RESEARCH ARTICLE OPEN ACCESS

A Novel Video Scaling Algorithm Based On Linear Interpolation WithQuality Enhancement

SafinazS[1],S. Ramachandran[2]
[1]Sir MVIT, Bangalore
[2] SJBIT, Bangalore

Abstract
A non-adaptive image interpolation algorithm is proposed to scale images for any given scaling factor with an enhancement scheme to ensure a better picture. |In the proposed algorithm, two reference frames, one with higher resolution and another with lower resolution are generated using an original videoframefor the User defined scaling factor. Later, two Intermediate frames are generated from these reference frames using the filtering based re-sampling Lanczos3 kernel. Finally, the desired scaled frame is obtained by linearly interpolating the two intermediate frames.The scaled frame is then passed through an enhancement phase, where a Sharpening Filter is employed, to obtain an enhanced scaled frame. The algorithm compares favorably with other interpolating techniques such as Bilinear Interpolation and B-Spline interpolation in terms of the image quality. The quality of the scaled frames expressed as PSNR is better than 45dB.
Keywords-Image scaling, Video scaling, Filtering, Sampling, Interpolation

I. INTRODUCTION

Scaling a video can be effective once an efficient Image scaling algorithm is determined**.** Digital Image scaling is the process of resizing a digital image, involving a trade-off between efficiency, smoothness and sharpness. An image interpolation algorithm is used to convert an image from one resolution (dimension) to another without losing the visual content in the picture. Image interpolation algorithms can be grouped into two categories, non-adaptive and adaptive Ref. [1-4]. In non-adaptive algorithms, computational logic are 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*. On the other hand, when the image is interpolated from a lower resolution to a higher resolution, it is referred as *up-scaling*. Image interpolation has a variety of applications in the areas of computer graphics, editing, medical image reconstruction, enlargingthe images for HDTV, shrinking images to fit mini-size LCD panel in portable instruments and so on. It is also a part of many commercial image processing tools or freeware graphic viewers such as Adobe Photoshop CS2 software, IrfanView [5], Fast Stone Photo Resizer, Photo PosPro, XnConvert etc.

Numerous digital image scaling techniqueshave been presented [6-10] 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.

In this paper, a non- adaptive interpolation algorithm is proposed with an enhancement scheme to ensure a better Image quality of the scaled image. The proposed algorithm can scale images to any given scaling ratio, be it up-scaling or downscaling. It is compared with various interpolating techniques such as the Bilinear, B-Spline and Lanczos. Various test images of different sizes ranging from 150x250 pixelsto 600x912 pixels are scaled by a scaling factor of 150%. Simulation results show the impact of this algorithm in terms of image quality metrics.

In the proposed algorithm, two reference frames, one with higher resolution and another with lower resolutions are generated using the original input video frame and scaling factor. These reference frames are used to interpolate two intermediate frames, using one of the filtering based re-sampling techniques such as the Lanczos3 kernel. Finally, the scaled frame is obtained by linearly interpolating the two Intermediate frames. Here a simple method of linear interpolation can be replaced by a more efficient architecture of Extended Linear Interpolator as described in Ref. [11].Thescaled picture is then passed through an enhancement phase, where a Sharpening Filter is employed to obtain the enhanced scaled picture.

The rest of the paper is organized as follows. Section II describes the various Interpolation Techniques followed by the description of the Proposed Algorithm in Section III. Section IV presents the experimental results. The conclusion is presented in Section V.

II. INTERPOLATION TECHNIQUES

The basic principle of image scaling is to have a reference image as the base image in order to construct a new scaled image. The reconstructed image can be smaller, larger, or equal in size with the original image depending on the scaling factor. 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 meaningful pixel valuesto fill the empty spaces, through any of the non-adaptive, adaptive or filter based interpolation techniques [12-14].

Linear interpolation: It is a basic form of interpolation. Here we interpolate or 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 as shown in Fig.1.Herein, P is the arbitrary point between two known pixel values P1 and P2, where the pixel value has to be interpolated or estimated using Eq. (1).

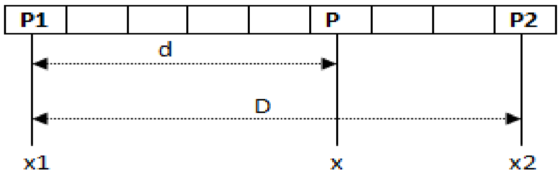


Figure1 Linear Interpolation

$$P = P1 + \frac{d(P2-P1)}{D} \quad \text{OR} \quad P = P1 + \frac{(x-x1)(P2-P1)}{(x2-x1)} \quad \ldots\ldots\ldots (1)$$

*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 as shown in Fig.2.Here, P is the arbitrary point between four known pixel values P1, P2, P3 and P4. We first apply the Linear Interpolation between P1 and P2 to obtain the Pixel value P12 using the Eq. no. (1). Similarly, P34 is interpolated between P3 and P4. Then the pixel value P is obtained using Eq. (2).

Filter Based Interpolation: The filtering-based methods are also known as re-sampling methods [15-17]. As shown in Fig. 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.

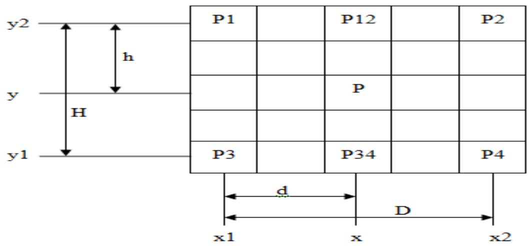


Figure 2 Bilinear Interpolation

$$P12 = P1 + \frac{d(P2-P1)}{D} \quad \text{OR} \quad P12 = P1 + \frac{(x-x1)(P2-P1)}{(x2-x1)}$$
$$P34 = P3 + \frac{d(P4-P3)}{D} \quad \text{OR} \quad P34 = P3 + \frac{(x-x1)(P4-P3)}{(x2-x1)} \quad .\ (2)$$
$$P = P12 + \frac{h(P12-P34)}{H} \quad \text{OR} \quad P = P12 + \frac{(y-y1)(P12-P34)}{(y2-y1)}$$

In this paper, two different 2-D separable filters are selected, such as Cubic B-Spline kernel and Lanczos3 kernel

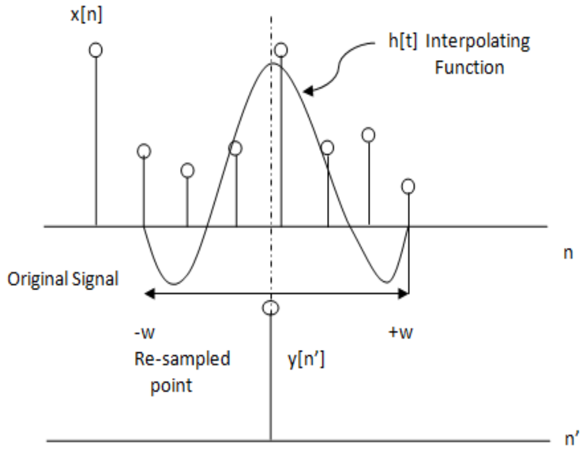


Figure 3 Re-sampling / Filter based Interpolation

forsimulation and comparison of experimental results. The kernel functions of these filters [18-21] are as follows.

Cubic B-Spline: It is a form of interpolation where the interpolantis a special type of piecewise polynomial, called a Spline [15-17]. The kernel function of the cubic B-Spline is described using Eq. (3).

$$\beta^3(x) = \left\{\frac{1}{2}|x|^3 + |x|^2 + \frac{2}{3} \quad , \quad |x| < 1\right.$$
$$\beta^3(x) = \left\{-\frac{1}{6}|x|^3 + |x|^2 - 2|x| + \frac{4}{3} \quad , 1 \le |x| < 2\right. \quad \ldots. (3)$$
$$\beta^3(x) = 0 \quad , \mathit{Otherwise}$$

Lanczos re-sampling/filter: It is a mathematical formula used to smoothly interpolate the value of a digital signal between its samples. It isa dilatedSinc 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 described using Eq. (4).

$$L(x) = \begin{cases} \operatorname{sinc}(x)\,\operatorname{sinc}(x/a) & \text{if } -a < x < a \\ 0 & \text{otherwise} \end{cases} \quad \text{....... (4)}$$

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

The parameter 'a' is a positive integer, typically 2 or 3, which determines the size of the kernel. As examples, the kernels are presented in Fig. 4 for a = 2 and a = 3.

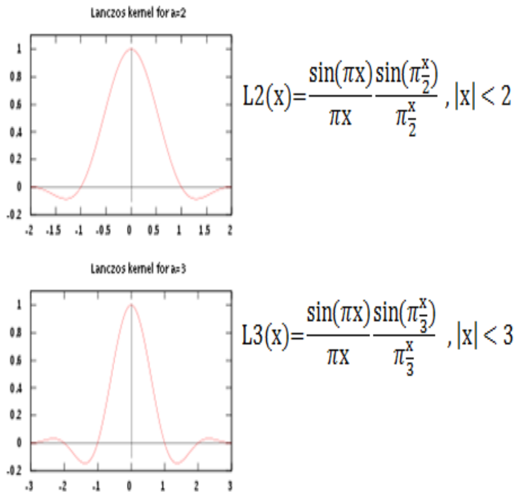


Figure 4Lanczos Kernels

III. PROPOSED ALGORITHM

The block diagram of the proposed algorithm is presented in Fig. 5.

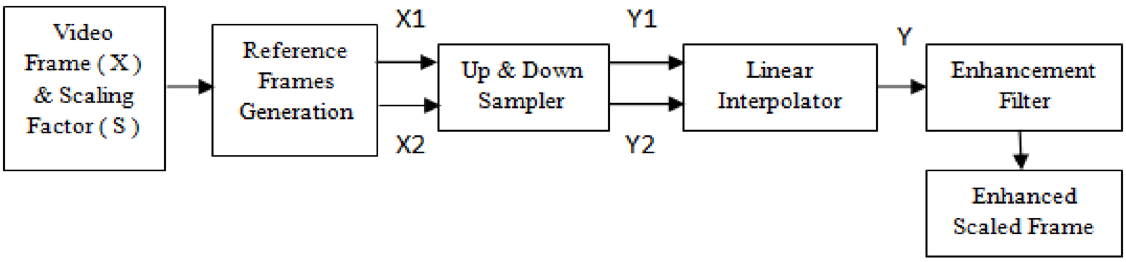


Figure5 Block Diagram of the Proposed Algorithm

The input image or a frame X of M x N pixels resolution is scaled by a factor S in order to obtain a scaled image or frame Y of a different resolution, say, I x J pixels. The following is a representation of images produced after every stage of the proposed algorithm:

X (M x N): Input Frame, S: Scaling Factor
X1 (M1 x N1): Larger Reference Frame
X2 (M2 x N2): Smaller Reference Frame
Y1 (I1 x J1): Intermediate Frame 1
Y2 (I2 x J2): Intermediate Frame 2
Y (I x J): Scaled output Frame

The Flow chart of the proposed algorithm is presented in Fig. 6. The 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. Fig. 7 and Fig. 8 show the first three stages. The two reference frames, one Larger resolution reference frame and another a Smaller reference frame are generated from the input image for a specific scaling factor using the Lancoz3 re-sampling method. The input frame isscaled by twice the scaling factor (2*S) in order to obtain the larger frame and scaled by half (0.5*S) to obtain the smaller frame.

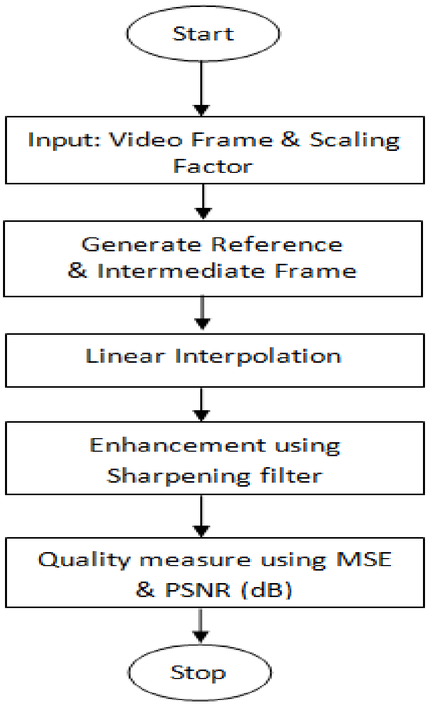


Figure 6 Flow Chart of Proposed Algorithm

This initial step to generate the reference frames is important with a view to ensure that the interpolated frame is within the range of pixel values of the input frame.

These reference frames are used to obtain the intermediate frames having the same resolutions. These are further used to linearly interpolate the required scaled output imageY (IxJ) using the interpolation equation described in Eq. no (5).

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

$$Y = Y1 + h(Y2 - Y1) \quad \ldots\ldots. (5)$$

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

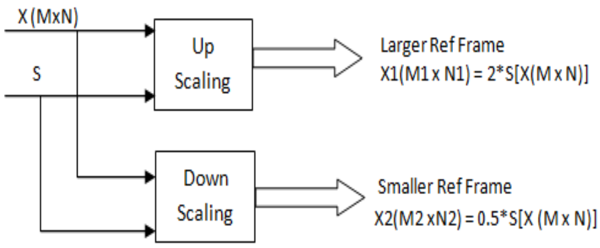


Figure7 Functional Blocks to Generate Reference Frames

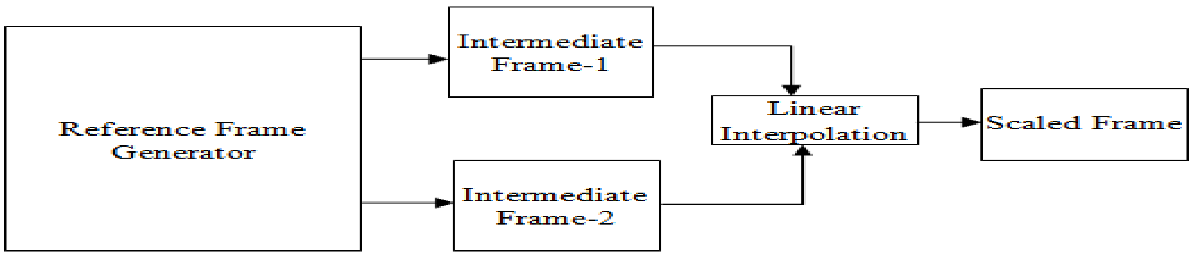


Figure8Functional Blocks of the Proposed Algorithm to Scale a Video Frame

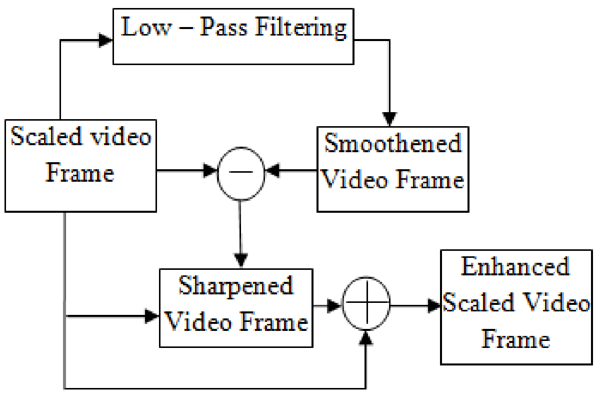


Figure 9 EnhancementUsing Sharpening Filter

The last stage of Enhancement involves a Sharpening Filter as shown in Fig. 9 [22-29]. The scaled video frame is filtered through a low-pass filter to obtain an Averaged or Smoothened video frame. Then a Sharpened frame is achieved by taking the difference between the scaled and smoothened frame. Finally an enhanced frame is obtained by adding the scaled frame and the sharpened frame. Through this, the quality of the scaled output frame is significantly enhanced.

IV. EXPERIMENTAL RESULTS

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 size to evaluate the error between them. In order to evaluate the quality of the scaled image, PSNR is computed between theoriginal image scaled using Image Processing freeware such as Irfan View orFastStone Photo Resizer, and the scaled image by the proposed algorithm. The PSNR is expressed in decibel scale (dB).High value of PSNR indicates a high quality of image. It is defined using 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:

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

WhereY_{IP} : Scaled Frame using Image Processing Freeware
Y_{PA} : Scaled Frame using the Proposed Algorithm.
i * j: Total number of Pixels in the scaled image.

$$PSNR = 10 * \log_{10}\left(\frac{255^2}{MSE}\right)$$

The proposed algorithm is implemented in MATLAB. Video sequences of various resolutions are selected for test purposes as shown in Fig. 10.Table 1 presents the PSNR values for these video frames/images scaled by the proposed algorithm.It may be seen that the quality obtained by the proposed algorithm is significantly better when compared to other methods such as Bi-linear and B-Spline. As an example, the popular image “Lena” has been scaled using Bi-linear, B-Spline and the proposed algorithm. Different scaling factors have been used. The reconstructed images are presented in Fig. 11. In addition, various images as well as video sequences have been scaled by 150% and the results are presented in Fig. 12. These demonstrate that the proposed algorithm is better than other methods in terms of reconstructed image quality.

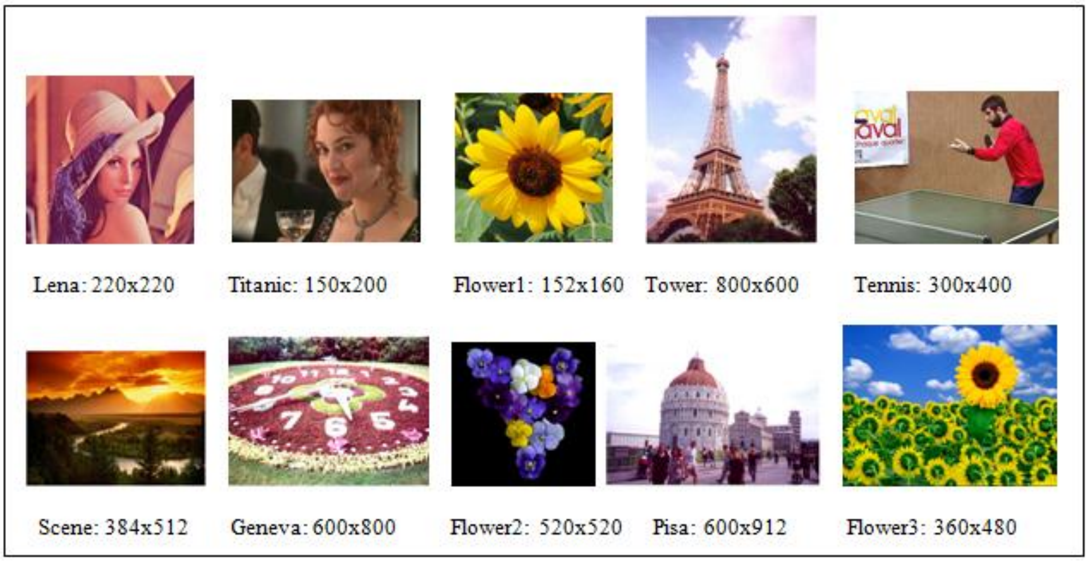
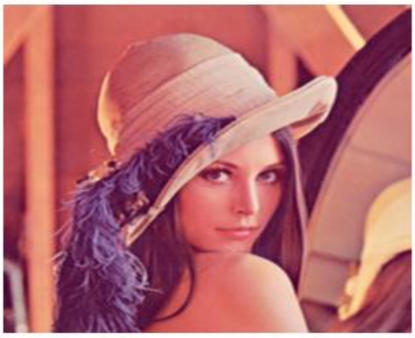


Figure10 Original Test Images

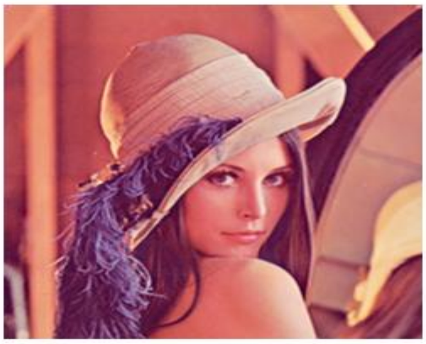
Table 1 Comparison of Quality for Images Scaled by a Scaling Factor S = 1.5 (150%) Using Different Interpolation Methods and the Proposed Algorithm

Test Images scaled using IP Softwares	Scaling Mathod	PSNR in dB		
		Bilinear	B-Spline	Proposed Algorithm
Lena : 330 x 330 Pixels	Irfan View	47	40	50
	FastStone Photo Resizer	35	42	54
Titanic: 225 x 300 Pixels	Irfan View	46	41	48
	FastStone Photo Resizer	36	44	52
Flower1: 228 x 240 Pixels	Irfan View	43	38	47
	FastStone Photo Resizer	34	43	53
Tower: 1200 x 900 Pixels	Irfan View	50	42	52
	FastStone Photo Resizer	36	45	57
Tennis: 450 x 600 Pixels	Irfan View	42	37	45
	FastStone Photo Resizer	35	39	48
Scene: 576 x 768 Pixels	Irfan View	46	39	47
	FastStone Photo Resizer	36	43	54
Clock: 900 x 1200 Pixels	Irfan View	44	37	46
	FastStone Photo Resizer	31	39	49
Flower2: 780 x 780 Pixels	Irfan View	45	41	49
	FastStone Photo Resizer	38	43	54
Pisa: 900 x 1368 Pixels	Irfan View	49	41	52
	FastStone Photo Resizer	35	43	56
Flower3: 360 x 480 Pixels	Irfan View	41	37	45
	FastStone Photo Resizer	35	42	52


(a)

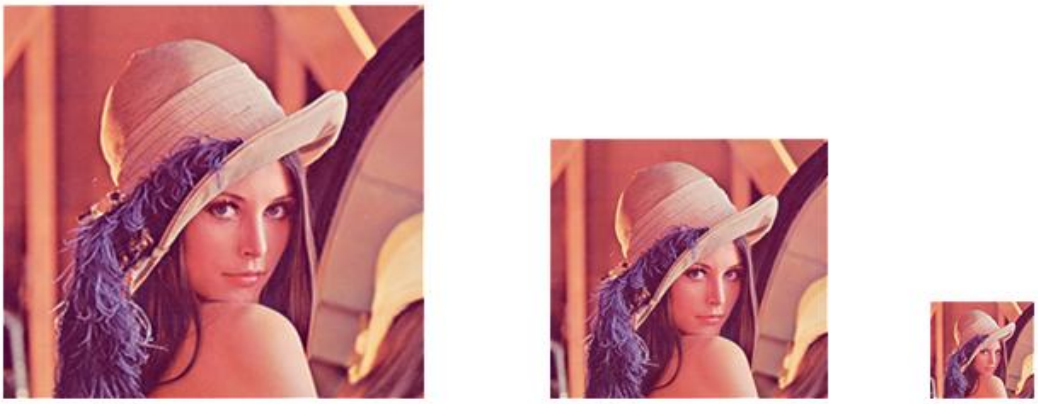

(b)


(c)


(d)


(e)

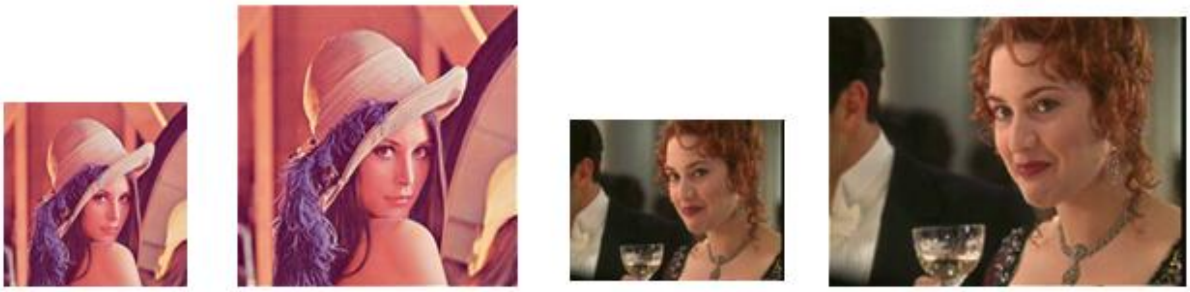

(f)



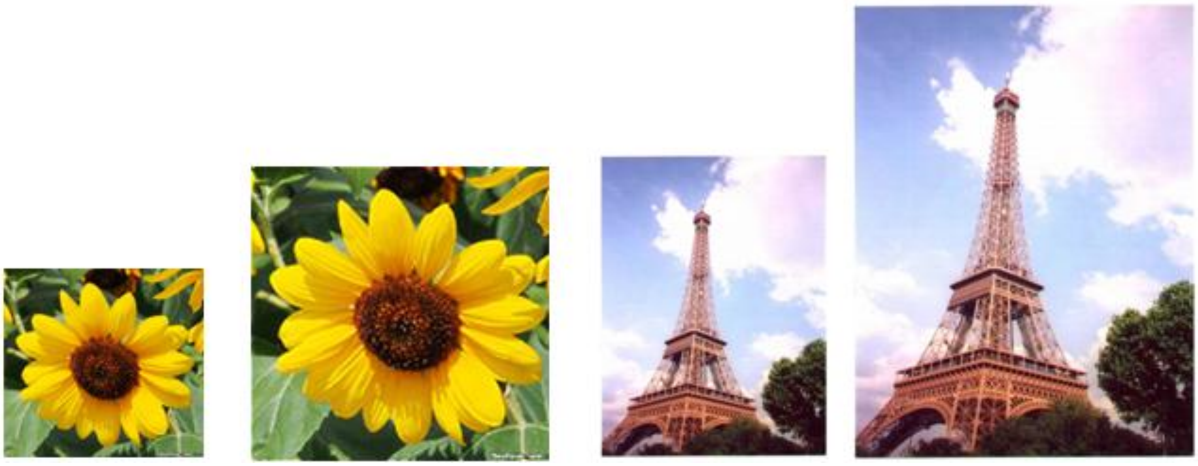
(g) (h) (i)

Figure 11 Comparison of various Scaling Algorithms and the Proposed Algorithm for Lena Image of Original Size: 220x220 pixels

(a)(b) (c) Bilinear Scaling for: S=2, up-scaled size: 440x440 pixels, PSNR=44, S=1.5,up-scaled size:330x330 pixels,PSNR=47,S=0.5, down-scaled size: 110x110 pixels, PSNR=40 (d) (e) (f) Bi-Spline Scaling, S=2, up-scaled size: 440x440 pixels, PSNR=40, S=1.5,up-scaled size: 330x330 pixels, PSNR=39, S =0.5(50%), down-scaled size: 110x110 pixels, PSNR=45(g)(h)(i) Proposed Algorithm, S=2, up-scaled size: 440x440 pixels, PSNR=45, S=1.5, up-scaled size: 330x330 pixels, PSNR= 50, S=0.5, down-scaled size: 110x110 pixels,PSNR=49



(a) (b) (c) (d)



(e) (f) (g) (h)

(i) (j) (k) (l)

Figure 12 Scaled FramesUsing the Proposed Algorithm for Scaling Factor S=1.5
(a) Original Lena Image(220x220 pixels)(b) Scaled Lena Image (330x330 pixels), PSNR= 50 dB
(c) Original Titanic Frame (150x200 pixels) (d) Scaled Titanic Frame (225x300 pixels), PSNR= 48dB
(e) Original Flower1Image(152x160 pixels)(f) Scaled Flower1 Image (228x240 pixels), PSNR= 47 dB
(g) Original E. Tower Frame(800x600 pixels)(h) Scaled E. Tower Frame (1200x900 pixels), PSNR= 52 dB
(i) Original Tennis Frame(300x400 pixels)(j) Scaled Tennis Frame (450x600 pixels), PSNR= 45 dB
(k) Original Geneva Image(600x800 pixels)(l) Scaled Titanic Image (900x1200 pixels), PSNR= 46dB.

V. CONCLUSION

An efficient Interpolation algorithm for image scaling has been proposed with an enhancement scheme. The algorithmyields a high image quality in comparison with Bilinear, B-Spline interpolating methods. The Proposed Algorithm can be effectively applied for images and video frames in order to achieve an efficient image/video scaling.

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