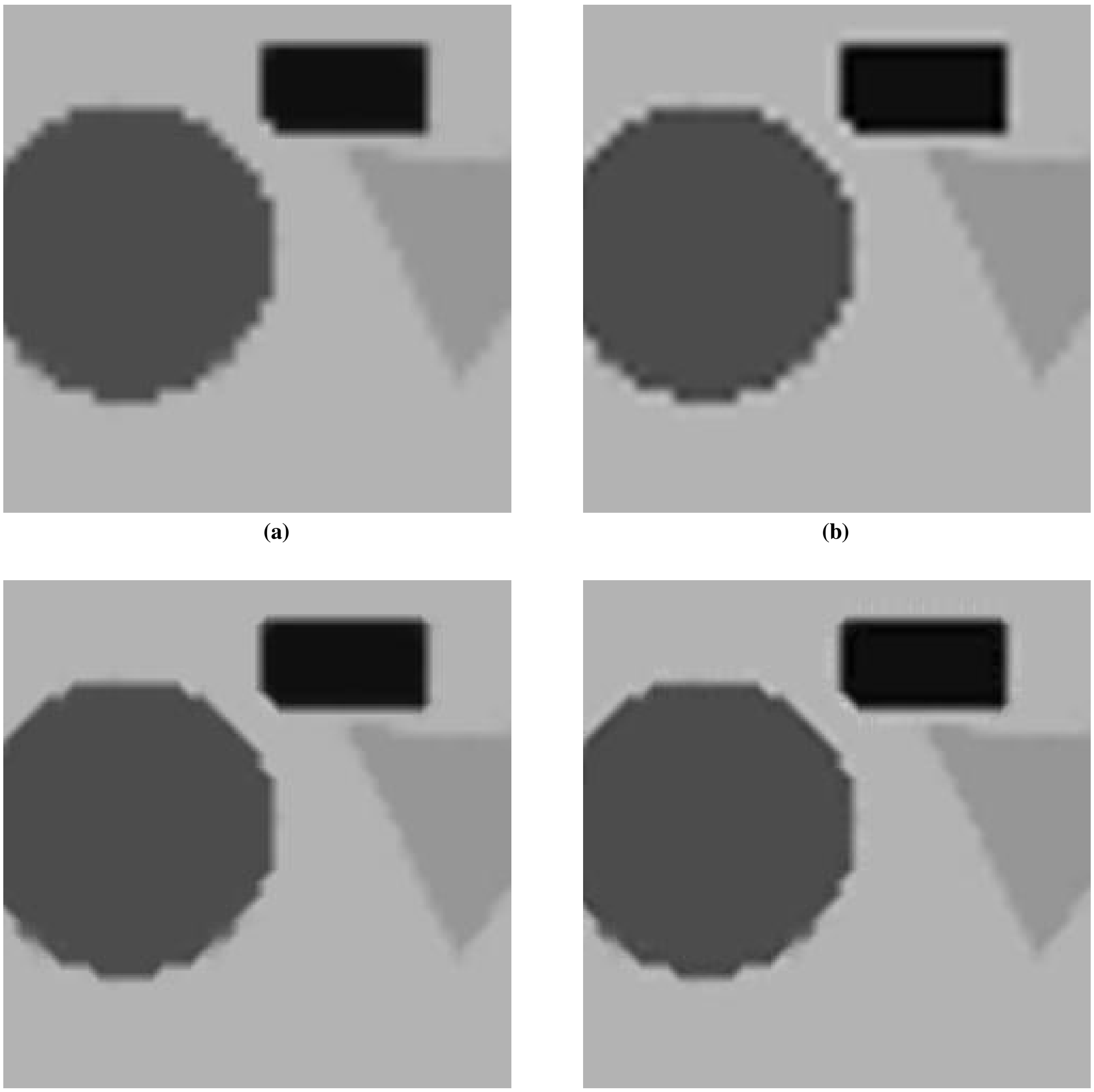
$$C = \left| \frac{\left[\sum_{x=1,y=1}^{M,N}\hat{I}(x,y)I(x,y)-MNab\right]}{\sqrt{\left(\sum_{x=1,y=1}^{M,N}\hat{I}^2(x,y)-MNa^2\right)\left(\sum_{x=1,y=1}^{M,N}I^2(x,y)-MNb^2\right)}} \right| \tag{7}$$

The use of these ranking criteria contains two steps. In the first step, original image is shrink into smaller size using a definite zoom out factor k and in the second step, zoomed out image is magnified to its original size using the zooming methods discussed here. In the above equations, $\hat{I}$ is the zoomed image, I is the original one, *a* and *b* are mean values of images $\hat{I}$ and I , *M* and *N* denote width and length of images.

Now, it is possible to compute *MSE*, *MAE* and *C* using (5), (6) and (7), for the several images. it is important to mention that *C* belongs to the interval [0,1]. The more the coefficient approaches 1, the better the reconstruction quality. The results of preceding criteria are shown in Tables 1 through 3. In all of them, zooming factor is $k=3$. Tables 1 include *MSE* calculated by using (5), confirm better efficiency of the proposed method to the other ones, specially with use of cubic interpolation in the first computation step of proposed method. The results shown in tables 2 which refer to *MAE*, again show less error in the images zoomed by the proposed method then the other two methods, i.e. *BC* and *BL* interpolations. Table 3 include cross correlation coefficients which are greater then for our method compared with other methods.

(a) (b)

Fig. 6. Sample image, (a) Lena in (90×90) cells, (b) Synthetic image in (50×50) cells



(a) (b) (c) (d)

Fig. 7. Synthetic image (6×6) magnified images by (a) the bilinear method, (b) the bicubic method, (c) LDDL method, and (d) LDDC method

(a) (b) (c) (d)

Fig. 8. Lena (4×4) magnified images by (a) the bilinear method, (b) the bicubic method, (c) LDDL method, and (d) LDDC method

Table. 1. *Minimum Square Error (MSE)*

Images	***BL***	***LDDL***	***BC***	***LDDC***
Pic1	127.6826	125.3857	129.0323	125.9689
Pic2	96.3321	93.2908	91.6993	90.3580
Pic3	208.8258	209.8359	213.6492	211.6956
Pic4	330.2595	332.9931	349.0603	346.5739
Pic5	242.6935	234.6361	248.6950	236.9914

Table. 2. *Mean Absolute Error (MAE)*

Images	*BL*	*LDDL*	*BC*	*LDDC*
Pic1	6.4443	6.3141	6.4816	6.3263
Pic2	6.0594	5.9227	5.9995	5.8768
Pic3	8.5567	8.4946	8.5943	8.4896
Pic4	11.8068	11.7312	12.0993	11.9462
Pic5	7.5710	7.2841	7.7933	7.4183

Table. 3. *Cross-Correlation Coefficient (C)*

Images	*BL*	*LDDL*	*BC*	*LDDC*
Pic1	0.9714	0.9719	0.9712	0.9718
Pic2	0.9784	0.9790	0.9794	0.9797
Pic3	0.9771	0.9769	0.9766	0.9768
Pic4	0.8682	0.8677	0.8635	0.8642
Pic5	0.9651	0.9662	0.9644	0.9660

V. CONCLUSION

The zooming method proposed in this paper, is based on least differential directions applied to the BL and BC interpolations. The experimental results show that this method has better and more efficient zooming results than the other competitive methods discussed here and that is because of considering edges with both 45° and 135° orientations in addition to 0° (180°) and 90° (270°) edges. Another advantage of this method is its simplicity in implementation. At the end, the proposed method improves zooming results even for low resolution images in both qualitative and quantitative aspects.

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