Comparison of commonly used non-adaptive image scaling techniques

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Abstract---The process of resizing the image up or down or changing the dimensions of an image is called image scaling. Image processing and computer vision are concerned with image scaling or image interpolation. There are many techniques developed to resize image to preserve the quality of the image and also have fine details. In this paper, the performance of nearest neighbor, bilinear and bicubic interpolation will be analyzed in both subjectively and objectively. A new algorithm will be introduced for the sake of analysis. Our analyses proved that the performance of these different techniques are dependent on image edges and image contrast.

Keywords---Digital Images, Image Processing, Image Analysis, Image Quality, Image Reconstruction.

I. Introduction

IMAGE interpolation is a process used to change the image size by estimating the values of new points using the image samples. In most cases, this process is achieved by finding the average of the samples around the new intended points. In other words, Image interpolation changes the low resolution image to a high resolution image [1 - 3]. The relationship between the high resolution image and low resolution image plays an important role in calculating the performance of the technique used. Conventional linear interpolation techniques are very simple models to resize the image with acceptable quality in situations where the fine details are not an essential requirement. Many techniques are proposed to improve the subjective and objective qualities of the interpolated images by imposing more complicated models. Current Non-adaptive interpolation techniques based on space-invariant models have limitations to capture the fast evolving statistics around edges and consequently produce interpolated images with blurred edges and annoying artifacts. The paper will be organized as follows: section II provides the different types of non-adaptive interpolation techniques. Section III provides the comparisons and results. Conclusion will be provided in section IV.

II. Non-Adaptive Interpolation Techniques

Non-adaptive interpolation techniques such as nearest neighbor, bilinear and bicubic interpolation techniques are conventional techniques used to resize images. These techniques estimate the value of the new pixels from the neighboring pixels using the mean values of the surrounding pixels and in some techniques using the weighted average. Nearest neighbor techniques is very simple method to resize image by repeating the value of the nearest neighbor [4 - 6].

The nearest neighbor technique is considered to be the most basic technique for image interpolation and requires the least processing time of all the interpolation techniques because it considers only one pixel, the closest one to the interpolated point. This has the effect of simply making each pixel bigger (see Fig. 1). This is very simple technique and needs less computation as it utilizes the pixel of nearest neighbor to fill the interpolated point. This techniques is just repeats available pixel value, not interpolated pixel value as it doesn’t change values [7 - 8].

The nearest neighbor technique doesn't generate new color pallet values. Instead, it repeats the values of pixels already exist in the image (see Fig. 2). The standard check board image is chosen with black and white colors to illustrate blurred and artifacts generated by the interpolation techniques. The equation that describes the mapping from one size to another is given as follows (see (1)).

The interpolated points in bilinear interpolation technique are calculated by finding the weighted average of the four closest pixel's. This weighted average becomes the new generated pixel or the interpolated point. The bilinear interpolation technique uses two linear interpolations, one in horizontal direction and the other in vertical direction. The estimated image pixels will be very close in values to the original image with some new values generated from the color pallet of the original image [9]. The equation is given as follows (see (2)).

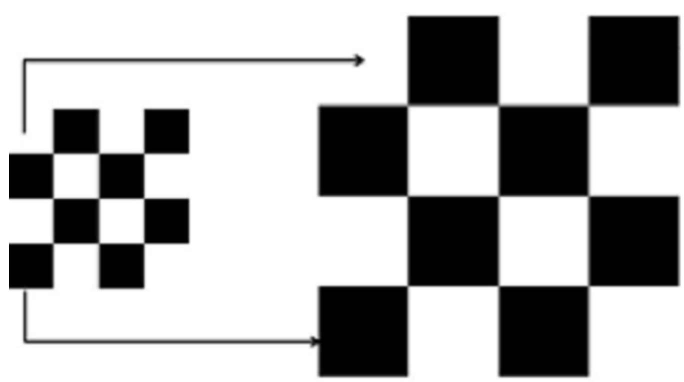

Fig.1. Nearest Neighbor Concept

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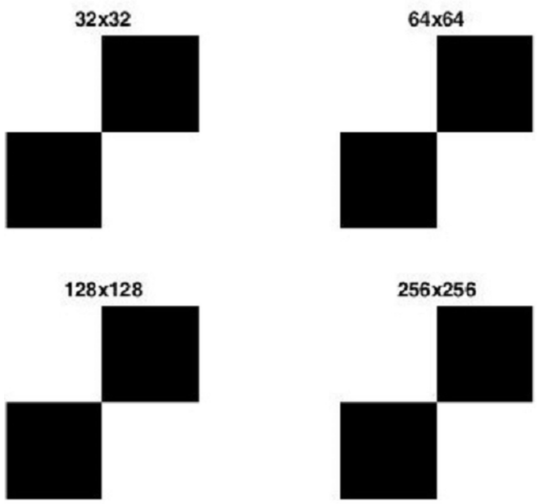

Fig. 2 Nearest Neighbor with Different Scales

$$y(i,j) = \begin{cases} x(i-1,j), & \text{i=m, 2m, … M, j=1,2,…N} \\ x(i,j-1), & \text{i=1,2, … M, j=n, 2n, … N} \end{cases} \quad (1)$$

Where: x (i, j) is the original image matrix pixels.
y (i , j) is the estimated image pixels using nearest neighbor method.
M x N is the dimension of the original image.
$\frac{m}{n}$ = resize ratio, m and n are two integer values.

$$y(i,j) = \begin{cases} ax(i-1,j) + bx(i+1,j) + cx(i,j-1) + dx(i,j+1) & \text{i=m, 2m, … M, j=n, 2n, … N} \\ ax(i-1,j) + bx(i+1,j) & \text{i=m, 2m, … M, j=1, 2, ….N} \\ cx(i,j-1) + dx(i,j+1) & \text{i=1, 2, … M, j=n, 2n, … N} \end{cases} \quad (2)$$

Where a, b, c and d are the weighted averages of the four pixels.

Some of the new pixels will not lie at exactly equal distances from four pixels of the original image. If the new pixel lies between two existing pixels, the average of the two closest pixels will be considered. The bilinear interpolation technique with different scales (4, 16 and 64 times the original image) has blurring edges as the resize ration increases (see Fig. 3). The original image has very high contrast with two color values. It is clear that the edges are the most affected region of blurring and artifacts [10 -11].

In bicubic interpolation technique, the closest 4x4 neighboring pixels are considered to estimate the new pixels [12 - 13]. These pixels are at different distances from the unknown pixel. Closer pixels are given higher weighting values in the calculation. Bicubic interpolation technique produces noticeably sharper images than the previous two methods, and is perhaps the ideal combination of processing time and output quality. For this reason, it is a standard in many image editing programs (including Adobe Photoshop), printer drivers and in-camera interpolation [14]. The bicubic interpolation technique equation is given as follows (see (3)).

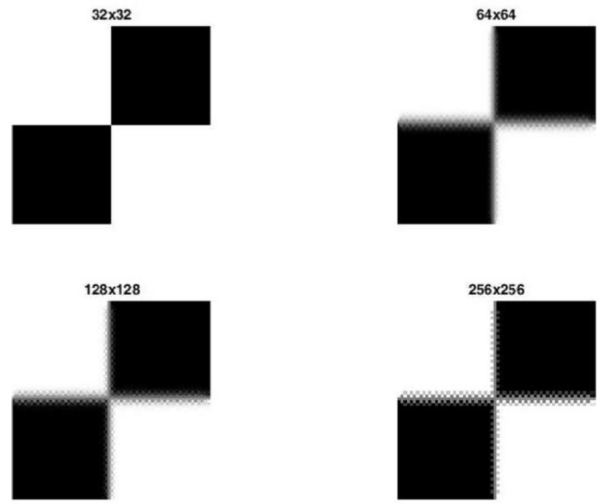

Fig. 3 Bilinear Interpolation

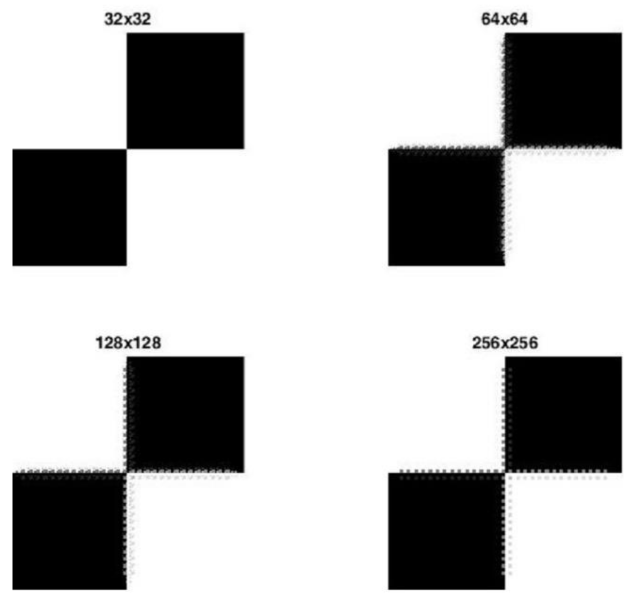

Fig. 4 Bicubic Interpolation

$$y(i,j) = \begin{cases} \sum_r \sum_c x(i+r, j+c) & \text{i=m, 2m, … M, j=1,2, .. N rows} \\ \sum_r \sum_c x(i+r, j+c) & \text{i=1, 2, … M, j=n,2n, .. N columns} \end{cases} \quad (3)$$

Where r and c have the values -1, -2, +1, +2 respectively.

$$y(i,j) = \begin{cases} \dfrac{x(i-1,j)+x(i+1,j)}{2} \\ i = 2,4,\dots M, j = 1,2,\dots N \\ \dfrac{x(i,j-1)+x(i,j+1)}{2} \\ i = 1,2,\dots M, j = 2,4,\dots N \end{cases} \quad (4)$$

Some new pixels don't have 4x4 available pixels when calculating the new estimated pixels. Some of the new pixels will lie between two existing pixels which make them have higher weight than the distant pixels. The bicubic interpolation technique with resizing 4, 16 and 64 times the original image has better subjective and objective qualities (see Fig. 4). There is an enhancement in the image in both subjective and objective quality.

III. Comparison and Results

Most of the interpolation techniques depend on one, four or 16 neighboring pixels to calculate the estimated pixels. There are many locations in the image where one or two pixels only available to find the new pixel [15], [16]. Linear interpolation is a technique used to resize images by utilizing the average of two pixels to find the unknown pixels. The equation that describes the relationship between existing pixels and estimated pixels is given as follows (see (4)).

The different resize ratios for a linear interpolation technique 4, 16 and 64 times the original image shows minimum quality compared to other techniques (see Fig. 5). The focus here is on the edges which have the maximum information as the colors change from one level to another. Unfortunately, the average value method brought up a new color values which are not existed in the first place with the original image [17 - 18].

The previous interpolation techniques resize the image by simply finding the average value for number of pixels which are close to the estimated pixel. Using this method generates new color levels which are not part of the original image [19]. The following equation describes the average changing value of total image color compared to the original image colors.

$$ave = \frac{\sum_i \sum_j |y(i,j) - c(i,j)|}{MN} \quad (5)$$

where ave = average changing value,
c(i, j) is the expected original color in this pixel.

The average value of changing from the expected original image color is proportional to the resize ratio and the interpolation technique used (see Fig. 6). One can observe that the nearest neighbor technique seems to be the best in this scenario based on our criteria of defining the average. In fact, nearest neighbor is performing very well provided limited colors and edges. On the other hand, Bicubic technique has better performance compared to other techniques [20 - 21]. All techniques have poor behavior when the resize ratio is getting larger. After certain value of resize ratio (in this case 16) the average value changes very slowly as the colors start to be repeated.

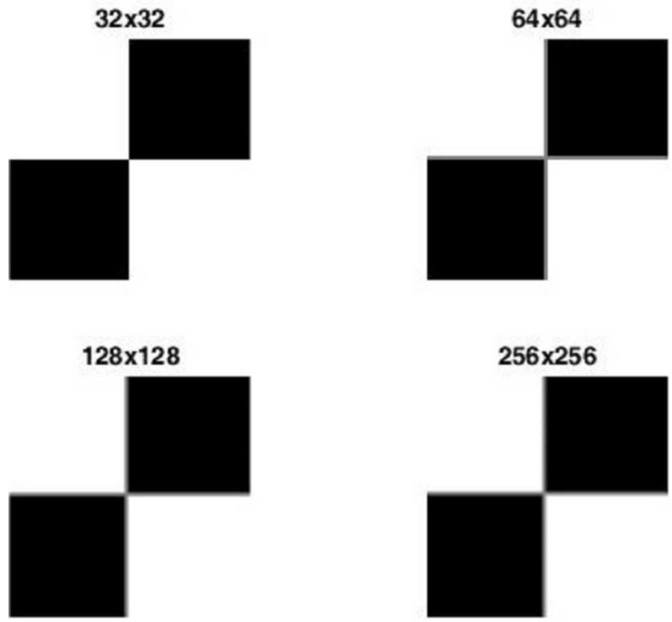

Fig. 5 The Different Resize Ratios for a Linear Interpolation Technique

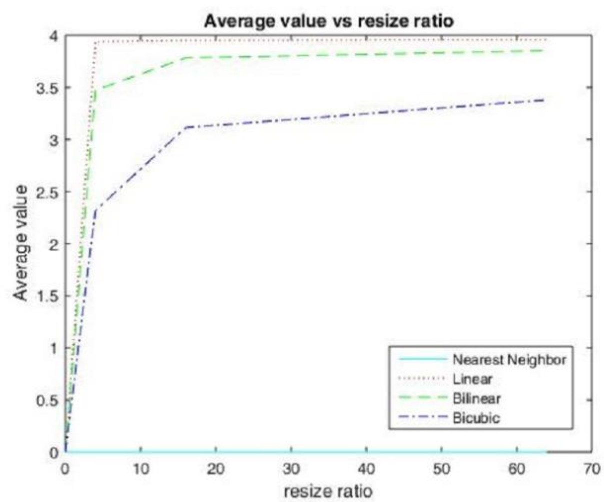

Fig. 6 The Average Value vs Resize Ratio

IV. Conclusions

Most of the interpolation techniques based on average calculation to estimate the new pixels as a result of resizing. Finding the average value is usually accompanied by creating new color values which exactly not exit in the original image colors. Non adaptive interpolation behaves reasonably well when the resizing ratio not too large. As a result of increasing the resize ration the average value start to be stable against variations of the resize ratio and interpolation techniques.

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