Image Magnification Using Adaptive Interpolation by Pixel Level Data-Dependent Geometrical Shapes

Muhammad Sajjad, Naveed Khattak, and Noman Jafri

***Abstract*—**World has entered in 21st century. The technology of computer graphics and digital cameras is prevalent. High resolution display and printer are available. Therefore high resolution images are needed in order to produce high quality display images and high quality prints. However, since high resolution images are not usually provided, there is a need to magnify the original images. One common difficulty in the previous magnification techniques is that of preserving details, i.e. edges and at the same time smoothing the data for not introducing the spurious artefacts. A definitive solution to this is still an open issue. In this paper an image magnification using adaptive interpolation by pixel level data-dependent geometrical shapes is proposed that tries to take into account information about the edges (sharp luminance variations) and smoothness of the image. It calculate threshold, classify interpolation region in the form of geometrical shapes and then assign suitable values inside interpolation region to the undefined pixels while preserving the sharp luminance variations and smoothness at the same time.

The results of proposed technique has been compared qualitatively and quantitatively with five other techniques. In which the qualitative results show that the proposed method beats completely the Nearest Neighbouring (NN), bilinear(BL) and bicubic(BC) interpolation. The quantitative results are competitive and consistent with NN, BL, BC and others.

***Keywords*—**Adaptive, digital image processing, image magnification, interpolation, geometrical shapes, qualitative & quantitative analysis.

I. Introduction

TODAY, there is a huge amount of digital images available to computer users. This is caused by the rapid growth both in computer hardware and software technologies. Low price digital cameras are now common, and as a result users are able to buy them and take as many digital images as desired. The significant development in the field of computer graphics has also boosted the production of digital images. As computer users become more familiar with digital images, the need to display and print them also increases. In an era where high-resolution display and printing devices are common, it is vital that high-resolution images are available in order to produce high quality displayed images and high quality prints. This is particularly important for desktop publishing, large artistic printing, etc. The problem is that high-resolution images are not usually provided. In these cases, there is a need to magnify the original images. Therefore, the development of a good image magnification algorithm is very important.

Until now, a large number of interpolation techniques for magnifying images have been proposed. A typical problem with most interpolation techniques is that although smoothing the data and keeping the low frequencies in the new zoomed picture, they are not able to enhance the high frequencies or preserve the edges equally well. Visually those problems will result in either blurring or blocking artifacts. A possible solution would need a sort of non-linear interpolation, taking into account the directional variation for maintaining the sharpness of the new enlarged image and smoothness as well.

The simplest method to magnify images is the pixel replication. However, the resulting magnified images have aliasing effect in the form of jagged edges. Nearest neighbor interpolation is the simplest method and basically makes the pixels bigger. The color of a pixel in the new image is the color of the nearest pixel of the original image[4]. Most image viewing and editing software use this type of interpolation to enlarge a digital image for the purpose of closer examination because it does not change the color information of the image and does not introduce any anti-aliasing. For the same reason, it is not suitable to enlarge photographic images because it increases the visibility of jaggies. More elaborate approaches use the bilinear or the bicubic interpolation. Bilinear Interpolation determines the value of a new pixel based on a weighted average of the 4 pixels in the nearest 2 x 2 neighborhood of the pixel in the original image [4]. The averaging has an anti-aliasing effect and therefore produces relatively smooth edges with hardly any jaggies. Bicubic interpolation is more sophisticated and produces smoother edges than bilinear interpolation. Here, a new pixel is a bicubic function using 16 pixels in the nearest 4 x 4 neighborhood of the pixel in the original image [1, 4]. This is the method most commonly used by image editing software, printer drivers and many digital cameras for resampling images. Commercial software Adobe Photoshop [1] provides these two functions for interpolating images. Other methods, using the B-spline interpolators [8, 11] or the cubic convolution methods [10] have also been proposed. However, these methods tend to blur the edges and cause them to be jagged.

Research on interpolating images taking into account the edges, has gained much attention. Allebach and Wong [2] proposed methods that search for edges in the input image and use them to assure that the interpolation does not cross

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them. The problem is one of how to define and find the important edges in the input image. Other edge-adaptive methods have been proposed by Jensen and Anastassiou [9], Li and Orchard [12], and Muresan and Parks [15, 16, 17, 18] . Currently, the methods presented in [12, 18] are the most widely known edge-adaptive methods. They can well enough avoid jagged edges, but a limitation is that they sometimes introduce highly visible artifacts into the magnified images, especially in areas with small size repetitive patterns. X. Yu, B. Morse, T.W Sederberg [19] presented a method that computes a triangulation of the input image where the pixels in the input image are the vertices of the triangles in the triangulation. The input image at any arbitrary scale is reconstructed by rendering its triangulation. However, since the edges in the input image are approximated using piecewise linear segments, curved edges cannot be properly reconstructed especially when the scaling factor is a large number. Morse and Schwartzwald [14] presented a level-set reconstruction method to solve the problem of jagged edges. Their approach starts by magnifying the input image using the bicubic interpolation method, then iteratively smoothing the contours in the image. This approach, however, does not overcome the blurring problem found in the bicubic interpolation method. Hertzmann *et al.* [7] and Freeman *et al.* [3] proposed methods that learn the correspondences between low and high resolution images from a set of training data. The advantage of these approaches is that fine details can be added when producing high-resolution images when the input image is in the same class of image as the training data. The disadvantages of these approaches are that they will fail if the input image is not in the same class as the training data and that the computational cost is high. Variational based approaches for image magnification have been presented by Malgouyres and Guichard [13]. The magnified images obtained using these methods are better than those obtained using the bicubic interpolation method. However, since these methods solve optimization problems where all the pixels in the magnified image are unknowns, these methods, too, have high computational costs. As a result, they are not suitable for practical use. Another good approach is presented by Henry Johan and Tomoyuki Nishita [5] which produces a high quality magnified image. They have proposed a progressive refinement approach for image magnification. They also claimed for sharp magnified image without generating distinct artifacts but some times it also produce jaggeis to magnify the image. Muneeb, Naveed khattak (KM) [6] and . Battiato, G. Gallo, and F. Stanco[20] also proposed an adaptive approach for image magnification which produces a high quality magnified image while preserving information contents of original image but it has also some defects. These [6, 20] has also been considered in qualitative and quantitative analysis of this paper.

The main contribution of this paper is to produce an enlarge image with high visual quality of the original image. The basic idea of the proposed technique is to separate the interpolation region in the form of geometrical shape and then the interpolator assign a proper intensity value to the undefined pixel inside this interpolation region. It does not require a preliminary gradient computation because the relevant information is collected during magnification process. The proposed technique is so intelligent that it can differentiate between low and high frequency content of the source image and thus it preserve the visual sharpness of the original image. The proposed technique is very easy to implement and efficient as well than other proposed techniques.

The quantitative and qualitative analysis of proposed technique shows that it has covered some of the weakness of other proposed technique up to some extent with respect to quality and efficiency.

II. Thresholding

Because of its intuitive properties and simplicity of implementation, image thresholding play a vital roll in application of digital image processing. In image magnification thresholding also plays a key roll in preservation of edges. So it's most important to select a suitable threshold during interpolation to preserve the fine detail of the image. To preserve the visual quality of the image, the threshold on the basis of safe color [21] is calculated. There are 16 true gray shades from 0 to 255 which can be differentiated visually.

Fig. 1 Sixteen Safe Gray Colors in the 256-Color RGB System

As in Fig. 1 there are 16 safe colors out of 256. If '256' is divided by '16' we will get 16 as a Quotient. It means that after adding 16 to any gray shad then it will change its visual depiction. To calculate the threshold ***'T'*** for the preservation of the edge using above concept. If N is equal to 16 and where $X_1=0$, $X_2=2$,.......... $X_N=15$ and Median denoted by M_d is defined as:

$$M_d = (X_{N/2} + X_{N/2+1})/2 \quad (1)$$

$$\boldsymbol{T} = M_d \quad (2)$$

It has been proved experimentally that it gives excellent result in preservation of edges during magnification and this threshold is also considered during magnification process.

III. Classification of Interpolation Regions and Geometrical Shapes

Edge preservation plays very important roll in magnification because it specifies the interpolation region in which interpolator adopt itself according to the region. To consider all possible interpolation region during magnification algorithm and assign a suitable value to the undefined pixel is very important. The concept relies on using the low resolution(LR) image to find zero crossing that indicate the presence of an edge passing through LR unit cell. These zero-crossing are then linked by straight line segments to obtain an estimate of the edge which divide the region in different interpolation region. The zero crossing are determined by applying Second order derivative on the LR image then for every LR unit cell after applying 2^{nd} derivative the absolute value either on each side of the zero is compared to the threshold calculated in section 2. If the value is greater than threshold it mean that the point of high contrast is present as shown in Fig. 2.

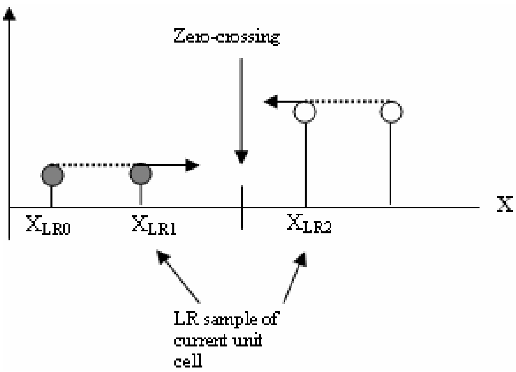


Fig. 2 Determination of zero-crossing and its parameter

In Fig. 2 sequence of LR samples from some function f are given. Now calculate the point of high contrast by applying $\partial^2 f / \partial^2 x$ on sequence of LR unit cell of some function f. After calculation the magnitude on either side of zero-crossing is compared as in equation 3.

$$\partial^2 f / \partial^2 x = f(x_{LR2}) + f(x_{LR0}) - 2f(x_{LR1})$$

$$\left| \partial^2 f / \partial^2 x \right| > \boldsymbol{T} \qquad (3)$$

If the above statement is true then it mean that there is point of high contrast i.e. edge is present. So to make the above description as a base, a LR (original image) unit cell is analyzed consist on four pixels and determines the point of high contrast to categorize the edges, which split the LR unit cell into different interpolation and its orientation. In this way the interpolation regions are classified which make different geometrical shapes.

A. Constant Region

The LR unit cell which has not any point of high contrast among the pixels is a linear area. It consists only on one interpolation region.

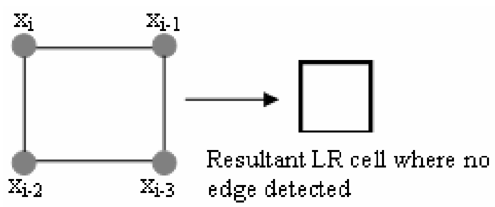


Fig. 3 Area where no edge passing through an LR unit cell

In Fig. 3 circles show pixels and their color content shows intensity level. All the pixels are at the same level of intensity, so the resultant region is linear and the total number of interpolation region is one, it has also been visualize in the form three dimensions as in Fig. 4.

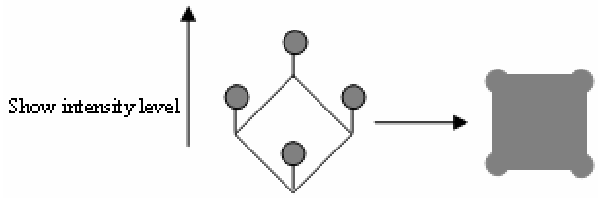


Fig. 4 3 D visualization of Fig. 3

As in Fig. 4 all the pixels are at the same level and it create a shape of *square* which consist only on one interpolation region.

B. LR Region with Corner Edges

The LR unit cell where an edge separates one pixel from the other three pixels of the LR unit cell. When the point of high contrast separate one pixel from the other three i.e. this pixel will have a value substantially different to the other three. This also call the outlier, imagine in Fig. 5.

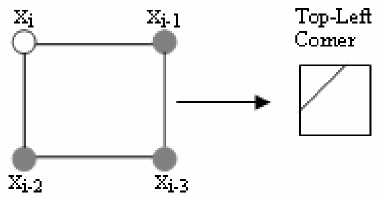


Fig. 5 LR unit cell where edge separate one corner from the other three i.e. two interpolation regions

In Fig. 5 color difference of pixels show intensity difference which has been explained above. This intensity difference split the LR unit cell in two interpolation region. It has been visualized in the following Fig. 6.

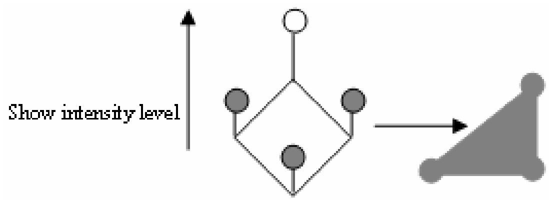


Fig. 6 Triangulation in a four-pixel square

In Fig. 6, pixels with same intensity level form a shape of triangle. This triangle has been considered one interpolation region. There are four possible cases of triangulation, which form triangle in different direction. So there are four different cases in which one pixel isolate from other three and in this way it divide the LR unit cell into two interpolation regions. The remaining cases have been shown in the next Fig. 7.

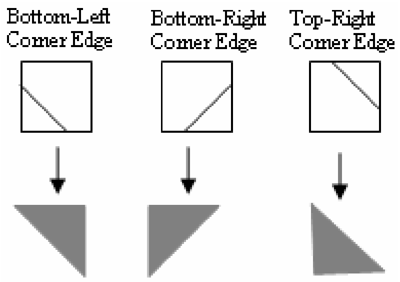


Fig. 7 Triangulations in a four-pixel square

In Fig. 7 these triangle in different direction are considered different interpolation region. If one pixel isolate itself form other pixels due to intensity difference in all scenarios, whatever the intensity difference, all three pixels will be considered in same region of triangle which has been shown above.

C. LR Region with Horizontal and Vertical Edeges

In this scenario edge separate a pair of pixels from other pair of pixels i.e. it split the LR cell in two horizontal or vertical regions having contrast intensity.

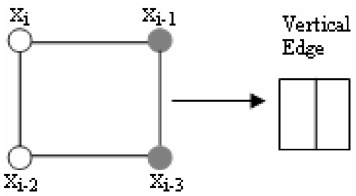


Fig. 8 Edge which split the LR unite cell vertically

In Fig. 9, one pair of pixels is on same side having different intensity level from other pair of pixels is on opposite side. So in such type of scenarios LR unit cell will be split horizontally or vertically.

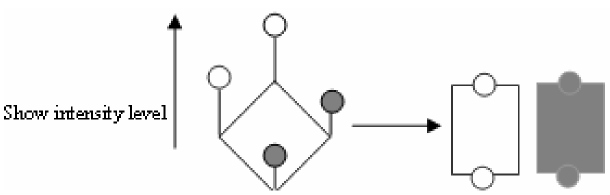


Fig. 9 Square split by edge into two interpolation region

The same process can be repeated for the horizontal case. Here important is the splitting of two poles, whether it is vertically or horizontally. If the intensity contrast occurs horizontally the shape of the LR unit cell will be become as in Fig. 10.

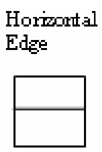


Fig. 10 Edge which split the LR unit cell into two horizontal interpolation regions

Now all the information is at hand about the interpolation regions. This information will be used in the implantation of algorithm. Due to this basic information the result of proposed algorithm has improved qualitatively and quantitatively as well. The concept of this section will be used in the coming section 'The Basic Concept of Algorithm'.

IV. THE BASIC CONCEPT OF ALGORITHM

In this section the detail description of the basic concept of proposed algorithm is described. First the proposed algorithm is explained for gray scale images and then it is generalized for colour images. Algorithm works in four phases. This has been described in this section.

In the first phase of the proposed algorithm the input image is expanded. Suppose the size of the input image is n x m where 'n' is number of rows and m is the number of columns. The image will be expanded to size of $(2n-1)$ x $(2m-1)$. The question arises that why one is subtracted from rows and columns. If it is not subtracted then there will be one additional row and column of undefined pixels which will have the intensity value of the adjacent row and column respectively. This is a sort of replication and the replication has been avoided completely in proposed algorithm.

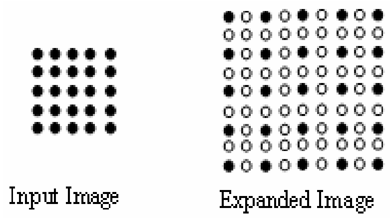


Fig. 11 Expansion phase showing source image (n x m) and expanded image (2n-1) x (2m-1)

In Fig. 11, solid circles show original pixels and hollow circles show undefined pixels. In the remaining three phases these undefined pixels will be filled with proper intensity values while preserving details and edges of original image and data smoothing.

The second phase of the algorithm is most important one. In this phase the interpolator assign value to the undefined pixel by pixel level data dependent geometrical shapes.

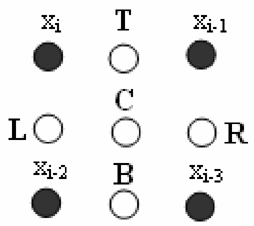


Fig. 12 HR unit cell with undefined pixels Top, Center, Bottom, Left, Right denoted by *T, B, C, L, R* respectively

As it has been mentioned that the assignment of proper intensity value to the undefined pixel is depend on the pixel level data dependent geometrical shapes. In this phase the algorithm scan the image and each time it consider the group of pixels as shown in Fig. 12 and checks that what type of geometrical shape form here. After confirmation of geometrical shape, it assigns value to the undefined pixel.

If the region is constant and there is no point of high contrast among the defined pixels of the High resolution (HR) cell as shown in Fig. 12. It will be confirmed by calculating the standard deviation of defined pixels in HR cell.

$$\sigma = \sqrt{\frac{(\overline{X} - Xi)^2 + (\overline{X} - Xi-1)^2 + (\overline{X} - Xi-2)^2 + (\overline{X} - Xi-3)^2}{N}} \quad (4)$$

$$2 * \sigma < \boldsymbol{T} \quad (5)$$

Where $\overline{X}$ is mean of defined pixels in HR cell and σ is standard deviation. If equation 5 is true it mean the HR cell is consist on constant region. No point of high contrast, then it form a square, and all the undefined pixels T, B, L, R, C which are inside the region of this square, will be assign the average value of the defined pixels in the HR cell and it will adopt a form as in Fig. 13.

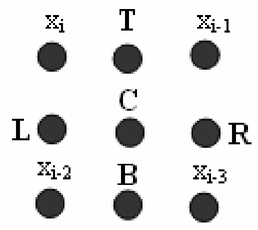


Fig. 13 HR cell which adopt the shape of Square. All undefined pixels inside this square, will have average intensity value of defined pixels

If the pixel X_i in the HR cell as shown in Fig. 12, isolate from other defined pixels due to intensity difference then there is a top-left corner edge, the detail also present in section 3.2 and it forms a shape of triangle. For confirmation, the standard deviation will be calculated of the defined pixels inside a triangle and then it will be compared with threshold as in equation 5 if it is true then it is a triangle with top-Left corner edge. After confirmation, all undefined pixels inside triangle which are C, R, B are assigned the average value of the defined pixels in the triangle which are x_{i-1}, X_{i-2}, X_{i-3} and other two undefined pixels of HR cell are left undefined and will be considered in next phase.

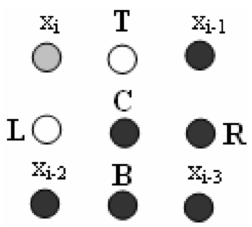


Fig. 14 A triangle with Top-Left corner edge

In Fig. 14 a circle 'x_i' has gray color which shows intensity difference from other three defined pixels of the triangle. The strength of employing triangles in this way is that edges are modeled in the image. In fact it tunes the interpolator to match the edges. In Fig. 14, when interpolating the HR pixel falling in triangle x_{i-1}, X_{i-2}, X_{i-3}, the interpolator will not use the value of x_i pixel which is very different to this plateau and thus the sharpness of the edge is kept. The interpolator keeps smoothness as well, even across triangle boundaries. The same procedure has been repeated for other three cases of triangle which are bottom-left corner edge triangle, top-right corner edge triangle and bottom-right corner edge triangle, detail present in section 3.2.

In case when pair of pixels on different poles have contrast intensity which split the HR square region into two vertical or horizontal regions, also explained in section 3.3. The pixels on the same side having intensity difference less then threshold will be considered in the same region.

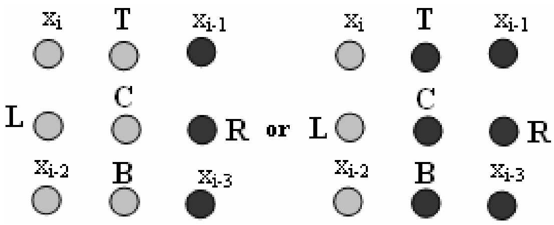


Fig. 15 HR cell which adopt the shape of Split Square which divide HR square into two vertical region of different intensity

In Fig. 15, when interpolating the HR pixel on different sides, the interpolator won't use the value of the other side and this vertical edge can be expanded to both side but one at the same time as shown in the diagram. So pixels of HR T, C and B would take the average value of left two original pixels x_i and x_{i-2} or right side pixels x_{i-1} and x_{i-3} because both have the same result. It has been proved experimentally during development of the algorithm. The pixels L will take average vale of left and R will take average value of right. The same procedure can be repeated for HR square split by horizontal edge.

This simply geometry suggest a way to guide the interpolator so that smoothness within the regions and sharpness between the flat region and cliff region can both be kept. In this 2nd phase of the algorithm, approximately 85% undefined Pixels of HR image are assigned proper intensity values.

In third phase of the algorithm it scans magnified image line by line and looking for those pixels which left undefined in the previous phase. Solid pixels are original pixels in Fig. 16.

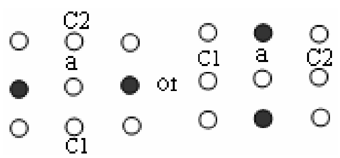


Fig. 16 Report the layout referred in the description of phase three of the algorithm

Two scenarios are there in 3rd phase. 1st when c1 and c2 are not assigned in both forms of the Fig. 16. Then the intensity difference of the original pixels is calculated. If this difference less than threshold then it is assigned the average value of both original pixels to 'a' otherwise leave it undefined. In 2nd scenario when both c1 and c2 are defined then the direction of edge is calculated to specify the interpolation region and then assign proper intensity value to 'a'. At the end of 3rd phase all pixels whose spatial dependence from the neighbourhood values is "sample" have been assigned. Using the information gathered insofar, in the next stage the remaining "holes" are eventually filled.

In fourth and last phase of the proposed algorithm the holes are filled which are left undefined up to this phase. In this phase of algorithm, the median of the neighbouring defined pixels of the undefined pixel is calculated and then assign this calculated value to the undefined pixel. So in this way the more frequent value can be selected and it has been tested experimentally that it guarantees a better detail preservation in the magnified image.

Eventually the algorithm scan image again by applying the 4th phase of the algorithm and look for undefined pixels whose value is still left undefined. But it has been observed that this last extra scanning of image unessential because most of the time, no pixels remain undefined up to this last extra scanning but it is only for care.

The magnification of color image is performed by independently applying the proposed method to each color channel.

V. Algorithm Analysis

In this section the complexity of proposed algorithm is analysed. Suppose the Image I has width n and height m. So it requires O (n x m) steps to magnify out of factor two of digital image. The algorithm does not require any preliminary information for geometrical shapes because it measures all the shapes during the execution of algorithm and therefore it also does not need any extra memory. Therefore the memory requirement is also simple. The algorithm requires only the storage space for the magnified image. Therefore proposed algorithm gives excellent result with respect to execution time and memory space as well.

VI. Result and Analysis

Only through extensive testing can an algorithm be considered a success. For any image magnification algorithm to be considered successful, it needs to excel in both a qualitative and a quantitative analysis when compared with other magnification techniques. Proposed Interpolation technique was tested and compared with several common magnification techniques. These include Nearest neighbor (Pixel Replication), Bilinear Interpolation, Bicubic Interpolation, and Battiato, G. Gallo, and F. Stanco[20] and Muneeb,Naveed khattak [6]. Qualitative analysis provides a set of image comparisons to the reader for personal analysis. A quantitative analysis is done utilizing several methods, including mean squared error, mean absolute error, cross-correlation coefficient. As is shown in the results, proposed Interpolation performs well in both qualitative and quantitative measurements, and can be considered successful in producing realistic higher resolution interpolations of real world images.

A. Qualitative Analysis

In qualitative analysis of proposed Interpolation comparison was made with series of image and was judge. Here only one comparison of the sub image of camera stand has been presented. Other comparison can be provided by demand. By this one comparison the reader can judge for themselves if proposed Interpolation produces results that are superior to common magnification techniques. The following pages include this image comparison, labeling with their corresponding interpolation algorithm. The magnification of aerial and color images are also given in Figs. 18 & 19 respectively.

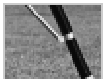
B. Quantitative Analysis

It is difficult to rank a technique by just looking at its visual results. So there must be a mathematical method used to compare different underlying interpolation techniques. Proposed interpolation method can be compared with other interpolation algorithms like nearest neighbor (NN), bilinear (BL), bicubic (BC), Muneeb & Khattak(MK)[6] , and Battiato(B)[20] interpolation. The 1st three interpolation algorithms are most common techniques and best options available for comparison. Three different quantitative analysis measurements were used on four real world images. In order to obtain these measures, an image was first down sampled by a factor 2. This lower-resolution image was then magnified by a factor of 2 using a variety of magnification techniques, and then compared with the original image. MK's code was provided by Khattak and pseudo code description of the Battiato's algorithm was present in [20] and it was implanted to make it executable for analysis purposes. Three of the measurements reflect the accuracy of the magnification. These measurements are Mean Squared Error(MSE), Mean Absolute Error(MAE), and Cross-correlation Coefficient(CCC) The equation are given from 6 to 8.

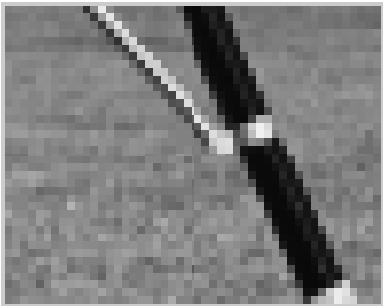
$$CCC = \left| \frac{\left[\sum_{x=1,y=1}^{M,N} \hat{I}(x,y) I(x,y) - n.a.b \right]}{\sqrt{\left(\left(\sum_{x=1,y=1}^{M,N} \hat{I}^2(x,y) - na^2 \right) \left(\sum_{x=1,y=1}^{M,N} I^2(x,y) - k.l.b^2 \right) \right)}} \right| \quad (6)$$

$$MSE = \frac{\sum_{x=1,y=1}^{M,N} \left(\hat{I}(x,y) - I(x,y) \right)^2}{MN} \quad (7)$$

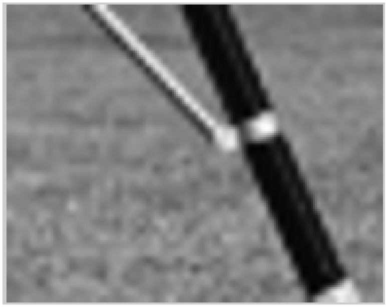
$$MAE = \frac{\sum_{x=1,y=1}^{M,N} \left| \hat{I}(x,y) - I(x,y) \right|}{MN} \quad (8)$$



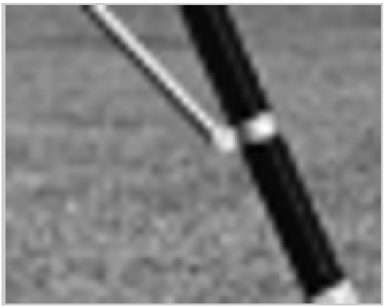
(a) Original Image



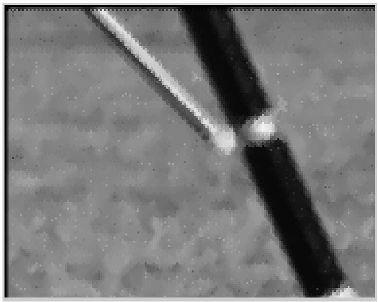
(b) Magnified 4x with Pixel Replication



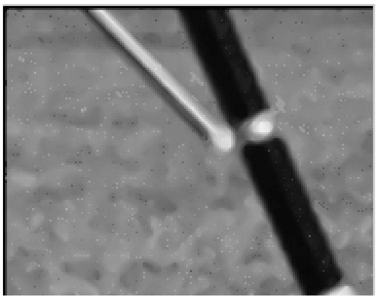
(c) Magnified 4x with Bilinear



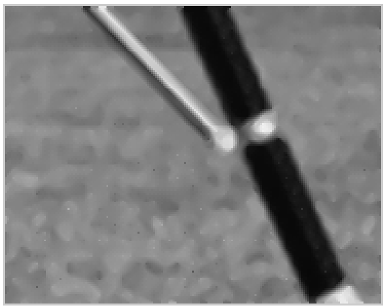
(d) Magnified 4x with Bilinear



(e) Magnified 4x with KM [6]

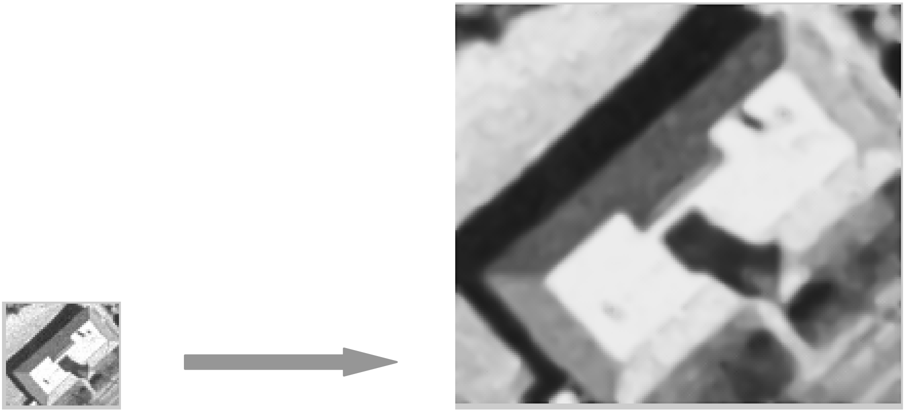


(f) Magnified 4x with Battiato [20]



(g) Magnified 4x with Proposed Algorithm

Fig. 17 Magnifying sub-Image of Camera Stand



Original image   Magnified 4x with Proposed Algorithm

Fig. 18 Magnified Aerial Image by 4x with proposed Algorithm. Other images were not shown due to space restriction

Original image   Magnified 4x with Proposed Algorithm

Fig. 19 Color Image magnification by applying independently proposed algorithm to each color channel

Where $\hat{\mathbf{I}}$ is the magnified image, I is the original image, n is the total number of pixels, and a, b are the corresponding average pixel value in each image. The Cross-Correlation Coefficient equation is further explained in "A New Edge-Adaptive Zooming Algorithm for Digital Images" [20]. It should also be noted that lower values of mean squared and absolute error indicate higher accuracy while values closer to one indicate higher accuracy in cross-correlation coefficient values.

TABLE I
CROSS-CORRELATION COEFFICIENT RESULTS

Images	NN	BL	BC	MK	B	Pr
CS	0.7786	0.8642	0.8952	0.8598	0.8531	0.9035
HE	0.9780	0.9911	0.9935	0.9848	0.9883	0.9936
BF	0.9795	0.9925	0.9970	0.9896	0.9939	0.9948
Ar	0.8863	0.9479	0.9637	0.9309	0.9541	0.9542

Where Pr stands for proposed, CS, HE, BF, Ar stand for camera stand, human's eye, butterfly and aerial respectively. These are all the sub samples of same size from the corresponding images.

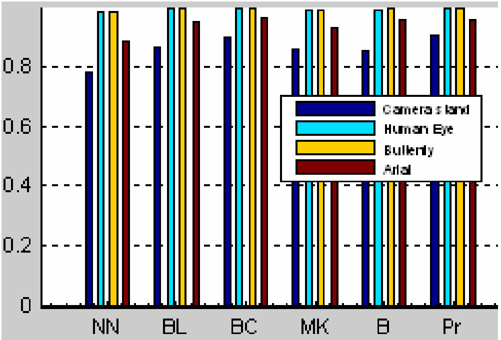


Fig. 20 Interpretation of data in Table I

TABLE II
MEAN SQUARE ERROR RESULTS

Images	NN	BL	BC	Mk	B	Pr
CS	47.0647	60.6039	52.1342	44.3086	42.1887	38.4514
HE	16.3256	8.9830	4.7213	11.0280	93.423	65.943
BF	24.2364	22.5537	12.1986	14.6804	13.6578	11.5617
Ar	49.8123	61.9811	49.3846	44.3935	42.8665	41.7496

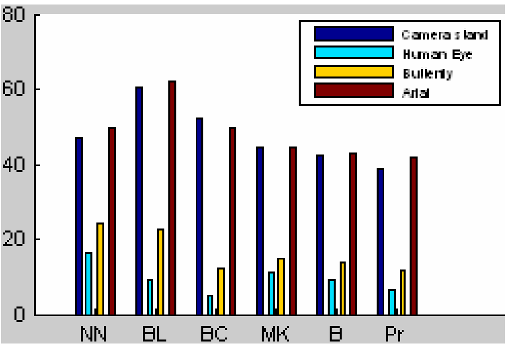


Fig. 21 MSE's data interpretation for Table II

TABLE III
MEAN ABSOLUTE ERROR RESULTS

Images	NN	BL	BC	MK	B	Pr
CS	7.1871	7.4091	6.1085	6.7249	4.8131	5.3844
HE	1.9900	1.4190	0.9893	1.4494	1.2745	1.0839
BF	3.4746	2.4590	1.4700	1.8185	1.6408	1.4416
Ar	7.0656	6.5497	5.1466	5.6973	5.0045	4.9157

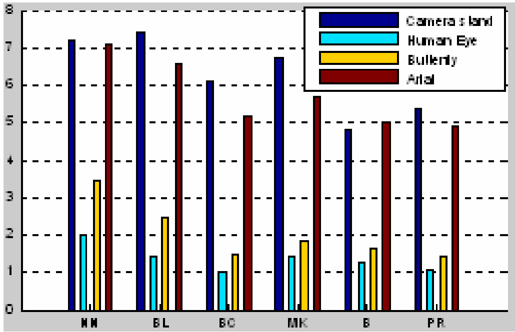


Fig. 22 Interpretation of data in Table III

Qualitative and quantitative analysis shows that proposed algorithm gives a constant result which shows a better performance. This proves the better or equal ability of proposed algorithm compare to other interpolation techniques.

VII. CONCLUSION

In this paper a new adaptive interpolation technique for digital image magnification for grey scale and color image has been proposed. The proposed technique has been compared with other interpolation techniques. The experimental results show that the propose method while of not greater complexity provide quantitatively and qualitatively good results. The third phase of the proposed algorithm has similarity with Battiato et. al [20] and Muneeb, Khattak [6], however it incorporate four new features: first it propose a way to calculate threshold on the bases of true gray shade; second it models the interpolation regions in the local vicinity of the interpolator; third it gives the concept of different geometrical shapes which make easy work of interpolator; fourth it provide easy way for gradient controlled filling; with all these feature it also does not need preliminary information about interpolation region and geometrical shapes but calculate these during execution of algorithm so proposed adaptive interpolation by pixel level data-dependent geometrical shape ranked one of the best choices for real time applications.

Propose algorithm has some limitation. It considers noise or weak edge present in the background feature of an image as sharp information and magnifies it. Therefore the image should be de-noised before magnification. The visual result of proposed algorithm is also not as good for some color images as it is excellent for gray scale images.

As the proposed algorithm is very simple to implement and has low complexity, so it would be interesting to check the performance of the proposed technique for active vision application and also other types of data such 3D volume data.

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