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Image Quality Comparison using PSNR and UIQI for Image Interpolation Algorithms

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ABSTRACT: Image quality assessment plays an important role in various image processing applications. Measuring the quality of the image is a complicated and hard process since humans opinion is affected by physical and psychological parameters. Many techniques are proposed for measuring the quality of the image but none of it is considered to be perfect. We have used different interpolation techniques such as Nearest Neighbor, Bilinear, Bicubic, Cubic B-Spline, Catmull-Rom and Lanzcos interpolation for generating images. The comparison is done for different interpolation schemes using Peak Signal to Noise Ratio (PSNR) and Universal Image Quality Index (UIQI). In this paper an attempt is made to highlight different image interpolation algorithms to compare image quality using PSNR and UIQI.

KEYWORDS: Interpolation, Nearest Neighbor, Bilinear, Bicubic, Cubic B-Spline, Catmull-Rom, Lanzcos, Universal Image Quality index (UIQI), Peak Signal to Noise Ratio (PSNR).

I. INTRODUCTION

Image interpolation is a procedure used in expanding and contracting digital images. Most of them attempt to reproduce a visually attractive replica of the original. To resize an image, every pixel in the new image must be mapped back to a location in the old image in order to calculate a new pixel value. Usually the resized image will be lower in quality but the quality of the image can be retained by introducing new pixels based upon some prediction or approximation [1]. There are ways of dealing with this problem, most of which involve some form of interpolation among the nearest pixels in the old image.

There are many algorithms currently in use for resizing digital images. Apart from fitting a smaller display area, image size is most commonly decreased (or sub sampled or down sampled) in order to produce thumbnails. Enlarging an image (up sampling or interpolating) is generally less common [2]. The main reason for this is that in "zooming" an image, it is not possible to discover any more information in the image than already exists, and image quality decrease significantly. However, there are several methods of increasing the number of pixels that an image contains, which result in a different look to final image. These methods are often termed as image interpolation algorithms.

With the increasing demand for image-based applications, importance of efficient and reliable evaluation of image quality has increased. Measuring the image quality is of fundamental importance for numerous image processing applications, where the goal of Image Quality Assessment (IQA) methods is to automatically evaluate the quality of images in agreement with human quality judgments. Numerous IQA methods have been proposed over the past years to fulfill this goal. A common use of an image quality measure is to judge the accuracy of an image compression or rendering algorithm against some reference ground-truth solution [3]. The interest in objective image quality assessment has been growing at an accelerated pace over the past decade. Depending on the application, the measurement of image quality conveys many different aspects from how much is the image degraded by a specific distortion type to how realistic or beautiful an image looks.

As a mathematical technology of the human behaviors in image quality evaluation, objective IQA metric has been widely used in various image processing application, e.g., compression, transmission and restoration [4]. The simplest and most common quality metrics are the mean square error, PSNR and UIQI which directly compute the differences between the reference and distorted images. In this paper we used different interpolation techniques to generate images and image quality have been evaluated with peak signal-to-noise ratio and universal image quality index.

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II. RELATED WORK

Image quality assessment can be performed using subjective and objective method. In Subjective image quality assessment the evaluation of quality by humans is obtained by mean opinion score (MOS) method where in objective evaluation of quality is done by algorithms [5]. However, subjective evaluations are expensive and time consuming, which makes them impractical in real-world. The objective IQA is to design mathematical models that are able topredict the quality of an image accurately and automatically. An ideal objectiveIQA method should be able to mimic the quality predictions of an average human Observe[4]. Lots of efforts have been done to develop objective image quality metrics. MSE, PSNR, UIQI, SSIM, MS-SSIM, MAD and FSIM are the most commonly used objective image quality assessment methods.

PSNR method compares the reference image and the distorted image on a pixel by pixel basis and calculates the PSNR in dB[6]. Universal image quality index (UIQI) proposed by Zhou Wang *et al.* [7] indicates the loss of correlation, luminance distortion and contrast distortion. Normally, the overall value of UIQI is calculated for a window of convenient size and the mean value is computed as the quality index. Natural images are highly structured and their pixel values exhibit strong dependencies. Thestructural similarity index (SSIM) [8] is analgorithm based on these structural dependencieswith in an image. The human visual system ishighly adapted to extract structural informationfrom the viewing field. The SSIM algorithmseparates the luminance component, contrastcomponent and the structural componentfrom the reference image and thedistorted image and compares thesecomponents. Multi-scale SSIM [9] an improved version of SSIM. For an M stage MS-SSIM index, the procedure involves M iterations. During each iteration, the reference and distorted images pass through a low pass filter, down sample the filtered image by a factor of 2 and the contrast and structural comparisons are done. In Most apparent distortion (MAD)[10] algorithm, two separate strategies are usedto compute the distortions, on images having near threshold distortions (detection based strategy) and images having clearly visible distortions (appearance based strategy). In the case of highquality images, the image is most apparent, and thus the human visual system(HVS) attempts to look for distortions. Inthe second case, the distortions are most apparent, and thus the HVS attempts to look for the image's subject matter. The distortions in the above two cases are calculated using visual detection model and image appearance model respectively. Local luminance and contrast masking are used to estimate distortion in the first case where as changes in the local statistics of spatial-frequencycomponents are used to estimate distortions in the second case. Finally, the above two perceiveddistortion measures are combined into a single estimate of overall perceived distortion. Feature similarity index (FSIM) [11] is based on the theory that HVS understands an image based on its low level features such as edges, and a good IQA metric could be obtained by comparing these low level features. At points of high phase congruency of the Fourier waves of different frequencies of the image, highly informative features can be extracted. FSIM utilizes this property of the Fourier transform of images for quality assessment.

III. IMAGE INTERPOLATION ALGORITHMS

Image interpolation algorithms convert or resize a digital image from one resolution (dimension) to another resolution without losing the visual content in the picture. There are many different types of image interpolation algorithms, each resulting in a different look to final image. Thus, it is best if the quality, or visible distinction for each pixel, is retained throughout the interpolation function. In this paper, we used Nearest-neighbor, Bilinear, Bicubic, Bicubic Cubic B-spline, Catmull-Rom, Lanzcos of order two and Lanzcos of order three algorithms for generating images and used for image quality assessment.

A. *NEAREST NEIGHBOUR:*

The Nearest Neighbor interpolation is the fastest and simplest option. It simply takes the color of a pixel and assigns it to the new pixels that are created from that pixel. Due to this simplistic approach, it does not create an anti-aliasing effect. Using this method one finds the closest corresponding pixel in the source (original) image for each pixel in the destination image. New pixels are made the same as others close-by. The pixels or dots of color are duplicated to create new pixels as the image grows. It creates pixilation or edges that break up curves into steps or jagged edges. This form of interpolation suffers from normally unacceptable effects for both enlarging and reduction of images. Nearest Neighbor interpolation is considered to be incapable of producing photographic quality work. [12].

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B. ***BILINEAR INTERPOLATION:***

Bilinear interpolation takes a weighted average of the four neighborhood pixels to calculate its final interpolated value. The result is much smoother image than the original image. When all known pixel distances are equal, then the interpolated value is simply their sum divided by four. This technique performs interpolation in both directions, horizontal and vertical. This technique is give better result than nearest neighbor interpolation and take less computation time compare to bicubic interpolation [13].

C. ***BICUBIC INTERPOLATION:***

Bicubic goes one step beyond bilinear by considering the closest 4x4 neighborhood of known pixels for a total of 16 pixels. Since these are at various distances from the unknown pixel, closer pixels are given a higher weighting in the calculation. Bicubic 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].

D. ***CUBIC B-SPLINE:***

As bicubic interpolation, the cubic B-spline interpolation algorithm also interpolates from the nearest sixteen source pixels. However, this algorithm uses B-spline interpolating functions instead of cubic splines, which in general yield quite smooth results. It performs a convolution with a two dimensional non separable filter, so its complexity is increased. In contrast, bicubic interpolation uses a convolution with a separable filter, and hence its complexity is less. Despite this performance difference, cubic B-spline has interesting characteristics of smoothness that make it a good option in some cases [15].

E. ***CATMULL-ROM INTERPOLATION:***

Catmull-Rom is a local interpolating spline developed for computer graphics purposes. Its initial use was in design of curves and surfaces, and has recently been used several applications. Catmull-Rom splines are a family of cubic interpolating splines formulated such that the tangent at each point is calculated using the previous and next point on the spline. The results are similar to ones produced by bicubic interpolation with regards to sharpness, But the Catmull-Rom reconstruction is clearly superior in smooth signal region [15].

F. ***LANCZOS INTERPOLATION:***

Lanczos interpolation function is a mathematical formula used to smoothly interpolate the value of a digital image between its samples. It maps each sample of the given image to a translated and scaled copy of the Lanczos kernel, which is a sinc function windowed by the central hump of a dilated sinc function. The sum of these translated and scaled kernels is then evaluated at the desired pixel [16]. Lanczos interpolation has the best properties in terms of detail preservation and minimal generation of aliasing artifacts for geometric transformations not involving strong down sampling. The number of neighboring pixels considered varies as the order of the kernel. If the order is chosen to be 2, 16 pixels are considered while if the order is 3, 36 neighboring pixels are utilized for interpolation. However the higher order Lanczos interpolation require high computational time, which make them not suitable for the many commercial software [17].

IV. IMAGE QUALITY ASSESSMENT ALGORITHMS

Image Quality Assessment Algorithms should be able to simulate the quality predictions of an average human observer. Based on the availability of a reference image, the objective quality assessment methods can be classified into three categories namely full-reference image quality assessment, reduced-reference image qualityassessment and no-reference image quality assessment. In this paper we used two different full-reference image quality assessment algorithms to evaluate image quality using peak signal-to-noise ratio (PSNR) and universal image quality index (UIQI).

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A. ***PEAK SIGNAL TO NOISE RATIO:***

PSNR is a classical index defined as the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation

$$PSNR = 10log\frac{S^2}{MSE}$$

Where S = 255 is the maximal possible value the image pixels when pixels are represented using 8 bits per sample and the MSE is Mean Squared Error [18].

B. ***UNIVERSAL IMAGE QUALITY INDEX:***

Wang and Bovik proposed Universal Image Quality Index measure [19], it breaks the comparison between original and distorted image into three comparisons: luminance, contrast, and structural comparisons as shown below[20].

$$l(x,y) = \frac{2\mu_x\mu_y}{\mu_x^2 + \mu_y^2}$$

$$c(x,y) = \frac{2\sigma_x\sigma_y}{\sigma_x^2 + \sigma_y^2}$$

$$s(x,y) = \frac{2\sigma_{xy}}{\sigma_x + \sigma_y}$$

Where **μxμy** denotes the mean values of original and distorted images. And **σxσy** denotes the standard deviation of original and distorted images, and **σxy** is the covariance of both images. Based on the above three comparisons the UIQI is given as

$$UIQI(x,y) = l(x,y).c(x,y).s(x,y) = \frac{4\mu_x\mu_y\mu_{xy}}{(\mu_x^2 + \mu_y^2)(\sigma_x^2 + \sigma_y^2)}$$

Universal quality index is mathematically defined and performs significantly better than the widely used distortion metric mean squared error and PSNR.

V. RESULT AND DISCUSSION

Image quality assessment algorithms, PSNR and UIQI are implemented using MATLAB. Images used for image quality assessment were generated using ImageJ. ImageJ is an open source java software developed by Wayne Rasband at National Institute for Health (NIH) used for image processing. The ImageJ distribution for Windows includes a Java compiler which allows to compile plugins inside ImageJ. As show in Fig. 1 (a), two input test image (Girl and Pepper) were downloaded from the USC-SIPI Image Database provided by the University of Southern California. Two images were scaled down to 128x128 pixel size for this research. The corresponding interpolated output images of size 256x256 produced by seven image scaling algorithmsnamely Nearest Neighbor, Bilinear, Bicubic, Cubic B-Spline, Catmull-Rom Lanzcos order 2 and Lanzcos order 3 as shown in Fig. 1 (b) to (h). The experiment is conducted for TIFF file format images. PSNR and UIQI values are calculated as show in Table 1 andare reported for discussion and conclusion.

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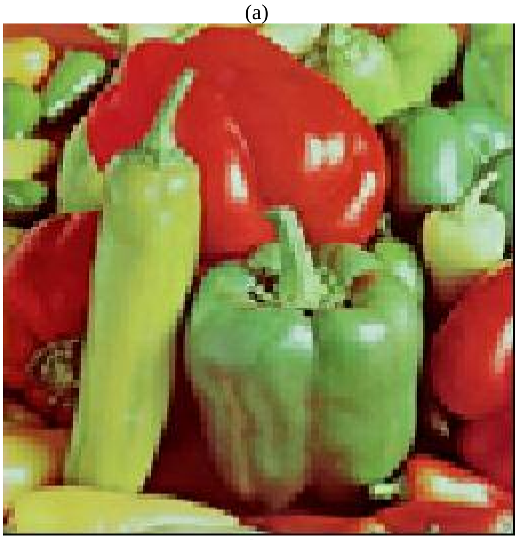
Table 1: PSNR, UIQI values for Girl and Pepper images

Interpolation Algorithms	Girl Image		Pepper Image	
	PSNR	***UIQI***	***PSNR***	***UIQI***
Nearest neighbour	25.7509	0.64005	20.5961	0.56532
Bilinear	30.1860	0.70768	22.7389	0.627784
Bicubic	29.9791	0.73132	22.6705	0.64580
Cubic B-Spline	29.1436	0.67739	22.7541	0.579943
Cutmull-Rom	30.2720	0.74474	22.7588	0.664042
Lanczos order 2	30.1083	0.71926	22.7581	0.625708
Lanczos order 3	30.0491	0.73206	22.6403	0.643760

(a)

(a)

(b)



(b)

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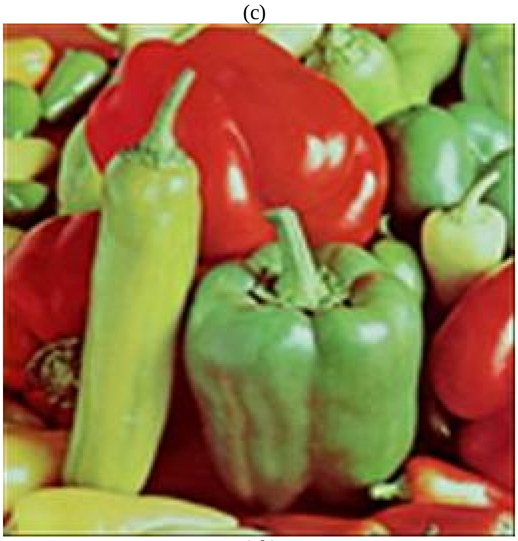
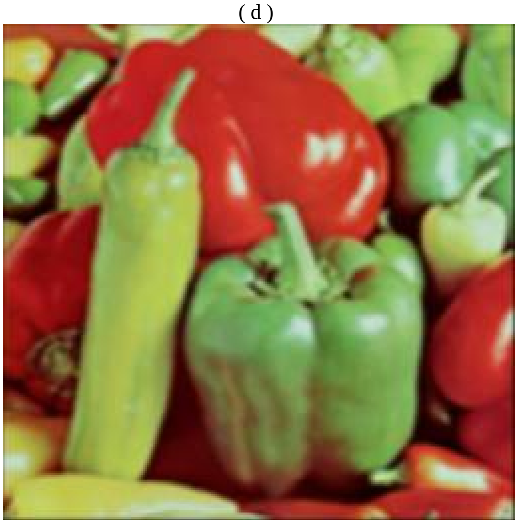
(c)


(c)


(d)


(d)


(e)


(e)

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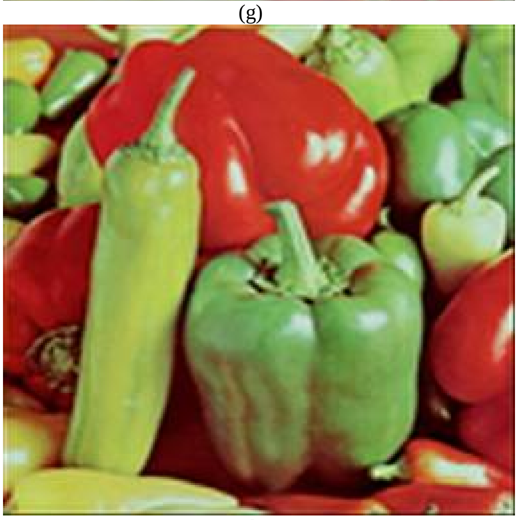
(f)

(f)

(g)

(g)

(h)



(h)

Figure 1. (a)Original image (Girl and Pepper) (b) Nearest-neighbour (c) Bilinear (d) Bicubic, (e) Cubic B-spline (f) Catmull-Rom (g) Lanczos order 2 (h) Lanczos order 3

PSNR and UIQI metrics are objective measurements that are calculated automatically and mathematically defined algorithms. PSNR compares the reference image and the distorted image on a pixel by pixel basis and calculates the PSNR value in decibels (dB). The value of UIQI lies between -1 and +1. The best value of UIQI is 1. Normally, the overall value of UIQI is calculated for a window of convenient size and the mean value is computed as the quality index.

After performing interpolation on the original images we got seven images included here as shown in Fig.1, and the image quality algorithms are applied to theses interpolated images and the results are compared. Measuring image quality using PSNR and UIQI for the seven images gave the results included in Table1. Simulation experiments reveal that the proposed PSNR and UIQI values for girl and pepper image for Nearest neighbor interpolation provides the least image quality output and Cutmull-Rom interpolation provides the best image quality output. Other interpolation algorithms such as Bicubic, Lanczos order 2 and Lanczos order 3 also generates better image quality output.

VI. CONCLUSION

From the result, it is clear that the Cutmull-Rom interpolation algorithm generates the best result with PSNR value 30.2720 and 22.7588 and UIQI value 0.74474 and 0.664042 for Girl and Pepper images respectively, where as the nearest Neighbor interpolation algorithm generates the worst result with PSNR value 25.7509 and 20.5961and UIQI value 0.64005 and 0.56532 for Girl and Pepper images respectively.As most of the images are ultimately viewed by human observers, the only reliable test to assess the quality of an image is by visually evaluating the image.Subjective image quality assessment not only takes a long time, but also is very expensive and not practical in real-time applications. Further, there can be individual factors that may influence the perceived image quality. Therefore, it is necessary to evaluate the image quality objectively, keeping the human visual system (HVS) as a basis for such an evaluation. Any objective IQA algorithm shall have a close correlation with the human perception of vision and it must have consistent performance over a wide range image types.

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