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Linear Image Upscaling :A Reveiw

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Abstract- ***Image upscaling is an important field of digital image processing. It is often required to create higher resolution images from the lower resolution images at hand in computer graphics, media devices, satellite imagery etc. Upscaling is also referred to as 'single image super-resolution'. Upscaling an image does not add new definition in the image, it increases the spatial resolution of the image and thus the total number of pixels in the image. The process of upscaling is a tradeoff between efficiency, computation time and the quality of output images obtained. Upscaling introduces some level of artifacts or blurriness in the output image. This paper is a brief review of some linear methods of image interpolation.***

Keywords: upscaling, super-resolution, interpolation, bicubic

1.INTRODUCTION

Digital images are used in many fields these days, medical imaging, satellite imagery, high-definition television broadcasts, printing etc. We require high resolution images a lot of times, however it's not always feasible to obtain or acquire images in high resolution. To obtain a higher resolution image from a lower resolution digital image is known as image upscalingor single image super-resolution. Figure 1 shows an example of upscaling of image. Resolution has been frequently referred as an important aspect of an image. Images are being processed in order to obtain more enhanced resolution. One of the commonly used techniques for image resolution enhancement is Interpolation [1] Interpolation calculates the new pixel values for the new image with a higher spatial resolution. Interpolation does not add new details to the image though. There are several issues with the perceived quality of interpolated images: sharpness of edges, freedom from artifacts and reconstruction of high frequency details. [18]

There are various interpolation methods available for image resolution upscaling.There are linear or non-adaptive methods, like nearest neighbor interpolation, bilinear interpolation and bicubic interpolation. And then there are adaptive interpolation methods like edge-directed interpolation, decision adaptive interpolation. The adaptive methods take into account the presence of edges and curves in the subject image. The paper reviews the linear image interpolation methods.

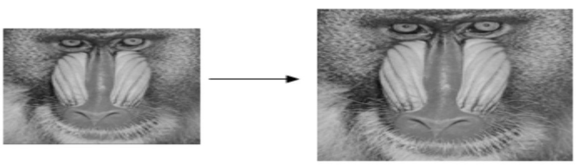

Figure 1: An example of image upscaling

1.1 Need for image upscaling

Scaling of images from lower resolution to a higher resolution is needed because of the following reasons:

1. It's easier to analyse and study higher resolution images.
2. Available sensors have limitation in respect to maximum resolution[17] So we need upscaling to overcome some of the inherent resolution limitations of low-cost imaging sensors [7]
3. To produce images of high perceptual quality and produce visually appealing results
4. To keep the text and graphics as original as possible, while avoiding noise and artifacts in the image [5]
5. To preserve the nature and texture of image while enlarging it
6. To allow for better utilization of the growing capability of High Resolution displays (e.g., HD LCDs). [7]

1.2 Applications of image upscaling

Image upscaling is used in many areas, some of these are:

1. Printing-To scale and print images according to canvas size while maintaining picture quality.

2. SURVEY OF RELATED WORK

1. Video playback-Televisions use real time up scaling algorithms to display simple definition content on high-resolution displays.
2. Mobile devices-To scale graphics and videos onto varying display sizes for viewing and playback.
3. Image processing packages-Image processing software use scaling for viewing and resizing the image. [3]
4. Satellite imaging-Nowadays, satellite images are used in many applications such as geosciences studies, astronomy, and geographical information systems. [4]
5. Computer Graphics-Computers perform screen image scaling which includes web pages, text, graphics, game scenes etc.[5]

Sr no.	Paper and author	Description
1	Gunturk B. K., Glotzbach J, Altunbasak Y., Schafer R. W., and Mersereau R. M. "Demosaicking: Color Filter Array Interpolation" IEEE SIGNAL PROCESSING MAGAZINE [44] JANUARY 2005	The paper surveys some interpolation algorithms and discusses the results in terms of objective and subjective measures.
2	Yuan S., Abe M., Taguchi A., Kawamata M. "High Accuracy bicubic interpolation using image local features" IEICE Trans vol.E90-A, no.8 pp 1611-1615	The paper proposes a bicubic method that adopts local asymmetry features and local gradient features while interpolatoing. Pros: Proposed method has high accuracy of output images and less MSE in images as compared to conventional bicubic method.
3	Demirel H. and Anbarjafari G., IMAGE Resolution Enhancement by Using Discrete and Stationary Wavelet Decomposition. IEEE transactions on image processing, vol. 20 pp 1458-1460	The paper proposes an image resolution enhancement technique based on interpolation of high subband images using DWT Pro: Superior than conventional state-of-art image resolution enhancement techniques on basis of PSNR.
4	Haichao Zhang, Yanning Zhang and Thomas S. Huang "Efficient sparse representation based image super resolution Via dual dictionary learning" 2011 IEEE	The paper presents a fast learning based super-resolution method. Pro: Speeds up sparse representation based super-resolution. Computationally more efficient
5	Kang X., Li S. and Hu J. "Fusing Soft-Decision-Adaptive and Bicubic methods for Image Interpolation" 21st International Conference on Pattern Recognition (ICPR 2012) Tsukuba, Japan pp 1043-1046	Paper proposes an image fusion based interpolation method. It uses Bicubic interpolation and Soft –decision-adaptive interpolation to interpolate an image. Pros: Removes the limitations of SAI and bicubic and produces better image quality
6	A Self-Learning Approachto Single Image Super-Resolution Min-Chun Yang and Yu-Chiang Frank Wang, Member, IEEE, IEEE TRANSACTIONS ON MULTIMEDIA, VOL. 15, NO. 3, APRIL 2013 pp 498-508	The paper proposes a novel self-learning approach for super resolution. The proposed framework, advances support vector regression (SVR) with image sparse representation, Pros:Does not require training low and high-resolution image data
7	Image and Video Upscaling from Local Self-Examples GILAD FREEDMAN and RAANAN FATTAL, 2009	The paper proposes a new high-quality and efficient single-image upscaling technique that extends existing example-based super-resolution frameworks. It does not rely on an external example database or use the whole input image as a source for example patches. Instead, it follows a local self-similarity assumption on natural images and extract patches from extremely localized regions in the input image. Pros: new filters are nearly-biorthogonal and hence produce high-resolution images.It allows GPU imlpementation
8	Super-Resolution Without Explicit Subpixel Motion Estimation, Hiroyuki Takeda, Peyman Milanfar, Matan Protter, and Michael Elad,, IEEE transactions on image processing, vol. 18, no. 9, september 2009. pp 1958-1975	The paper, introduces a novel framework for adaptive enhancement and spatiotemporal upscaling of videos containing complex activities without explicit need for accurate motion estimation. The approachis based on multidimensional kernel regression, whereeach pixel in the video sequence is approximated with a 3-D local (Taylor) series, capturing the essential local behavior of its spatiotemporal neighborhood. Pros: significantly widens the applicability of super-resolution methods to a broad variety of video sequences containing complex motions, andimproved overall performance.
9	Couple Dictionary Training for Image Super-resolution Jianchao Yang, Zhaowen Wang, Zhe Lin, Scott Cohen and Thomas Huang. IEEE TRANSACTIONS ON IMAGE PROCESSING. 2012	The paper proposes a novel coupled dictionary training method for single image superresolution based on patch-wise sparse recovery, where the learned couple dictionaries relate the low and high-resolution image patch spaces via sparse representation. The learning process enforces that the sparse representation of a low-resolution image patch in terms of the low-resolution dictionary can well reconstruct its underlying high-resolution image patch with the dictionary in the high-resolution image patch space. Pros: can outperform the existing joint dictionary training method both quantitatively and qualitatively.
10.	Image Interpolation by Pixel Level Data dependent Triangulation, Dan Su, Philip Willis.	The paper proposes a novel algorithm that can be used in arbitrary resolution enhancement. The 'mesh image' algorithm is faster because it does not involve any cost function or a repeating optimization process. Pros: Implemented in graphics hardware using OpenGL and thus can be used in real time applications like gaming and image processing
11.	SoftCuts: A Soft Edge Smoothness Prior for Color Image Super-Resolution. Shengyang Dai, Mei Han, Wei Xu, Ying Wu, Yihong Gong, Aggelos K. Katsaggelos	This paper characterizes soft edge smoothness based on a novel SoftCuts metric by generalizing the Geocuts method The proposed soft edge smoothness measure can approximate the average length of all level lines in an intensity image. This paper presents a novel combination of this soft edge smoothness prior and the alpha matting technique for color image super-resolution. This leads to the adaptive SoftCuts algorithm, which represents a unified treatment of edges with different contrasts and scales. Pros: The length of all image level lines can be minimized simultaneously for the super-resolution task. Thus, results with smooth edges can be obtained. The edge preserving property of the proposed prior term can also make the resulting edges have sharp transitions. All three color channels are utilized simultaneously
12.	Example-based Learning for Single-Image Super-Resolution and JPEG Artifact Removal. Kwang In Kim and Younghee Kwon, Max Planck Institute for Biological Cybernetics. 2008	The paper proposes a framework for single-image super-resolution and JPEG artifact removal. The underlying idea is to learn a map from input low-quality images (suitably preprocessed low-resolution or JPEG encoded images) to target high-quality images based on example pairs of input and output images. Pros: The generic learning part can be applied to any problem when suitable examples of input and target output images are available. Cons: the proposed method is application agnostic, i.e., the learningpart is independent of specific problem at hand and does not fully utilize domain knowledge. This implies that although the proposed method shows comparable performance to that of state-of-the-art methods, it is still far from being optimal and could be further improved.
13.	Image Upsampling via Imposed Edge Statistics, Raanan Fattal. University of California, Berkeley. ACM Transactions on Graphics, Vol. 26, No. 3, Article 95, Publication date: July 2007.	The paper proposes a new method for upsampling images which is capable of generating sharp edges with reduced inputresolution grid-related artifacts. The method is based on a statisticaledge dependency relating certain edge features of two different resolutions, which is generically exhibited by real-world images. Pros: able to retrieve sharp edges even when they are poorly sampled in the low resolutioninput. Artifacts, which are typical for such operations, are quite minimal in relative to the gain in clarity and sharpness of the resulting images. Cons: The proposedmethod involves more computations than some of the existingtechniques.
14.	Fast and Robust Multiframe Super Resolution. Sina Farsiu, M. Dirk Robinson, Michael Elad, and Peyman Milanfar. IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 13, NO. 10, OCTOBER 2004 pp 1327-1344	This paper reviews some of these methods and addresses their shortcomings. The paper proposes an alternate approach using 1 norm minimization and robust regularization based on a bilateral prior to deal with different data and noise models. Pros: This method is computationally inexpensive, is robust to errors in motion and blur estimation and results in images with sharp edges.
15.	Image Super-Resolution using Gradient Profile Prior. Jian Sun, Jian Sun, Zongben Xu, Heung-Yeung Shum	The paper proposes an image super-resolution approach using a novel generic image prior – gradient profileprior, which is a parametric prior describing the shape andthe sharpness of the image gradients. Using the gradientprofile prior learned from a large number of natural images,a constraint on image gradients can be provided whena hi-resolution image from a low-resolution image is estimated. Pros: The reconstructed high resolution image is sharp while has rare ringing or jaggy artifacts. Cons: For noisy input LR image, estimating the gradient profile might be inaccurate due to the noise

3.NEAREST NEIGHBORINTERPOLATION

In nearest neighbor interpolation, the value of the new interpolated pixel is calculated by the nearest sample point in the input image. The nearest neighbor produces a lot of blurriness and artifacts. It executes very fast, but the resulting image quality is not satisfactory. The interpolation kernel for the nearest neighbor is defined as[2] The figure 2 gives an example of how its used.

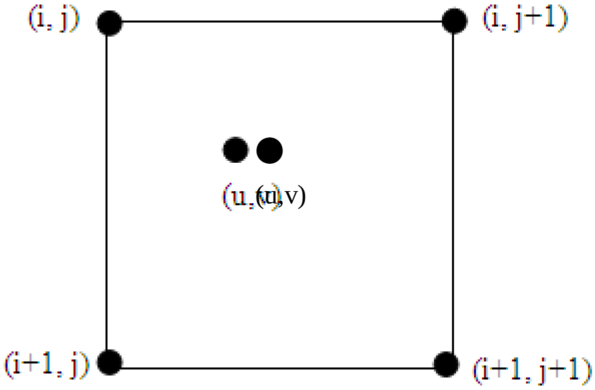

Figure 2: Nearest neighbor interpolation algorithm[3]

4. BILINEAR INTERPOLATION

In Bilinear interpolation, the position of new pixel is calculated by the influence of the neighboring four pixel points. The nearer they are , the greater their influence on the new pixel value. It performs better than nearest neighbor interpolation, but still has some visible artifacts and blurring.

The figure 3 shows how a new pixel P can be interpolated using four closest neighbors.

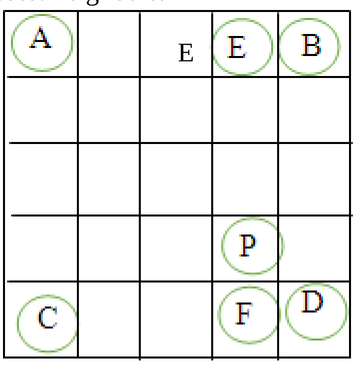

Figure 3: Bilinear interpolation[3]

5. BICUBIC INTERPOLATION

Bicubic interpolation is a common image interpolation technique that produces goodinterpolation results when applied to grayscale images.[4]Like other linear/non-adaptive methods, bicubic interpolation does not exploits the underlying structures in natural images, such as edges, thus may blur the fine details and introduce artifacts.

The interpolated pixels in bicubic interpolation are calculated as a weighted average of the neighboring sixteen pixels in a 4 by 4 matrix. The bicubic interpolation method produces better quality images. However it is more complex than bilinear and nearest neighbor interpolation.

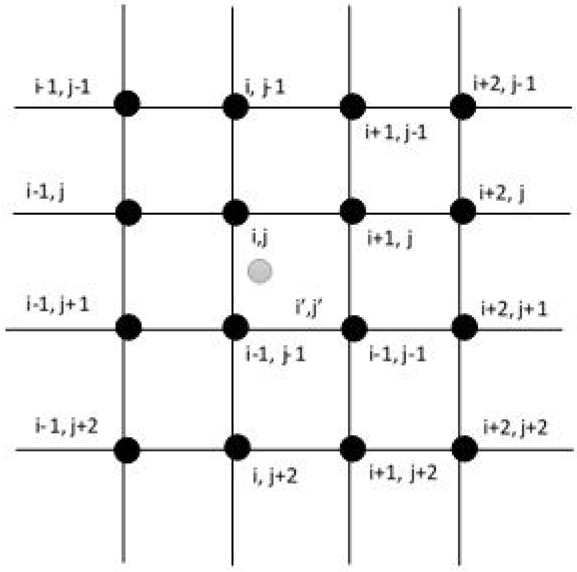

Figure 4: Bicubic Interpolation, position (i', j') [6]

6. PERFORMANCE MEASURES

To compare the performance of discussed interpolation methodswe compare their PSNR, MSE and SSIM values.

6.1 PSNR (Peak Signal to Noise Ratio) [16]

Signal to noise ratio is the ratio between the average power of a signal andthe power of corrupting noise while PSNR is the ratiobetween the maximum possible power of a signal and thepower of noise. SNR and PSNR are usually expressed interms of the logarithmic decibel scale and they can beexpressed as:

$$SNR = 10 \log_{10} \frac{\sum_i \sum_j a_{i,j}^2}{\sum_i \sum_j (a_{i,j} - b_{i,j})^2}$$

$$PSNR = 10 \log_{10} \frac{255}{MSE}$$

where, $a_{i,j}$ and $b_{i,}j$ are pixels from original and interpolated image, and x and y are the height and width of the image.

6.2 MSE(Mean Square Error)

The Mean Square Error is the cumulative squared error between the reconstructed image and the original image[18] It is used widely to evaluate the constructed image fidelity.[18]

$$MSE = \frac{\sum_i \sum_j (a_{i,j} - b_{i,j})^2}{x.y}$$

6.3 SSIM (Structural Similarity Index) [16]

The Structural Similarity (SSIM) is a novel methodfor measuring the similarity between two images . TheSSIM can be viewed as a quality measure of one of the images being compared, while the other image is regarded as of perfect quality. It can give results between 0 and 1, where 1 means excellent quality and 0 means poor quality[16]

7. IMPLEMENATION DETAILS

The tests were performed on an AMD A8 CPU running Windows 8. Instead of using the inbuilt methods of MATLAB for upscaling, we coded the interpolation methods from our understanding of their concepts. The images were first reduced to a third of their size and then were upscaled to thrice the size. The upscaled image thus had six times the pixels of the reduced image.

Table 1: Nearest neighbor interpolation performance

Image	PSNR	MSE	SSIM
Baboon	18.1527	0.0121	0.4223
Lena	20.0913	0.0053	0.7425
Peppers	20.5187	0.0053	0.7276
Office	22.4043	0.0020	0.7747

Table 2: Bilinear interpolation performance

Image	PSNR	MSE	SSIM
Baboon	19.1863	0.0153	0.4097
Lena	20.4596	0.0090	0.7281
Peppers	20.7189	0.0085	0.7280
Office	22.8457	0.0052	0.7558

Table 3: Bicubic interpolation performance

Image	PSNR	MSE	SSIM
Baboon	19.0250	0.0125	0.4592
Lena	22.7755	0.0098	0.7032
Peppers	22.7469	0.0089	0.7277
Office	26.8830	0.0057	0.7465

Figure 5: Output quality of image Lena. Nearest neighbor, Bilinear and Bicubic interpolation respectively

Figure 6: Output quality of image Peppers. Nearest neighbor, Bilinear and Bicubic interpolation respectively

8. CONCLUSION

The Bicubic interpolation provides the best output quality out of all the linear/non adaptive image interpolation methods. Even though it's more complex than nearest neighbor and bilinear interpolation it is still a viable solution to image upscaling needs for real time applications despite the availability of complex adaptive upscaling techniques.

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