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Grid Based Image Scaling Technique

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Abstract: The growing interest in image scaling is mainly due to the availability of digital imaging devices such as, digital video cameras, digital camcorders, 3G mobile handsets, high definition monitors etc. Scaling a digital image is a demanding and very important area of research. The grid based image scaling technique is proposed, where grid size equals the new desired dimensions of digital image. Virtually the grid is placed on the image and the intensity value of each pixel of grid is computed by taking weighted average of all intensities which are part of the imaginary pixel. The proposed grid based scaling algorithm outperforms other standard and widely used scaling techniques like linear interpolation, B-spline with order 2, B-spline with order 3. The algorithm is capable of scaling both grey-scale and color images of any resolution in any scaling factor. MSE and PSNR comparisons for down-after-up image scaling proves that the proposed technique gives better quality scaled images over other methods.

Categories and Subject Descriptors

I.4 IMAGE PROCESSING AND COMPUTER VISION

- I.4.0 General
  Image displays
- I.4.5 Reconstruction
  Series expansion methods

General Terms

Algorithms, Design.

Keywords Digital Image Scaling, Interpolation, B-spline scaling.

1 INTRODUCTION

The basic concept of image scaling is to resample a two-dimensional function on a new sampling grid [1,2]. In the literature, many methods for image scaling are proposed, with each approach providing tradeoffs between various factors [1-11]. Existing techniques include linear or non-linear approaches in the area domain. Very complex algorithms based in frequency domain are also proposed as well as techniques using neural networks. The most widely used techniques are in the area domain with linear approaches due to their simplicity and low computational burden, allowing real time operation, which is crucial for practical and consumer applications.

The simplest method is the *nearest neighbor* [5], which samples the nearest pixel from original image. It is regarded as the zero-order sample-and-hold and has good high frequency response, but degrades image quality due to aliasing. The most widely used method is the *bilinear* [6] which is regarded as the first-order sample-and-hold. In *bilinear*, the output pixel value changes linearly according to sampling position. There is more complex method called *bicubic* [7]. The weakness of *bilinear* and *bicubic* is blur effect causing bad high frequency response. Recently, many other methods using polynomial [8], adaptive[9], or correlative property [10] have been proposed. However, these methods have complex computation comparatively. In another method [11], the scale ratio is fixed at powers of two. It prohibits the method from being used in screen resolution change requiring a fractional scaling ratio.

The proposed algorithm is based on linear area domain and is capable of processing both grey-scale and color images of any resolution and performs both scale up or scale down processes. It uses the area coverage of the source pixels from the applied mask in combination with their difference of their intensity for calculating new pixels values of the scaled image.

2 LINEAR INTERPOLATION [12,13]

For separated bi-linear interpolation, the values of both direct neighbors are weighted by their distance to the opposite point of interpolation. Therefore, the linear approximation of the sinc function follows the triangular function

3 B-SPLINE SCALING [14-19]

In the mathematical subfield of numerical analysis, a B-spline is a spline function that has minimal support with respect to a given degree, smoothness, and domain partition. A fundamental theorem states that every spline function of a given degree, smoothness and domain partition, can be represented as a linear combination of B-splines of that same degree and smoothness, and over that same partition.[1] The term B-spline was coined by Isaac Jacob Schoenberg and is short for basis spline.[2] B-splines can be evaluated in a numerically stable way by the de Boor algorithm. In the computer science subfields of computer-aided design and computer graphics the term B-spline frequently refers to a spline curve parameterized by spline functions that are expressed as linear combinations of B-splines (in the mathematical sense above).

3.1 Interpolation with scaling functions:

A scaling function H(t) is a function with a non-vanishing integral such that the set {*H(t – l*), l *l* E Z} generates a closed subspace [4, 5]. For example, if H(*t)* is the rectangular window function, $N_i(t)$ = 1 for 0 <= *t*<= 1, then the set {*H(t – l*), *l* E Z} generates the space of functions that are piecewise constant on [*l*, *l* + 1].

Suppose that a function *x(t)*, represented by a sequence of *N* + 1 samples *x(n), n* = 0,1,2 ,..., *N*, is to be interpolated. We may approximate *x* by expressing it as an expansion in terms of H*(t)*

$$\hat{x}(t) = \sum_{k} x(k)H(t + kh - k) \qquad \textbf{(1)}$$

where *kh* is the centre of the scaling function and the range of *k* depends on the support of H(t). This equation allows us to calculate any *P* - 1 interpolated points in each sample interval. Although a number of functions are suitable as scaling functions, we focus our attention in the following on B-spline scaling functions because their compact support leads to simple and efficient algorithms for the calculation of the interpolated points.

3.2 Linear B-spline scaling functions:

We consider first the second order B-spline scaling function *N2(t)* where

$$N2(t) = \begin{pmatrix} t........if\, 0 <= t <= 1 \\ 2 - t.......if\, 1 <= t <= 2 \\ 0.........otherwise \end{pmatrix} \qquad \textbf{(2)}$$

Substituting this into eqn. 1 leads to the following expression for

X :

$$\hat{x}(t) = \sum_{n=0}^{N} x(n)N2(t - 1 - n) \qquad (3)$$

Using equation 3 to calculate an arbitrary interpolated point *x(k/P), k = 0,* 1, ._.*N, P* requires only two multiplications and one addition because the support of *N2(t)* is *[0,* 21. *N,(t)* needs to be evaluated at 2(P - 1) fixed points which are precalculated and stored as a lookup table. Symmetry of the scaling function could be exploited to halve the dimension of the table.

3.3 Quadratic B-spline scaling functions:

We consider now the third order B-spline scaling function *N3(t)* defined as follows:

$$N3(t) = \begin{pmatrix} t * t....................if\, 0 <= t <= 1 \\ -2t * t + 6t - 3........if\, 1 <= t <= 2 \\ (3 - t) * (3 - t).........if\, 2 <= t <= 3 \\ 0..................otherwise \end{pmatrix} \qquad (4)$$

A substitution into eqn. **1** yields the following expression for ***x:***

$$\hat{x}(t) = \lambda \sum_{n=-1}^{N} x(k)N3(t + \frac{3}{2} - n) \qquad (5)$$

where λ is a fitting factor whose value is ***-0.5.*** A method for calculating the optimum value of h is given later. The calculation of an arbitrary interpolated point ***x(k/P)*** requires at most three multiplications and two additions because the support of ***N&)*** is [0, 31. As previously, the required values of ***N3*** are precalculated and stored in a look-up table. Although eqn. 5 indicates that samples outside the sequence are desirable for interpolation near the end points, we show in the results that good accuracy is obtained by setting ***x(-1)*** = ***x(0)*** and ***x(N*** + **1)** = ***x(N).*** Greater accuracy can, of course, be achieved by extrapolating the end points, but our method does not depend **on** this.

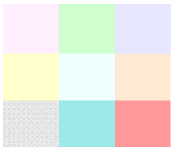
4 GRID BASED SCALING ALGORITHM

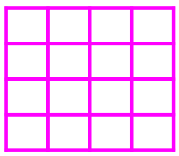
In case of expansion, the distance between the adjacent pixels in the compressed grid corresponding to the expanded image is made less than unity, as compared to the unit spacing between two pixels in the original image. Similarly, for compressing an image we have to expand an imaginary grid, which fits on the smaller version of the image, hence the distance between the adjacent pixels in the expanded grid corresponding to the shrunken image is made more than unity. To implement this algorithm, we will have to take into consideration the intensities of all the pixels surrounding the pixel in the imaginary grid under consideration. Hence the new intensity of every pixel in the imaginary grid will be calculated using the interpolation of the intensities of its diagonal neighbors.

The proposed Grid based Scaling Algorithm is……….

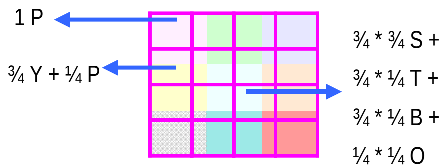
a. Reading the image which has to be scaled
b. Compute the scaling factors in the x direction and in the y direction
c. x_direction = New_x_resolution / original_x_resolution
d. y_direction = New_y_resolution / Original_y_resolution
e. Create a new grid based on the new size of the image
f. Compute the location of each new point in the imaginary grid relative to the nearest neighbor of the original image
g. Perform interpolation element by element using the intensities of its diagonal neighbors

Diagrammatically the working of scaling algorithm can be explained with help of Figure 1.1. In figure 1.1.a the original image with size 3x3 is shown. Each square is representing the pixel with different intensity value as different color. To scale this image to size 4x4 the grid is considered in figure 1.1.b. Virtually that grid is placed on the image and the intensity value of each pixel of grid is computed by taking weighted average of all intensities which are part of the imaginary pixel. The process of scaling is shown in figure 1.1.c. After the computation each pixel of grid gets new value as given in figure 1.1.d. After completion of the process scaled image is obtained as shown in figure 1.1.e. Thus original image (with size 3x3) is scaled to size 4x4.



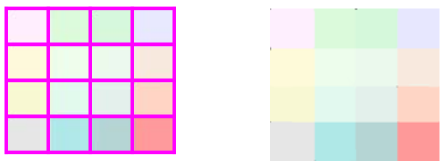


1.1.a Original Image 1.1.b Grid



1.1.c Scaling process

P : Pink Intensity, Y: Yellow Intensity,
S: Sky Blue Pink Intensity, T: Tint Intensity,
B: Blue Intensity, O: Orange Pink Intensity.



1.1.d Scaling completed 1.1.e Scaled Image

Fig 1. Working of Scaling Algorithm
a) Original Image 3x3, b) The grid 4x4, c) Mapping the grid on original image to scale up original image to 4x4, d) Scaling process is completed with new intensity value of every pixel in grid, e) Final Scaled Image with size 4x4.

5 RESULTS AND DISCUSSION

The proposed algorithm is compared with Linear Interpolation , B-spline Interpolation of order two and B-spline interpolation of order 3. The MSE and PSNR values of down-after-up scaling of sample images are shown in table 1.

From the statistical data given in table 1, we can conclude that the proposed grid based scaling algorithm gives better quality scaled images as compared to the considered counterparts.

Table 1: MSE and PSNR comparisons for up-after-down image scaling of sample images given in appendix.

Image	Scaling Factors		Comparison parameter	Proposed Grid Based Scaling	Linear Interpolation	B-spline order-2	B-spline order-3
	C	R					
Lena 32x32x3	2	2	MSE	497.833	614.754	761.553	778.486
			PSNR	21.1600	20.2430	19.3136	19.2183
Lena 128x128x3	3	3	MSE	137.300	NA*	249.773	242.647
			PSNR	26.7541	NA*	24.1553	24.2811
Pepper 128x128x3	4	4	MSE	231.336	273.913	316.070	298.485
			PSNR	24.4884	23.7547	23.1330	23.3816
Crawford 118x56x3	2	2	MSE	419.264	474.979	968.439	859.534
			PSNR	21.9059	21.3641	18.2701	18.7882
TajHotel 234x71x3	1	2	MSE	422.233	433.698	516.088	480.152
			PSNR	21.8753	21.7589	21.0036	21.3170

***Scaling factors should be in multiple of 2 for Linear Interpolation**.

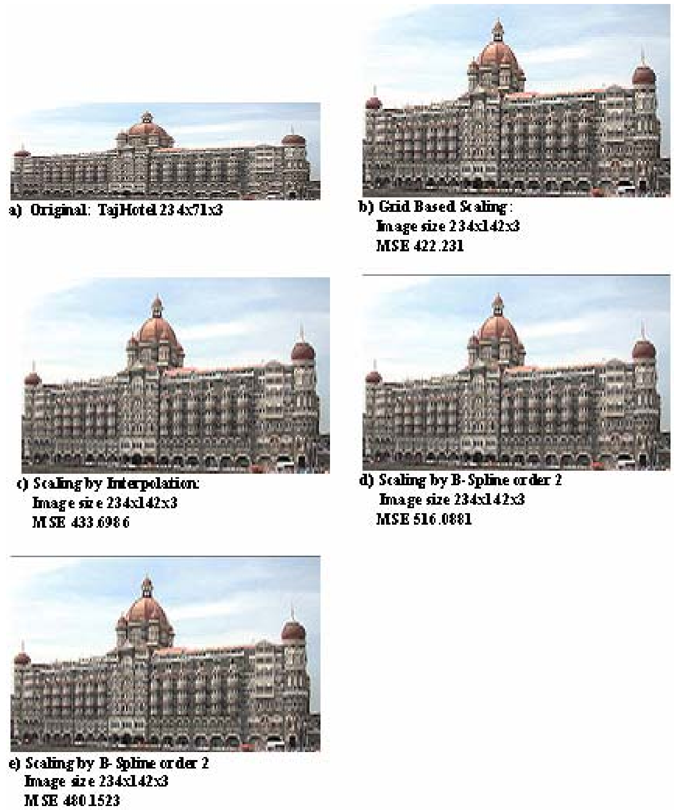


Fig. 2 Shows the results for Image TajHotel Mumbai

6 CONCLUSION

Grid Based Image scaling Technique is proposed. This technique can scale up or scale down color as well as grayscale images with any non uniform scaling factors. From the statistical data given in table 1, we can conclude that the proposed grid based scaling algorithm gives better quality scaled images as compared to the considered counterparts.

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