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Interpolation of Images: A Review

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Abstract— For easy transmission of images in digital computing various processes such as compression, decompression, image enhancement, watermarking, hazing, de-hazing etc are performed so that images can be used in applications easily and very efficiently. Almost all of these techniques use the process of interpolation. The interpolation is the process of finding out the unknown pixels of the image. There are various methods for interpolation. Thus, this paper discusses various interpolation techniques, such as Linear, Bi-Linear, Nearest Neighbor, and Bi-Cubic. Out of these techniques nearest neighbor interpolation is best because it is the most simple and fast algorithm. It can provide fast results with some distortion.

Keywords— Interpolation, image, digital, compression, NNI, LI, BLI, BCI.

I. INTRODUCTION

An image is a visual representation of any object. For example a 2-D image that has same appearance like original object. Digital image is a collection of pixels. When an image is represented in numerical form is called as digital image. Number of elements having particular location and value makes a digital image. Digital images are called as either raster images or bitmap images. Raster images are output of various devices such as camera and scanner etc [11]. The digital images takes too much space and time to transmit from one location to another location so for transmission of these digital images we need compression which reduce the size of that digital images [7].

Compression is a process which reduces number of bits required to represent an image so that it can be transferred and stored easily. Compressed data takes small storage space, high transmission speed and decreased cost of storage hardware and network bandwidth. A reverse process which is applied at receiver side for retrieve original image from compressed image is called as decompression process. Compressed image is small in size that can be zoom using interpolation process [13].

Interpolation is a process of discover some unknown points or pixels of an image by using given or existing points or pixels, or we can say that it is the process of calculating the value which is unknown but its nearest values from upper and lower bounds are given. For example we want to calculate the value at f(1.5), and we have the values of f(1) and f(2) the we can calculate the value at f(1.5) by using interpolation method [6].

A. Needs of interpolation

- Interpolation is used to find the function that satisfy the properties of the same class to which that particular data belong. For example, data may be created by using the functions of the form:

$$q(x) = b_0 + b_1 e^x + b_2 e^{2x} + \ldots\ldots\ldots + b_n e^{nx} \qquad \ldots(1)$$

  Then we find the value of coefficients $\{b_i\}$ based on the given values of data class.
- We may want to implement function q(x) on value which is not present in table which consist values of x the that particular value can be calculated by using interpolation.
- Some time we have given only the point (x,y) through which a straight line passes but we don't having another point to draw line that can be calculated by using interpolation.

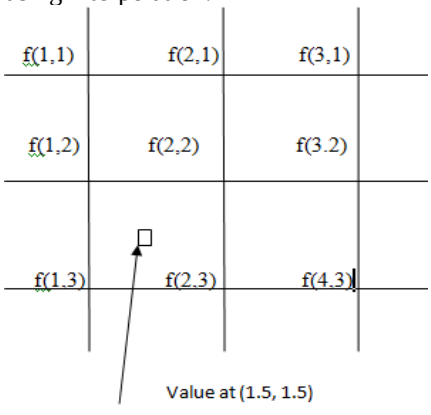


Fig.1 Interpolation

The formulation of this paper is as follows. The section 2 consist of literature survey which include previous research done . Section 3 discusses various methods of interpolation like linear, Bi-linear, Bi-cubic and nearest neighbor interpolation. Finally, Section 4 draws the main conclusion of the paper.

II. LITERATURE SURVEY

The image refinement using various interpolation techniques is main concept which is used in daily life. Based on the previous ongoing researches of the interpolation techniques, surveyed literature is given below:

In [8] the author has proposed that image interpolation is a process of converting or changing the resolution of image so that it shows all contents of the image. Interpolation is required to make images suitable for viewing, transmission, downloading, sharing, editing and further processing. Author also explain various adaptive and non- adaptive algorithms and also proposed a new algorithm for image interpolation based on DWT and at the end compare the results of proposed algorithms with existing algorithms.

In [5] the author has presented a new interpolation algorithm which is based on the nearest neighbor interpolation algorithm. But it uses the nearest values rather than distance to calculate the missing pixels. In this paper at the end the author has present various experimental results of that algorithm, and shows its MET and PSNR values as result, which shows the comparison of this algorithm with various other existing algorithms.

In [12] the author has introduced various adaptive and non-adaptive techniques of interpolation, and compare these two type of techniques. Author has present that adaptive techniques takes more computational time as compare to non-adaptive interpolation techniques but adaptive techniques are preferred where more visual quality of image is required, so both techniques are best to use but depend upon application requirements where high quality is required or not.

In [2] the author has presented an interpolation method which is good as compare to existing algorithms of interpolation. Bi-cubic interpolation is suitable for 3-D images and medical use. But for general application bilinear interpolation is used but it is unable to remove noise from the image . proposed algorithm has ability to remove noise from the input image as compare to bilinear interpolation. This technique is compared with existing techniques by using various factor such as SSIM, PSNR and noise density etc.

In [3] the author has discussed an interpolation technique which change the traditional operations of the existing techniques like bilinear, bi-cubic ,and cubic spline into space variant techniques. This technique takes less computational time as compare to other techniques. In this paper author has compared it with various other techniques of interpolation.

In [4] the author has designed a new grid interpolation algorithm. The existing methods of grid interpolation have the draw backs of long back searching. Author has present fast searching capacity algorithm J-nearest neighbor searching strategy is based on "priority queue" and "neighbor lag" concepts. This method can be implement by using inverse distance weighting and kringing experimental results shows that it has high operating efficiency as compare to others

In [1] the author has proposed various interpolation methods like linear, cubic B-spline, nearest neighbor and high resolution cubic spline, and compare all these methods . author proposed that the method which extend more picture elements or pixels is best as compare to other, and that method having good response in case of frequency and says that image quality can be improved by using the high resolution cubic spline method as compare to other methods.

In [6] the author has presented various interpolation techniques by using filter and tells about which technique is best in which band either pass band or stop band. The nearest neighbor method is good in pass band. But bilinear function perform good in stop band. Cubic B-spline has better stop band performance as compare to nearest neighbor and at the end PSNR values of all these methods are compared.

As far as survey is concerned for the interpolation techniques, the authors have used various interpolations but are not described or provide good results for colored images. Therefore, the techniques that are best suited for colored images are discussed in next section.

III. METHODS OF INTERPOLATION

There are various methods of interpolation because out of the existing interpolation techniques some like linear interpolation, Bi-linear interpolation, Bi-cubic interpolation, nearest neighbor interpolation are discussed below [9].

A. Linear interpolation (LI)

Linear interpolation is used to interpolate value between two existing points. Interpolated value is the weighted sum of existing points. p = p1 + t(p2-po calculate the weighted some for a point for this value of t lies between $0 < t < 1$. This is a combination of p1 and p2.

Application: Interpolate location for morphing (move position of nose from face 1 to face 2) or motion synthesis [3].

For example two points $(4,y_1)$ and $(6,y_2)$

Are given and from these we can calculate the value of y_2,y_2 and we use equation

$$y - y_1 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1) \quad \ldots(3)$$

to find the value of x where y=5 is given.

B. Bilinear interpolation (BLI)

In the Bi-linear interpolation, the value of output pixel 'q' is calculated by calculating the weighted sum of nearest four pixels., The mapped pixel point in the original image is given by 'h' and 'i' if the zooming factor is 't' as follows [6].

$$h = floor\left(\frac{x}{t}\right) and\ i = floor\left(\frac{y}{t}\right) \quad \ldots(4)$$

And the distance can be calculated by using following equation:

$$x_d y_d = \{rem\left(\frac{x}{t}, 1\right), rem\left(\frac{y}{t}, 1\right)\} \quad \ldots(5)$$

So 4 pixels neighbor pixels are given as,

$$q_{topLeft}, q_{topRight}, q_{btmLeft}, q_{btmright} = \{f(h,i), f(h+1,i), f(h,i+1), f(h+1,i+1),\} \quad \ldots(6)$$

By using these values we can calculate the value of pixel in output image as follows.

$$u(x,y) = (1-y_d)\left(x_d . q_{toprig\ ht} + (1-x_d).q_{topLeft}\right) + y_d\left(x_d . q_{btmrig\ ht} + (1-x_d).q_{btmLeft}\right) \quad \ldots(7)$$

(a)

(b)

Fig. 1 Image formed by using Bi-linear Interpolation (a) Original Image (b) Zoomed Image

C. Bi-cubic interpolation (BCI)

In bi-cubic interpolation the intensity value of particular pixel u(x,y) can be calculated by using the neighbor 16 pixels of input image [8]. Let The mapped pixel point in the original image is given by 'h' and 'i' if the zooming factor is 't' then the neighbor-hood matrix can be defined as.

$$\begin{bmatrix} q_{11}q_{12}q_{13}q_{14} \\ q_{21}q_{22}q_{23}q_{24} \\ q_{31}q_{32}q_{33}q_{34} \\ q_{41}q_{42}q_{43}q_{44} \end{bmatrix} = \begin{bmatrix} f(h-1,i-1)\ f(h-1,i)\ f(h-1,i+1)\ f(h-1,i+2) \\ f(h,i-1) \quad f(h,i) \quad f(h,i+1) \quad f(h,i+2) \\ f(h+1,i-1) f(h+1,i) f(h+1,i+1) f(h+1,i+2) \\ f(h+2,i-1) f(h+2,i) f(h+2,i+1) f(h+2,i+2) \end{bmatrix} \quad \ldots(8)$$

Using the bi-cubic algorithm;

$$u(x,y) = \sum_{i=0}^{3}\sum_{j=0}^{3} b_{i,j}\ q_{i,j} \quad \ldots(9)$$

The coefficients $b_{i,j}$ can be find using the La-grange equation.

$$b_{i,j} = b_i * c_j \quad \ldots(10)$$

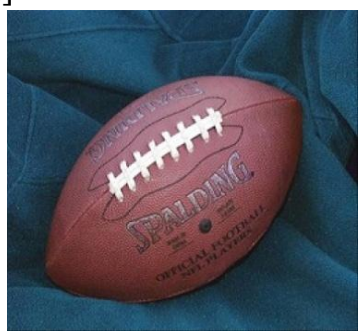
$$b_i = \prod_{k=0}^{3}, \quad k \neq i\ \frac{(x - ceil\,(w*(d+l)))}{ceil\,(w*(d+i)) - ceil\,(w*(d+l))} \quad \ldots(11)$$

$$c_j = \prod_{k=0}^{3}, \quad k \neq j \frac{(y - ceil\,(w*(h+l)))}{ceil\,(w*(h+j)) - ceil\,(w*(h+k))} \quad \ldots(12)$$

When implementing this algorithm I made a mask for defining a_i and b_j using matrix and then I applied it to the matrix containing the selected 16 points, due to reduce the complexity of the algorithm in-order to reduce the calculation time. Zero padding is added to surround the original image to remove the zero reference error occurred [12].

$$u(x,y) = [b_1 b_2 b_3 b_4] * \begin{bmatrix} q_{11}q_{12}q_{13}q_{14} \\ q_{21}q_{22}q_{23}q_{24} \\ q_{31}q_{32}q_{33}q_{34} \\ q_{41}q_{42}q_{43}q_{44} \end{bmatrix} * \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix} \quad \ldots(13)$$

(a)



(b)

Fig. 1 Image formed by using Bi-Cubic Interpolation (a) Original Image (b) Zoomed Image

D. Nearest Neighbor Interpolation (NNI)

Nearest neighbor interpolation is a simplest interpolation from computational point of view [4] . in this the intensity value of each pixel is assigned to nearest neighbor of that point in the input image. This is the process of replications. In this technique the intensity value of f(x,y) is assigned to output image pixel u(x,y). The equation for this is shown below [10].

$$u(x,y)=\begin{cases} f(floor(\frac{x}{t}),floor(\frac{y}{t}),\ rem(\frac{x}{t},1)\le 0.5\ and\ rem(\frac{y}{t},1)\le 0.5) \\ f\left(ceil(\frac{x}{t}),floor(\frac{y}{t})\right),\ rem(\frac{x}{t},1)\succ 0.5\ and\ rem(\frac{y}{t},1)\le 0.5 \\ f\left(floor(\frac{x}{t}),ceil(\frac{y}{t})\right),\ rem(\frac{x}{t},1)\le 0.5\ and\ rem(\frac{y}{t},1)\succ 0.5 \\ f\left(ceil(\frac{x}{t}),ceil(\frac{y}{t})\right),\quad rem(\frac{x}{t},1)\succ 0.5\ and\ rem(\frac{y}{t},1)\succ 0.5 \end{cases} \quad \ldots(2)$$

(a) (b)

Fig. 1 Image formed by using Nearest Neighbor Interpolation (a) Original Image (b) Zoomed Image

From all the studied techniques, it is concluded that nearest neighbor interpolation technique is best because it is a fast and good interpolation technique, it can provide results in very efficient manner but the drawback of this technique is that it produces image with some distortion. As far as other interpolation techniques are concerned, Bi-linear interpolation provides quality wise good and smooth image. The Bi-cubic interpolation provide very sharp images and it is useful from quality point of view whereas nearest neighbor interpolation takes less time for computation because only one point is used to find unknown pixel values.

IV. CONCLUSIONS

In this paper various interpolation techniques are studied and reviewed like linear, Bi-linear , Bi-cubic and nearest neighbor interpolation. Linear interpolation is basically used to calculate the values in a single line basically line equation is used to calculate the value of unknown point that exist between two known points the three points are in a single line. In bi-linear interpolation, nearest four pixels of any unknown point are used to calculate the value of that point. In case of Bi-cubic interpolation, nearest sixteen pixels are used it also include diagonal pixels of unknown point, but in case of nearest neighbor interpolation only one pixel is used which is nearest to that unknown point which we want to calculate. So we can say that nearest neighbor interpolation is a best method from all discussed technique of interpolation, it is fast and good technique it provide very good results as compare to other interpolation technique but some time some distortion is there in results.

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