Comparative Analysis of Different Interpolation Schemes In Image Processing

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Comparative Analysis of Different Interpolation Schemes in Image Processing

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ABSTRACT

Image interpolation techniques often are required in medical imaging for image generation and processing such as compression or resampling. Since the ideal interpolation function spatially is unlimited, several interpolation kernels of finite size have been introduced. This paper discusses different interpolation schemes. The comparison is made using spatial analysis, computation time for qualitative and quantitative interpolation error determinations for particular interpolation tasks. Scaling and interpolation are performed using same techniques and analyzed using MSE and PSNR.

***Keywords**:*

Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), interpolation, Bilinear, Bicubic, Nearest neighbor, Histogram

I. INTRODUCTION

Image interpolation has many applications in computer vision, image processing and biomedical applications. Resampling is required for discrete image manipulations, such as geometric alignment and registration, to improve image quality on display devices or in the field of lossy image compression wherein some pixels or some frames are discarded during the encoding process and must be regenerated from the remaining information for decoding.

In computed tomography (CT) or magnetic resonance imaging (MRI), image reconstruction requires interpolation to approximate the discrete functions to be back projected for inverse Radon transform. In modern X-ray imaging systems such as digital subtraction angiography (DSA), interpolation is used to enable the computer-assisted alignment of the current radiograph and the mask image. Moreover, zooming or rotating medical images after their acquisition often is used in diagnosis and treatment, and interpolation methods are incorporated into systems for computer aided diagnosis (CAD), computer assisted surgery (CAS), and picture archiving and communication systems (PACS)[1].

However, the goal of the study is not to determine an overall best method, but to present a comprehensive catalog of methods to enable the user to select that method which is optimal for his specific application in image processing applications.

The paper is organized as follows. Section 2 discuses about the different interpolation methods. Section 3 discusses about the validation, section 4 discusses about the test results, and finally conclusions are made in section 5.

II. INTERPOLATION METHODS

For image resampling, the interpolation step must reconstruct a two-dimensional (2-D) continuous signal s(x,y) from its discrete samples s(k,l) by convolving discrete image samples with continuous 2D impulse response of the reconstruction filter. Interpolation (sometimes called resampling) is an imaging method to increase (or decrease) the number of pixels in a digital image. Some digital cameras use Interpolation to produce a larger image than the sensor captured or to create digital zoom.

Nearest neighbor interpolation

The nearest neighbor algorithm simply selects the value of the nearest point and does not consider the values of other neighboring points. The algorithm is very inexpensive to implement and is commonly used.

Using this method one finds the closest corresponding pixel in the source (original) image (i, j) for each pixel in the destination image (i^1, j^1). If the source image has dimensions w and h (width and height) and the destination image w' and h', then a point in the destination image is given by integer division as follows.

$$i^1 = i\, w^1 / w$$

$$j^1 = j\, h^1 / h$$

This form of interpolation suffers from normally unacceptable aliasing effects for both enlarging and reduction of images.

Bilinear 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. The averaging has an anti-aliasing effect and therefore produces relatively smooth edges with hardly any jaggies.

Suppose that we want to find the value of the unknown function f at the point $P = (x, y)$ and the value of f at the four points $Q_{11} = (x_1, y_1)$, $Q_{12} = (x_1, y_2)$, $Q_{21} = (x_2, y_1)$, and $Q_{22} = (x_2, y_2)$ is known,

$$f(R_1) \approx \frac{x_2 - x}{x_2 - x_1} f(Q_{11}) + \frac{x - x_1}{x_2 - x_1} f(Q_{11})$$

Where $R_1=(x, y_1)$,

$$f(R_2) \approx \frac{x_2 - x}{x_2 - x_1} f(Q_{11}) + \frac{x - x_1}{x_2 - x_1} f(Q_{11})$$

Where $R_2=(x, y_2)$,

$$f(P) \approx \frac{y_2 - y}{y_2 - y_1} f(R_1) + \frac{y - y_1}{y_2 - y_1} f(R_2)$$

The desired estimate of $f(x, y)$ is

$$f(x,y) \approx \frac{f(Q_{11})}{(x_2 - x_1)(y_2 - y_1)}(x_2 - x)(y_2 - y) + \frac{f(Q_{21})}{(x_2 - x_1)(y_2 - y_1)}(x - x_1)(y_2 - y)$$

$$+$$

$$f(x,y) \approx \frac{f(Q_{12})}{(x_2 - x_1)(y_2 - y_1)}(x_2 - x)(y - y_1) + \frac{f(Q_{22})}{(x_2 - x_1)(y_2 - y_1)}(x - x_1)(y - y_1)$$

The matrix representation of the operation is

$$f(x,y) \approx \begin{bmatrix} 1 - x & x \end{bmatrix} \begin{bmatrix} f(0,0) & f(0,1) \\ f(1,0) & f(1,1) \end{bmatrix} \begin{bmatrix} 1 - y \\ y \end{bmatrix}$$

In effect the bilinear interpolation is not linear and it is only a product of two linear functions. The result of bilinear interpolation is independent of the order of interpolation.

Bicubic Interpolation

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. This is the method most commonly used in image editing software, printer drivers and many digital cameras for resampling the images.

With this method, the value $f(x, y)$ of a function f at a point (x, y) is computed as a weighted average of the nearest sixteen samples in a rectangular grid (a 4x4 array). Here, two cubic interpolation polynomials one for each plane direction, are used. There are a number of techniques one might use to enlarge or reduce an image. The simplest method to enlarge an image by a factor 2 is to replicate each pixel 4 times. This willlead to more pronounced jagged edges than existed in the original image. Aliasing of high frequency components in the original will occur. In bicubic a point (i', j') corresponds to a non integer position in the original (source) image.

The cubic weighting function R(x) is given below.

$$R(x) = \frac{1}{6}\left[P(x+2)^3 - 4P(x+1)^3 + 6P(x)^3 - 4P(x-1)^3\right]$$

$$P(x) = \begin{Bmatrix} x\ ;\ x > 0 \\ 0\ ;\ x \le 0 \end{Bmatrix}$$

Bicubic interpolation results in an interpolating function which is continuous, has continuous first partial derivatives, and has continuous cross derivatives everywhere. Bicubic interpolation is calculated as follows:

$$\sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij} x^i y^j$$

The procedure used to calculate the coefficients a_{ij} depends on the interpolated data source properties.

III. Implementation Details

Validation of the proposed project is done using MATLAB 7.0. Four different images of different situations such as image of a Lena, image of a text, image of a flower and image of a tree with image size 512 X 512, 146 X 110, 600 X 401 and 190 X 125 respectively are considered.

For each case MSE and PSNR is computed and graph is drawn. Reconstruction of Lena image for different scaling factors is observed. Histograms are also drawn for Lena image. Run time evaluations are computed for all the three case by considering Lena image. Operations are done on gray scale images.

IV. TEST RESULTS

PSNR and MSE Vs SCALING FACTOR:

All the three techniques considered (Nearest neighbor, bilinear and bicubic) are compared on various images including situations typically encountered in image processing applications.

In each case, the PSNR is evaluated for different scaling factors. A graph is drawn and it can be seen that for nearest neighbor PSNR is more and variation takes irregular path.

$$MSE = \frac{\left(img_1(row, col) - img(row, col)^2\right)}{\left((m+n)/2\right)^2}$$

$$\text{PSNR} = 20\log_{10}(255/\sqrt{MSE})$$

Input Images

Lena image:

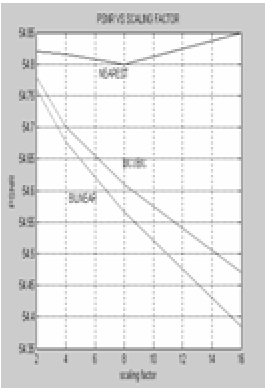
Text image:

Flower image:

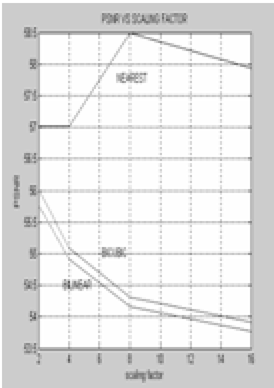
Tree image:

PSNR Vs SCALING FACTOR

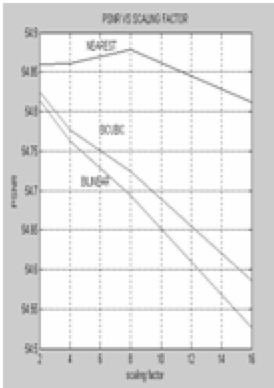
LENA IMAGE



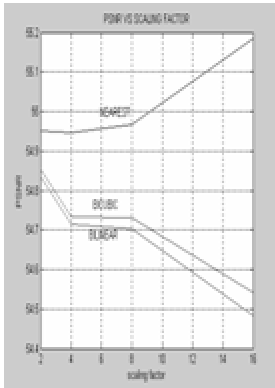
TEXT IMAGE



FLOWER

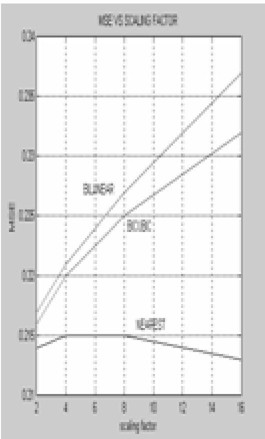


TREE

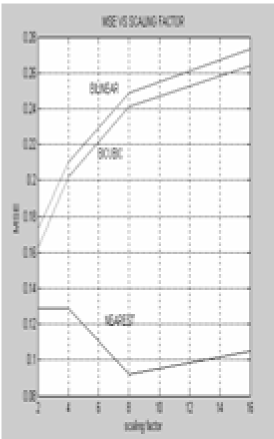


MSE VS SCALING FACTOR

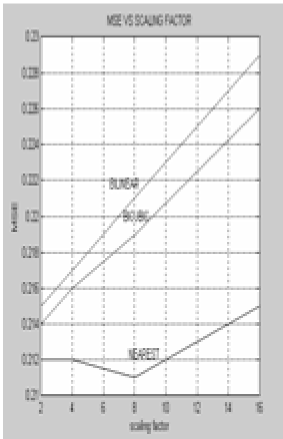
LENA IMAGE



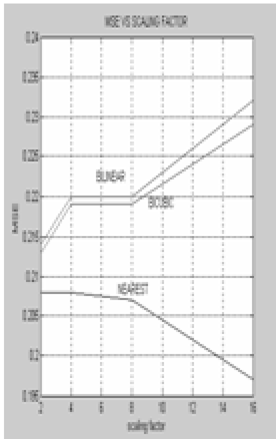
TEXT IMAGE



FLOWER



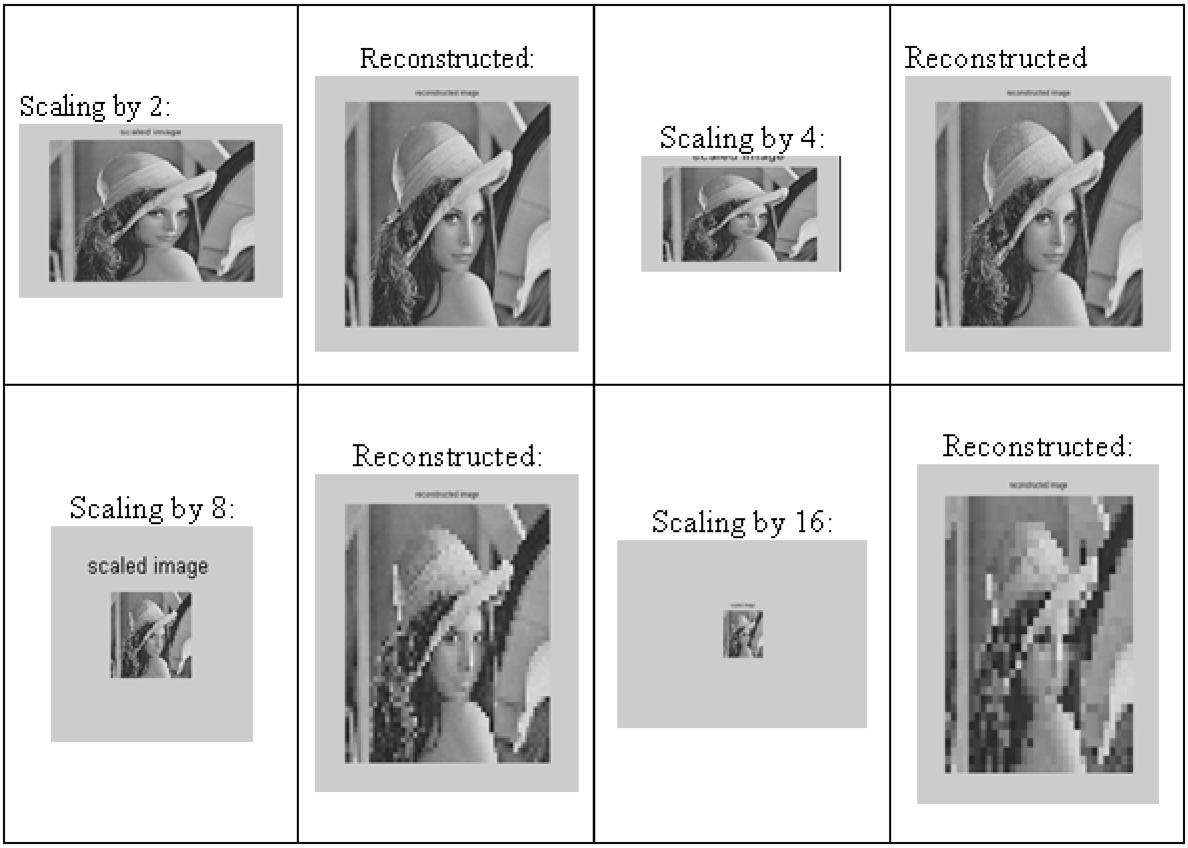
TREE



LENA IMAGE AFTER SCALING AND RECONSTRUCTION

The Lena image considered here are first scaled by a factor of 2 (reducing the size of the image by 2) and reconstructed by the same factor. The images are scaled by 4, 8 and 16 and they are reconstructed by the same factor.

NEAREST NEIGHBOR



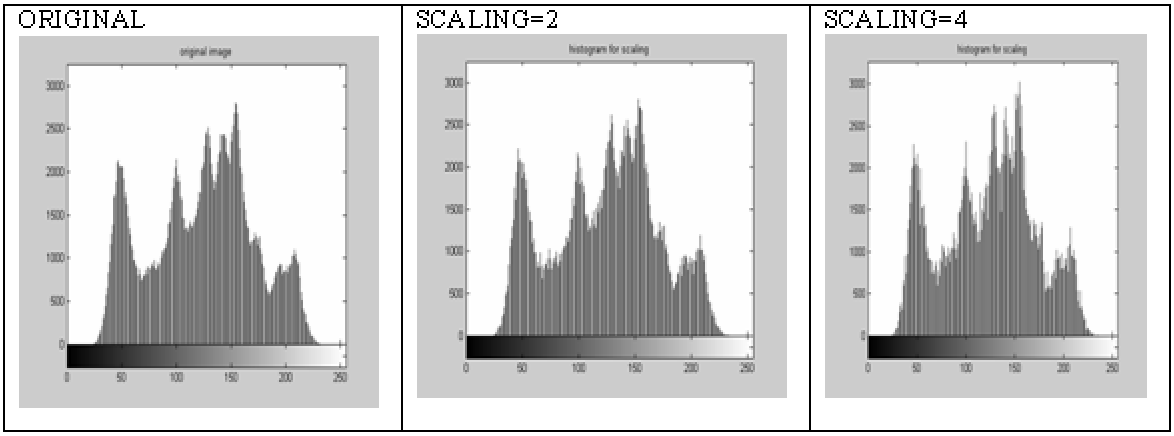
BILINEAR

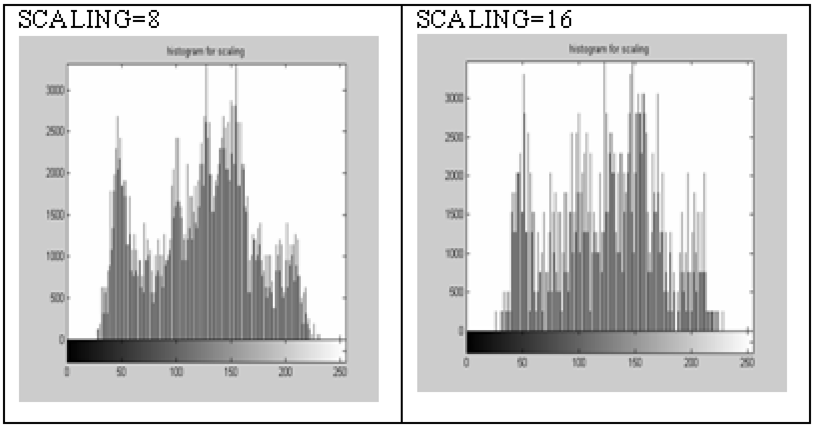
BICUBIC

HISTOGRAM FOR DIFFERENT SCALING FACORS

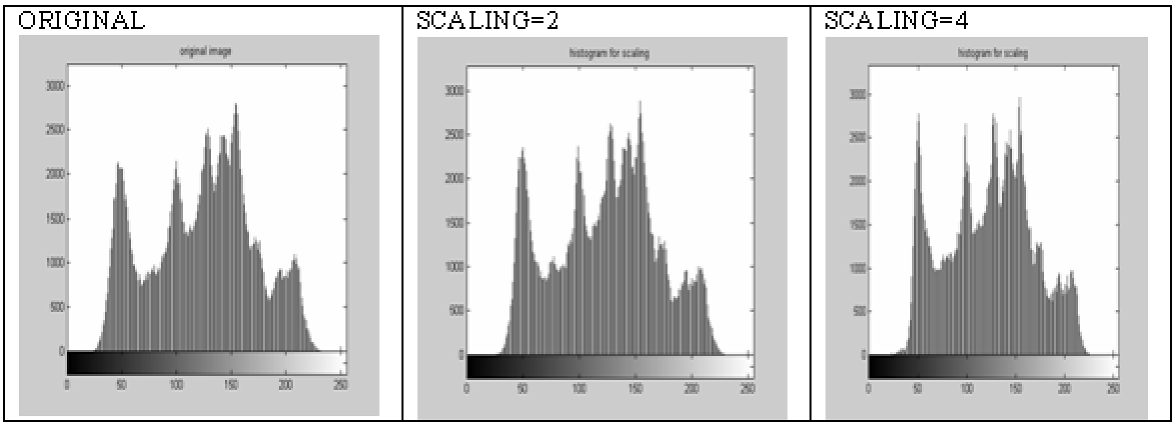
The Histogram shows the total tonal distribution in the image. It is a bar chart of the count of pixels of every tone of gray that occurs in the image. It helps us to analyze, and correct the contrast of the image. Technically, the histogram maps Luminance, which is defined from the way the human eye, perceives the brightness of different colors. For example, our eyes are most sensitive to green, we see green as being brighter than we see blue.Luminance can be the "apparent brightness" of the RGB pixel tones in the image. Histogram is plotted for Lena image for all the three techniques such as nearest neighbor, bilinear and bicubic.

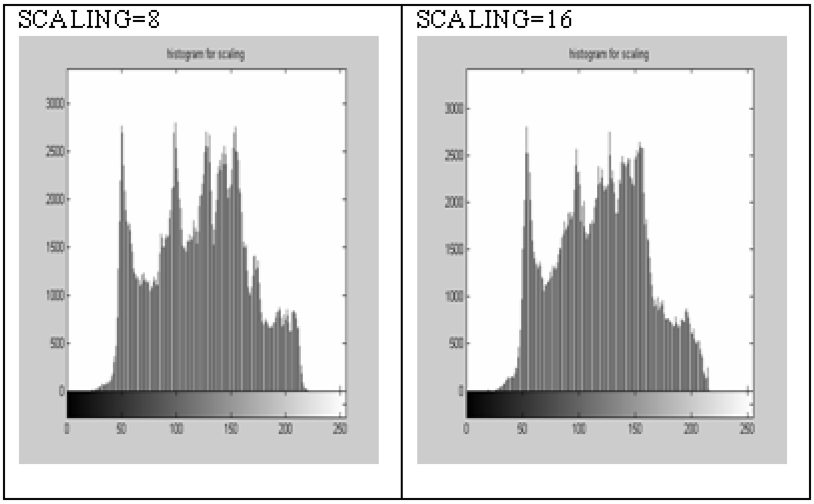
NEAREST NEIGHBOR



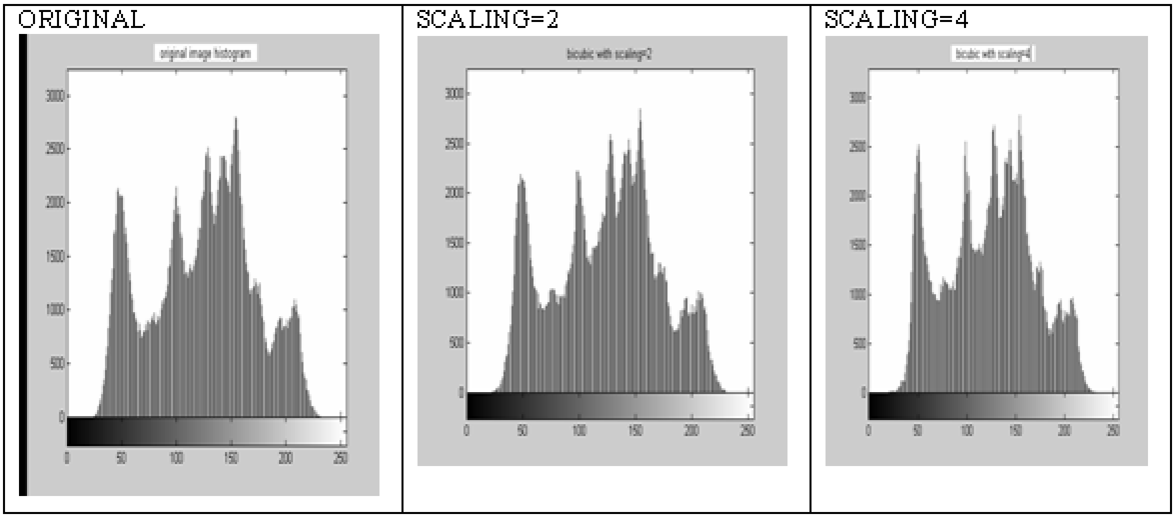


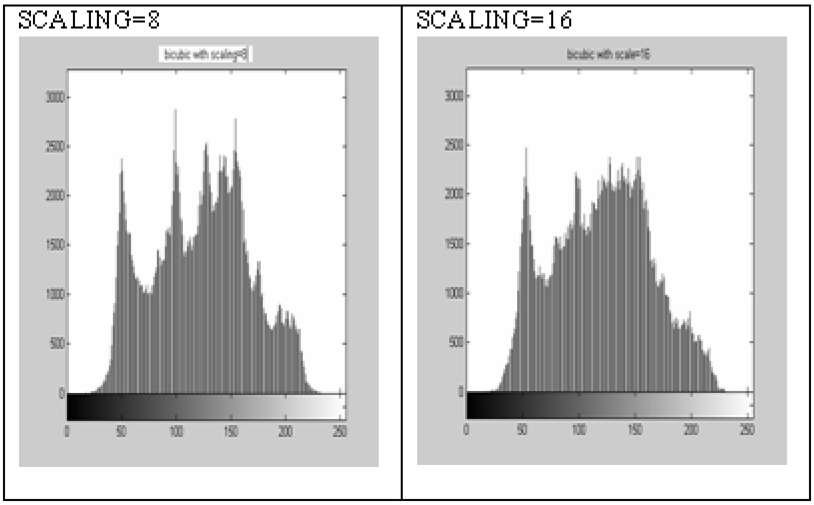
BILINEAR




SCALING=8
histogram for scaling
SCALING=16
histogram for scaling

BICUBIC:


ORIGINAL
original image histogram
SCALING=2
bicubic with scaling=2
SCALING=4
bicubic with scaling=4


SCALING=8
bicubic with scaling=8
SCALING=16
bicubic with scale=16

Run time evaluations (in seconds)

METHOD	TECHNIQUE		
Scaling	Nearest	Bilinear	Bicubic
2	0.0156	0.1094	0.1563
4	0.0156	0.2188	0.2969
8	0.0313	0.4375	0.5781
16	0.0938	0.8281	1.0625

Table shows the run time required for different Techniques such as nearest neighbor, bilinear and bicubic techniques. We can observe from the table that nearest neighbor takes less run time evaluations compared to the other techniques.

V. CONCLUSIONS

In terms of PSNR, nearest neighbor has high value of PSNR and low value of MSE compared to bilinear and bicubic methods. In terms of histogram, bicubic is better method compared to the nearest neighbor and bilinear methods. Bicubic method has smoother edges compared to the other two methods. In terms of run time evaluations, nearest neighbor is better compared to bilinear and bicubic methods.

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