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An Efficient Algorithm for Image Scaling with High Boost Filtering

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Abstract- Image scaling is the process of resizing a digital image, wherein an image is converted from one resolution/dimension to another resolution/dimension without losing the visual content. It has many terminologies in literature such as Image Interpolation, image re-sampling, digital zooming, image magnification or enhancement, etc [1] [2]. Image interpolation algorithms can be grouped in two categories, non-adaptive and adaptive [3] [4]. Interpolating from lower to higher resolution it is termed as up-scaling / up-sampling and from higher to lower resolution it is termed as down-scaling / down-sampling. In this article we propose a non-adaptive image interpolation algorithm to scale images for any given scaling ratio with an enhancement scheme to ensure a better image quality metric (PSNR in dB) of the scaled image.

In the proposed algorithm, two reference images, one with higher resolution and another with lower resolutions are generated using the original input image and scaling factor. Later, two Intermediate images are generated from these reference images, using the filtering based re-sampling Lanczos3 kernel. Finally, the desired scaled image is obtained by linearly interpolating the two intermediate images. The desired scaled image is then passed through an enhancement phase, where a High Boost Filter is employed, to obtain an enhanced scaled image. Finally the algorithm is compared with the other interpolating techniques such as Bilinear Interpolation, B-Spline interpolation, Lanczos interpolation etc. in terms of the Image Quality metric: PSNR in dB.

Keywords - Image scaling, Filtering, Sampling, Interpolation.

I. INTRODUCTION

Digital Image scaling is the process of resizing a digital image, involving a trade-off between efficiency, smoothness and sharpness. This technique of resizing is referred in literature by many terminologies, such as image interpolation, image resizing, image re-sampling, digital zooming, image magnification or enhancement etc.. An image interpolation algorithm is used to convert an image from one resolution (dimension) to another resolution without losing the visual content in the picture. Image interpolation algorithms can be grouped in two categories, non-adaptive and adaptive. In non-adaptive algorithms, computational logic is fixed irrespective of the input image features, whereas in adaptive algorithms computational logic is dependent upon the intrinsic image features and contents of the input image.

When the image is interpolated from a higher resolution to a lower resolution, it is called as image *down-scaling* or *down-sampling*. On the other hand, when the image is interpolated from a lower resolution to a higher resolution, it is referred as image *up-scaling* or *up-sampling* [8] [9] [10]. Image interpolation has a variety of applications in the areas of computer graphics, editing, medical image reconstruction; for instance scaling up is used to enlarge images for HDTV or medical image displays and scaling down is applied to shrink images to fit mini-size LCD panel in portable instruments. It is also a part of many commercial image processing tools or freeware graphic viewers such as Adobe Photoshop CS2 software, IrfanView, Fast Stone Photo Resizer, Photo PosPro, XnConvert etc.

Numerous digital image scaling techniques have been presented, of which the most popular methods are: pixel replication based nearest neighbor replacement algorithm, Pixel interpolation based Bi-linear, Filter/Kernel based Cubic, Bi-cubic, B-Spline, Box , Triangle, Lanczos etc.[5] [6].

In this paper a non- adaptive interpolation algorithm is proposed with an enhancement scheme to ensure a better Image quality metric (PSNR in dB) of the scaled image. The proposed algorithm can scale images to any given scaling ratio (it performs up-scaling as well as downscaling). It is compared with various interpolating techniques, of which the Bilinear, B-Spline and Lanczos3 were selected for tabulating the PSNR value. Various test images of varying sizes ranging from 150x250, 220x220, 800x600, 600x912 etc. are scaled by a scaling factor of 150% (s=1.5)for ease of comparison of the algorithm with other interpolation technique. Simulation results show the impact of this algorithm in terms of image quality metrics.

In the proposed algorithm, two reference images, one with higher resolution and another with lower resolutions are generated using the original input image and scaling factor. These reference images are used to interpolate two Intermediate images, using the one of the filtering based re-sampling such as Lanczos3 kernel. Finally, the desired scaled image is obtained by linearly interpolating the two Intermediate images. Here a simplest method of linear interpolation can be replaced by a more efficient architecture of Extended Linear Interpolator as described in [7]. The desired scaled image is then passed through an enhancement phase, where a High Boost Filter is employed, to obtain the final desired and enhanced scaled image. Finally this image is compared with the other images, scaled by other interpolating techniques, by evaluating the Image quality metric: PSNR in dB[12][18].

II. INTERPOLATION TECHNIQUES

The principle in image scaling is to have a reference image as the base image, to construct a new scaled image. The constructed image can be smaller, larger, or equal in size depending on the scaling ratio. When enlarging an image, we are actually introducing empty spaces in the original base picture, which is the process of up-sampling. From this image we need to interpolate an appropriate pixel value to fill the empty spaces, through any of the non-adaptive, adaptive or filter based interpolation techniques [10] [11].

Nearest Neighbor Interpolation: It is one of the fastest and simplest forms of interpolation technique. During enlarging (up-scaling), the empty spaces will be replaced with the nearest neighboring pixel. Shrinking, on the other hand involves reduction of pixels.

Linear interpolation: It is a basic form of interpolation. Here we interpolate / estimate pixel value of any arbitrary point between two or more given points. Mathematically linear interpolation is for interpolating functions of one variable (either ‘x’ or ‘y’) on a regular 1D grid.

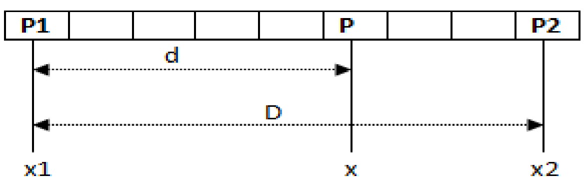


Figure 1: Linear Interpolation

$$P = P1 + \frac{d(P2-P1)}{D} \quad \text{OR} \quad P = P1 + \frac{(x-x1)(P2-P1)}{(x2-x1)}$$

Bilinear image Interpolation: It is an extension of linear interpolation for interpolating functions of two variables (‘x’ and ‘y’) on a regular 2D grid. This algorithm is a combination of two linear interpolations. The key idea is to perform linear interpolation first in one direction, and then again in the other direction.

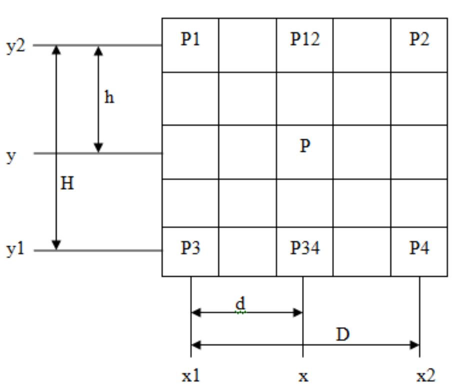


Figure 2: Bilinear Interpolation

$$P12 = P1 + \frac{d(P2-P1)}{D} \quad \text{OR} \quad P12 = P1 + \frac{(x-x1)(P2-P1)}{(x2-x1)}$$

$$P34 = P3 + \frac{d(P4-P3)}{D} \quad \text{OR} \quad P34 = P3 + \frac{(x-x1)(P4-P3)}{(x2-x1)}$$

$$P = P12 + \frac{h(P12-P34)}{H} \quad \text{OR} \quad P = P12 + \frac{(y-y1)(P12-P34)}{(y2-y1)}$$

Filter Based Interpolation: The filtering-based methods are also known as re-sampling methods[13] [14]. As shown in

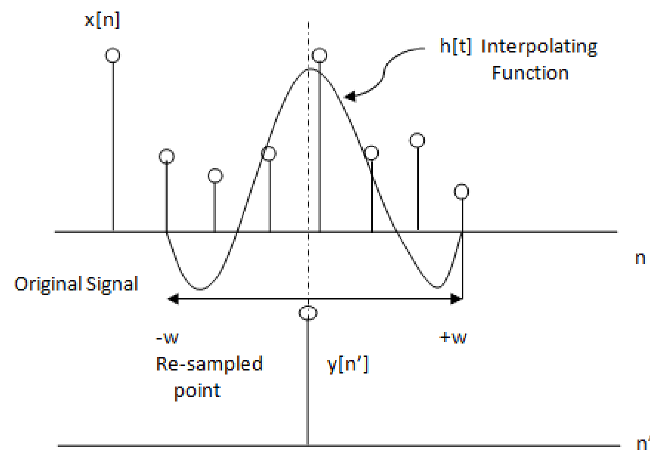


Figure 3: Re-sampling / Filter based Interpolation

Figure 3, the re-sampling from one discrete signal x[n] to a re-sampled signal y[n'] of a different resolution is computed as: $y[n'] = \sum_{t=-w}^{w} h[t]x[n'-t]$, where h[t] is the interpolating function and w is the desired filtering window.

In this paper, two different 2-D separable filters are selected, such as Cubic B-Spline kernel and Lanczos3 kernel for simulation and comparison of experimental results. The kernel functions of these filters are given below.

Cubic B-Spline: It is a form of interpolation where the interpolant is a special type of piecewise polynomial called a Spline [15] [16] [17]. The kernel function of the cubic B-Spline is as follows:

$$\beta^3(x) = \left\{\frac{1}{2}|x|^3 + |x|^2 + \frac{2}{3} \qquad , \quad |x| < 1\right.$$

$$\beta^3(x) = \left\{-\frac{1}{6}|x|^3 + |x|^2 - 2|x| + \frac{4}{3} \qquad , 1 \le |x| < 2\right.$$

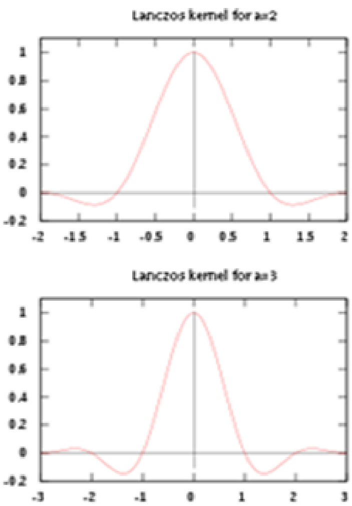
$$\beta^3(x) = 0 \qquad , \textit{Otherwise}$$

Lanczos re-sampling/filter: It is a mathematical formula used to smoothly interpolate the value of a digital signal between its samples. It a dilated Sinc function windowed by the central humps. The sum of these translated and scaled kernels is then evaluated at the desired points. The Lanczos Kernel functions are as follows.

$$L(x) = \begin{cases} \mathrm{sinc}(x)\,\mathrm{sinc}(x/a) & \text{if } -a < x < a \\ 0 & \text{otherwise} \end{cases}$$

$$L(x) = \begin{cases} 1 & \text{if } x = 0 \\ \dfrac{a \sin(\pi x) \sin(\pi x / a)}{\pi^2 x^2} & \text{if } 0 < |x| < a \\ 0 & \text{otherwise} \end{cases}$$

The parameter 'a' is positive integer, typically 2 or 3, which determines the size of the kernel. For a=2 and a=3, the kernels are as shown in the Figure 4.



$$L2(x) = \frac{\sin(\pi x)}{\pi x} \frac{\sin(\pi \frac{x}{2})}{\pi \frac{x}{2}}, |x| < 2$$

$$L3(x) = \frac{\sin(\pi x)}{\pi x} \frac{\sin(\pi \frac{x}{3})}{\pi \frac{x}{3}}, |x| < 3$$

Figure 4: Lanczos Kernels

III. PROPOSED ALGORITHM

The block diagram of the proposed algorithm is shown in the Figure 5. The input image X, with a resolution (m x n) is scaled by a factor S (scaling factor) to obtain an output image Y of a different resolution (i x j). We have the following representation for images produced after every stage of the proposed algorithm.
X (m x n): Input Image, S: Scaling Factor
X1(m1 x n1): Larger Reference Image
X2(m2 x n2): Smaller Reference Image
Y1 (i1 x j1): Intermediate Image 1

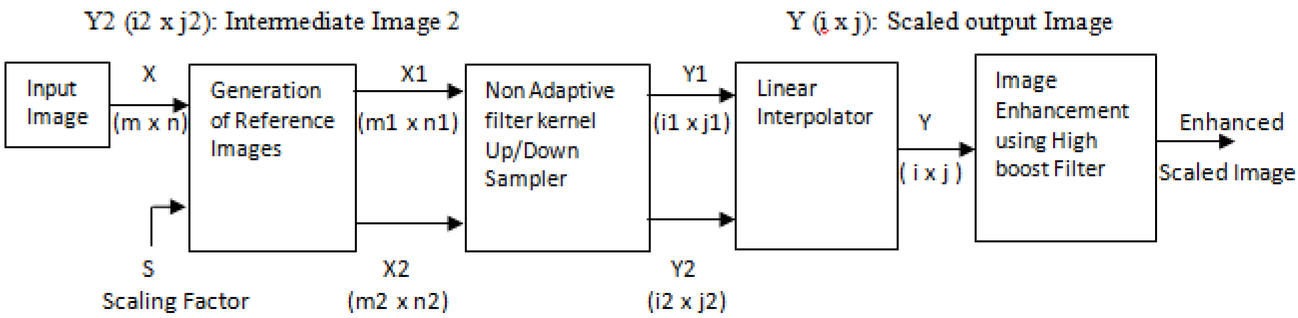


Figure 5: Block Diagram of Proposed Algorithm

The Flow chart of the proposed algorithm is shown in the Figure 6.

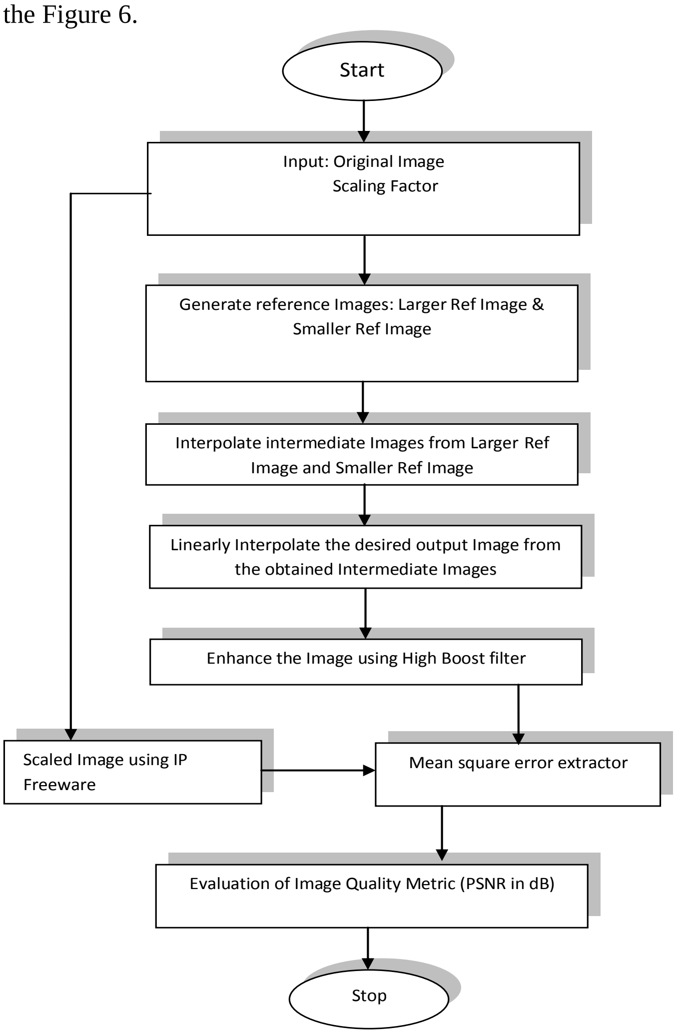


Figure 6: Flow Chart of Proposed Algorithm

The algorithm consists of basically four stages:
1. Reference image generation
2. Intermediate image generation
3. Linear interpolation
4. High Boost filtering for Image enhancement.

The proposed algorithm makes use of some of the previously mentioned scaling methods. Out of the various methods, Lanczos3 kernel is selected for simulation in the proposed algorithm. Figure 7 and Figure 8 show the first three stages. The two reference images are generated (Larger reference image and Smaller reference image) from the input image and scaling factor, using the Lancoz3 re-sampling method. The input image is scaled by twice the scaling factor i.e. (2*S) to obtain the larger image and is scaled by half the scaling factor (0.5*S) to obtain the smaller image. This initial step to generate the reference images is important, with a view to ensure that the interpolated image is within the range of pixel values of the input image. These reference images are used to obtain the intermediate images having the resolutions as per the desired scaling factor specified. These two images of same sizes are further used to linearly interpolate the required scaled output image(Y (i x j)) using the interpolation equation.

$$Y = Y1 + h(Y2 - Y1)$$

$$h = \frac{W1 - \text{width}}{W1 - W2}$$

W1: Width of larger reference image
W2: Width of smaller reference image
Width: Width of larger reference image

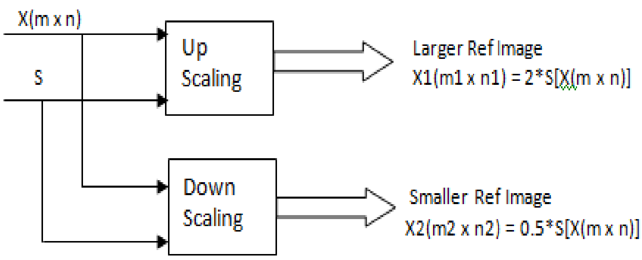


Figure 7: Blocks to Generate Reference Image

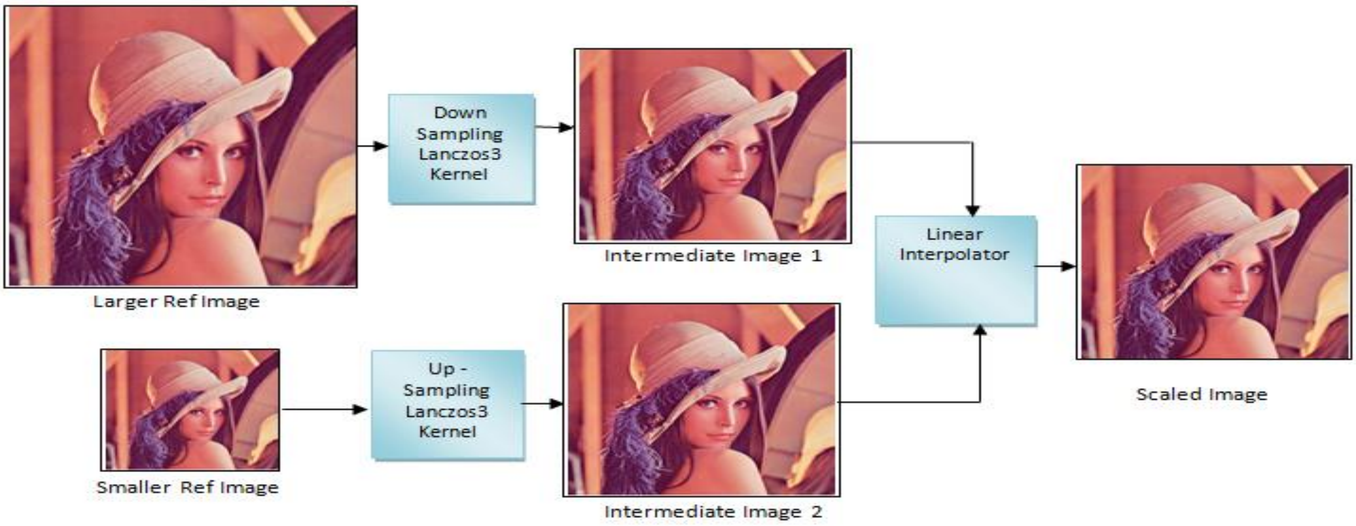


Figure 8: Blocks of Proposed Algorithm to obtain the Scaled Image

The last stage of Image Enhancement [22] [23] [24] [25] involves a High Boost Filter (HBF) as shown in the Figure 9. This filter is simulated by a simple Averaging Kernel/Mask along with a Subtraction and an addition. The quality of the scaled output image is significantly enhanced using the HBF.

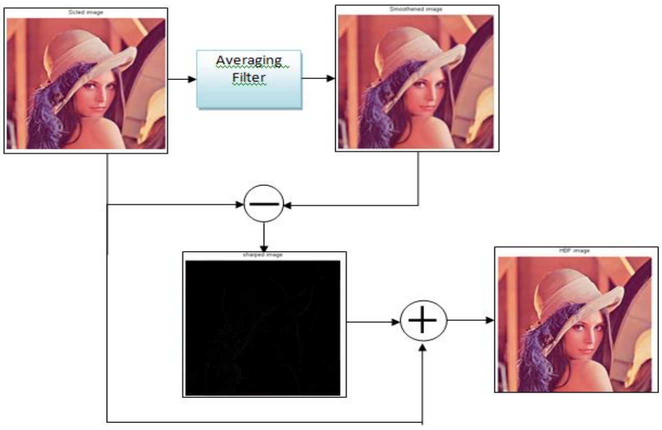


Figure 9: Image Enhancement of the Scaled Image using High Boost Filtering

IV. EXPERIMENTAL RESULTS AND COMPARISONS

The performance of the proposed algorithm, and the quality metric of the enhanced scaled image is measured using a Mean Square Error Extractor. The extractor requires two images of same sizes to evaluate the error between them. In order to evaluate the quality of the scaled image obtained from the PA, comparison is done a scaled image obtained from a Image Processing freeware such as Irfan View(IRV), Adobe Photoshop, FastStone Photo Resizer(FSPR), Image Analyzer, XnConvert, Photo PosPro etc. In this paper we have selected Irfan View and FastStone Photo Resizer for tabulation purpose. The image quality metric: Peak Signal to Noise Ratio PSNR is commonly used to measure the quality of the image. It is expressed in decibel scale (dB).High value of PSNR indicates a high quality of image. It is defined via Mean Square Error (MSE). Lower value of MSE results in High value of PSNR [12]. The Extractor uses the following relationships to evaluate the PSNR:

$$MSE = \frac{1}{i * j} \sum_{k=1}^{i} \sum_{l=1}^{j} Y_{IP}(k,l) - Y_{PA}(k,l)$$

Where YIP : Scaled image using Image Processing Freeware (IRV / FSPR)
YPA : Scaled image using Proposed algorithm.
i * j: Total number of Pixels in the scaled image.

$$PSNR = 10 * \log_{10}\left(\frac{Max\_peak\_value^2}{MSE}\right)$$

The proposed algorithm is implemented in MATLAB. Images of various resolutions and sources are selected for test purpose as shown in the Figure 10. Comparison of PSNR (dB) value of the Scaled images using the Proposed Algorithm and various Interpolation methods along with related graphs are shown in Table I. and Figure 11. Some of selected original and scaled images with their PSNR in dB (for Irfan View freeware) are shown in the Figure 12.

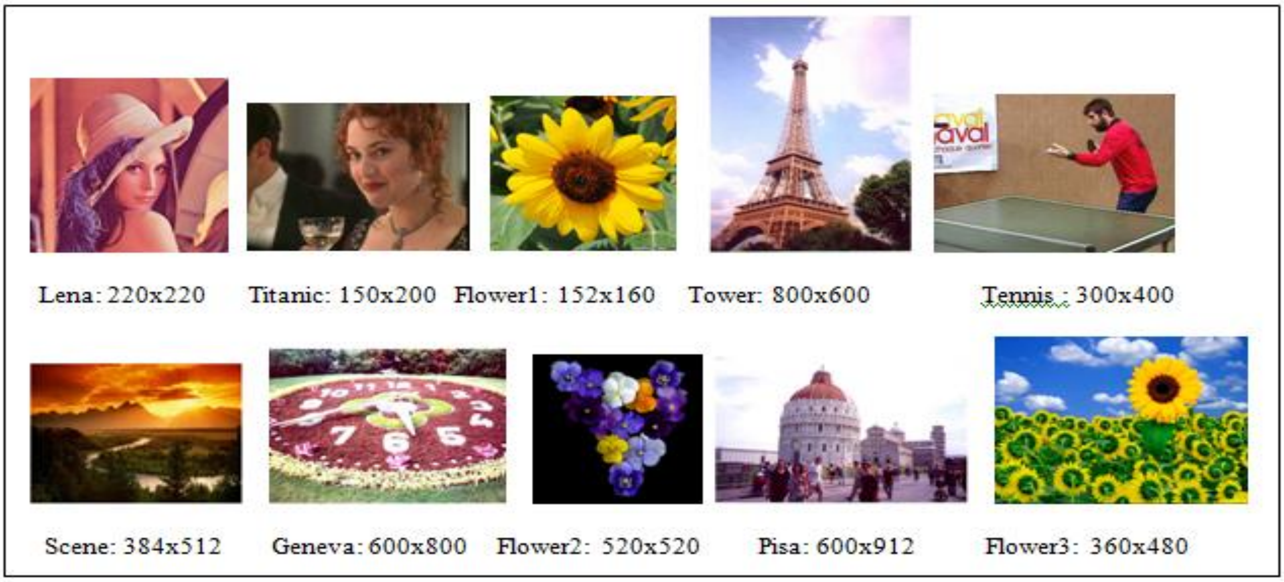


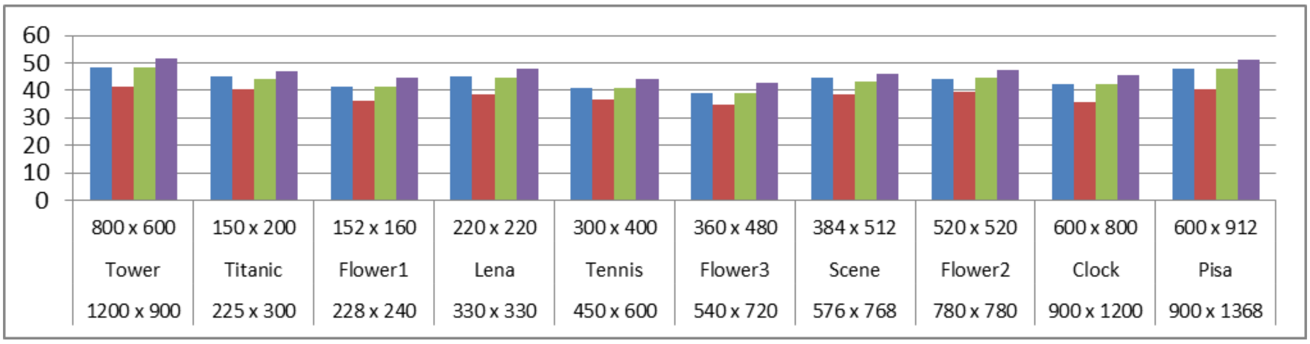
Figure 10: Various Original Images of different resolutions selected for scaling by a factor of S=1.5 (150%)

TABLE I: Average PSNR (dB) values over 3 RGB channels for images scaled by a scaling factor S=1.5 (150%), using different Interpolation methods and Proposed Algorithm.

Test Images scaled using IP Softwares	Scaling Mathod	PSNR in dB			
		Bilinear	B-Spline	Lanczos	Proposed Algorithm
Lena 220 x 220 → 330 x 330	Irfan View	44.9199	38.4665	44.5689	**48.1416**
	FastStone Photo Resizer	33.6841	40.5043	47.5912	**51.5424**
Titanic 150 x 200 → 225 x 300	Irfan View	45.0269	40.2033	44.3559	**46.7531**
	FastStone Photo Resizer	34.9572	42.9569	46.9319	**49.8649**
Flower1 152 x 160 → 228 x 240	Irfan View	41.1948	36.2809	41.1465	**44.7460**
	FastStone Photo Resizer	32.7533	38.8471	44.1186	**48.7715**
Tower 800 x 600 → 1200 x 900	Irfan View	48.5737	41.5097	48.2700	**51.4781**
	FastStone Photo Resizer	35.6265	44.1880	52.1714	**55.9652**
Tennis 300 x 400 → 450 x 600	Irfan View	40.8483	36.7906	41.0073	**44.1243**
	FastStone Photo Resizer	33.8338	38.3241	42.8303	**46.7703**
Scene 384 x 512 → 576 x 768	Irfan View	44.4918	38.4490	43.2950	**45.9669**
	FastStone Photo Resizer	34.5588	41.6524	47.9475	**52.7681**
Clock 600 x 800 → 900 x 1200	Irfan View	42.3524	35.9430	42.2440	**45.5074**
	FastStone Photo Resizer	30.7017	37.9400	44.7180	**48.2819**
Flower2 520 x 520 → 780 x 780	Irfan View	44.0837	39.6072	44.5883	**47.6646**
	FastStone Photo Resizer	36.8752	41.9555	47.9808	**52.4849**
Pisa 600 x 912 → 900 x 1368	Irfan View	47.9018	40.5232	47.7685	**51.2051**
	FastStone Photo Resizer	34.2324	42.9351	51.5311	**55.5937**
Flower3 360 x 480 → 540 x 720	Irfan View	39.2479	34.8677	39.1715	**42.5708**
	FastStone Photo Resizer	32.8687	37.4669	42.4229	**47.0576**

Bilinear B-Spline Lanczos Proposed Algorithm

Irfan View



FastStone Photo Resizer

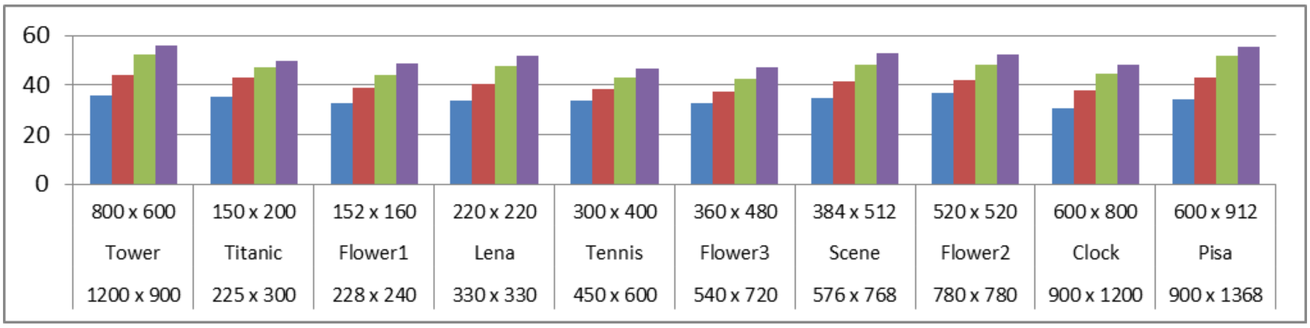


Figure 11: Comparison graphs of the various Interpolation methods and PA.

V. CONCLUSION

An efficient Interpolation algorithm for image scaling is proposed with an enhancement scheme which provides a high image quality (PSNR in dB) in comparison with Bilinear, B-Spline and Lanczos interpolating methods. Image interpolation algorithms are extensive used in medical imaging. The presented work deals with Spatial domain analysis [26] of the images, therefore resulting in a breakthrough for a Fourier domain and Wavelet domain analysis [21] of the images for researchers. The PA for image scaling can be effectively applied for video frames, in order to achieve an efficient video scaling algorithm [19] [20]. A video scaler with a good video scaling algorithms are suitable for gaming, real-time image processing software and wide range of emulators, allowing a low resolution game to be more visually appealing on a High Definition displays and in wide range of applications such as consumer electronics (HDTV, Mobiles, Video game, DVD/Blu-ray disc), AV equipments (video editing, video switching) found as a part of home theatre and projected presentation systems. Hence there is a need of an efficient scaling algorithm to be incorporated in video processing devices to improve the apparent definition of video signals.

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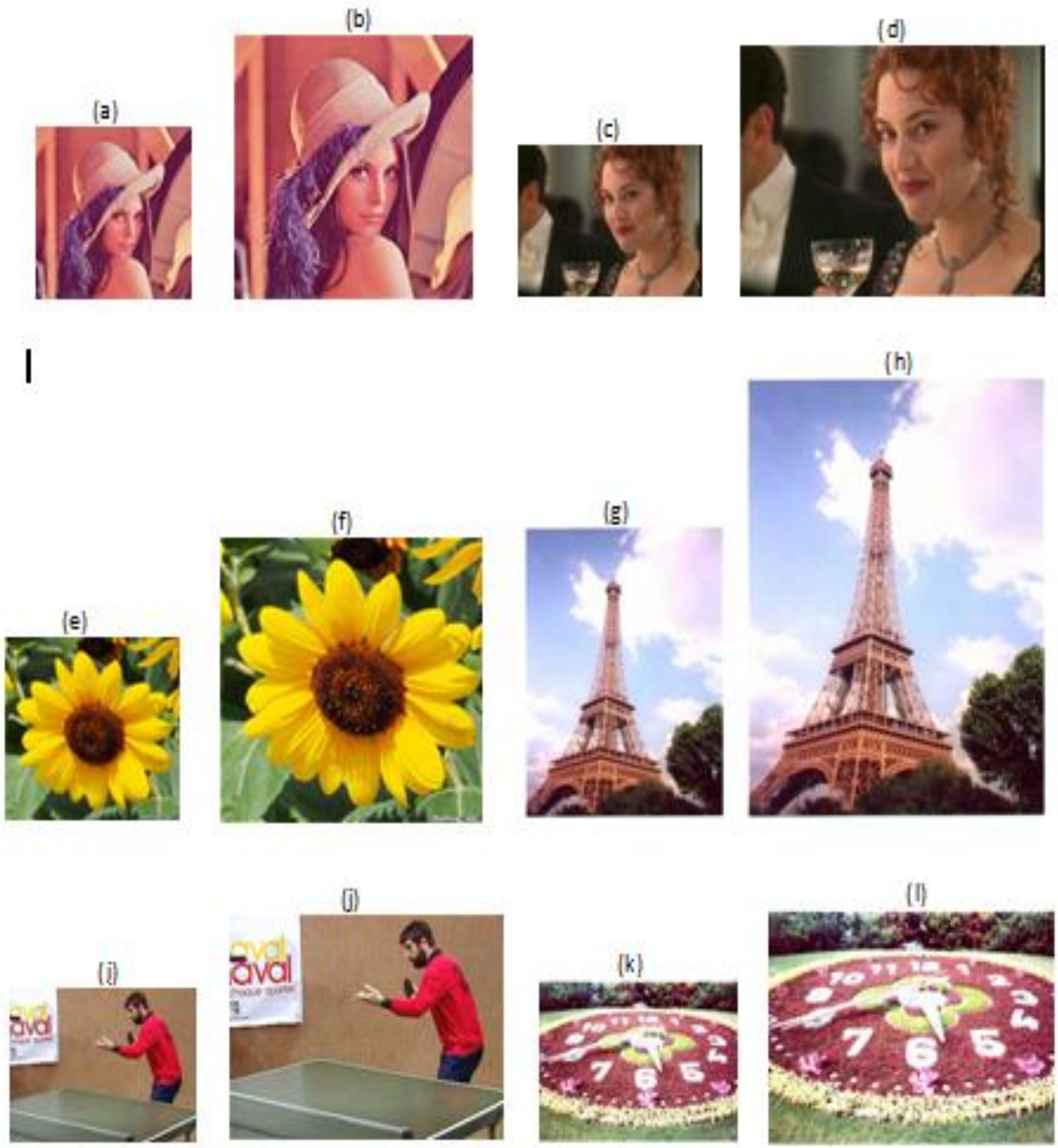

Figure 12:Scaled images using the Proposed Algorithm, for scaling factor S=1.5. (a) Original Lena image(220x220). (b) Scaled Lena image (330x330), PSNR= 48.1416 dB.(c) Original Titanic image(150x200). (d) Scaled Titanic image (225x300), PSNR= 46.7531 dB. (e) Original Flower1 image(152x160). (f) Scaled Flower1 image (228x240), PSNR= 44.7460 dB. (g) Original Tower image (800x600). (h) Scaled Tower image (1200x900), PSNR= 51.4781 dB. (i) Original Tennis image(300x400). (j) Scaled Tennis image (450x600), PSNR= 44.1243 dB. (k) Original Geneva image (600x800). (l) Scaled Titanic image (900x1200), PSNR= 45.5074 dB.

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