

**An Adaptive Image Zooming Algorithm Using
Interpolation Techniques**

Thesis submitted in partial fulfillment of the requirements for the award
of degree of

Masters of Science
in
Mathematics & Computing

Submitted By:
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SCHOOL OF MATHEMATICS AND COMPUTER APPLICATIONS

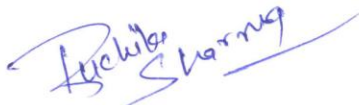
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Certificate

I hereby certify that the work which is being presented in the thesis entitled, "**An Adaptive Image Zooming Algorithm Using Interpolation Techniques**", in partial fulfillment of the requirements for the award of degree of Master of science in Mathematics & Computing submitted in School of Mathematics & Computer Applications (SMCA), Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Mrs. Geeta Kasana** and refers other researcher's works which are duly listed in the reference section. The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.



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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.



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Acknowledgment

I wish to express my deep gratitude to Mrs Geeta Kasana, Lecturer, SMCA, TU, Patiala for providing their uncanny guidance and support throughout the thesis.

I would like to extend my special thanks to Dr. S. S. Bhatia, Prof. and Head, SMCA, TU, Patiala, for the motivation and inspiration that triggered me for the thesis work. I would also like to thank all the staff members who were always there at the need of the hour and provided with all the help and facilities, which I required for the completion of the thesis.

Last but not the least, I express my heartfelt thanks to my family and all my friends for encouraging me and providing me useful information during my work. Special thanks to Rajeev, Shalika Sharma, Sanpreet, Payal, Samita Thakur, Parul who helped me lot in many way during my work.

Most importantly, I would like to give God the glory for all of the efforts I have put into this report.

Finally, my special thanks go to authors whose works I have consulted and quoted in this work.

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Abstract

Image Zooming is an important task used in many applications. It is the process of enlarging the image to any factor of magnification. While zooming an image, there are few parameters that we have to keep in mind. Applying function indiscriminately to an image, to resample it, will generally result in aliasing; edge blurring and other artifacts may arise. So the main focus is on the reduction of these artifacts.

This thesis considers various interpolation schemes, particularly focusing on adaptive methods because of their inherent abilities to preserve sharp edges and detail. Proposed algorithm is an adaptive resampling algorithm for zooming up images. The algorithm is based on analyzing the local structure of the image and applying a near optimal and least time-consuming resampling function will preserve edge locations and their contrast. This is done by segmenting the image dynamically into homogeneous areas, as it is scanned or received zooming algorithm which focuses on preserving edges. The algorithm reduces the jaggling, blurring.

To compare existing algorithms with proposed method algorithm, we have taken real world images and results are compared. And we have come to the decision that proposed algorithm is better than the existing algorithms. We have compared the images by two ways – Mean Square Error (*MSE*) and Peak Signal to Noise Ratio (*PSNR*).

Abbreviations

AEE	Adaptive Edge Enhancement
HR	High-Resolution
LR	Low-Resolution
MSE	Mean Squared Error
PSNR	Peak Signal to Noise Ratio
RIIR	Resolution-Invariant Image Representation
TH	Threshold value
Wt	Weight

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Chapter 1

Introduction

Digital images are the most common and convenient means of conveying or transmitting information. They convey information about positions, sizes and inter-relationships between objects. They portray spatial information that we can recognize. Human beings are good at deriving information from such images, because of our innate visual and mental abilities. About 75% of the information received by human is in pictorial form. The present contexts, the analysis of pictures that employ an overhead perspective, including the radiation not visible to human eye are considered. Thus our discussion will be focusing on analysis of remotely sensed images. These images are represented in digital form.

1.1 Digital Images

An image may be defined as a two dimensional function $f(x, y)$ where x and y are spatial (plane) co-ordinates. The amplitude of 'f' at any pair of co-ordinate (x,y) is called the intensity 'or' gray level of the image at that point.

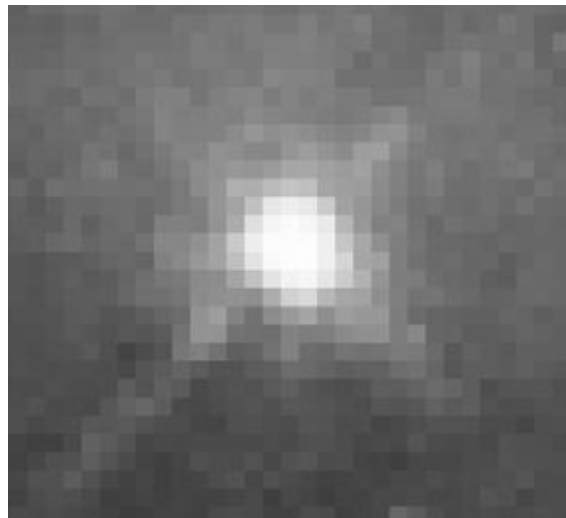


Figure 1.1: An image — an array or a matrix of pixels arranged in columns and rows

Digital images are electronic representations of images that are stored on a computer. The most important thing to understand about digital images is that you can't see them and they don't have

any physical size until they are displayed on a screen or printed on paper. Until that point, they are just a collection of numbers on the computer's hard drive that describe the individual elements of a picture and how they are arranged. These elements are called pixels (short for **picture elements**), and they are arranged in a grid format with each pixel containing information about its color or intensity.[1]

1.1.1 Different formats

The format use to save the image file will be determined by its intended use. Some formats are common for the web, others for presentation or print. Listed below are some of the most common:

PICT: Stands for 'Picture' and is used for storing 8-bit, 16-bit or 24-bit color or gray scale images. PICT files work well for the onscreen presentation of graphics.

TIFF: Stands for Tagged Image File Format that is used to exchange files between applications and computer platforms. It's supported by virtually all paint, image editing, and page-layout applications.

GIF: Stands for 'Graphic Interchange Format', which is used for simple web images. Because GIF files are limited to 256 colors, it is suggested that you not use this format for photographs or other images with high color ranges.

JPEG: Stands for Joint Photographic Experts Group. JPEG is actually a standard method of compressing graphics by removing nonessential information. A JPEG file can be created from most file formats and is frequently used for web-based images because small file size is essential.

BMP: Images are used for simple black and white images. Note that 'black and white' refers to those images that have only two tones, either black or white.

PNG: Stands for Portable Network Graphics format, an open source substitute for GIFs. PNGs provide a higher lossless compression rate than GIFs, and help to reduce cross-platform differences in image display quality, among other technical advantages.

For the purposes of sharing files, adding images to PowerPoint presentations and posting them to websites, the formats you are most likely to use are JPG and GIF. These files are almost universally readable by image editors, work well on websites, and offer small file sizes with reasonable quality levels [1,3,4].

1.2 Image zooming

Image zooming with respect to their high storage size and within Multi Media is a Valuable subject in image processing.

Zooming an image means changing the number of display pixels per image pixel only in appearance. At Zoom = 1, there is one display pixel per image pixel. At Zoom = 2, there are 2 display pixels per image pixel in both x and y. This enlargement is quantified by a calculated number or number is greater than one, called magnification. When this number is less than one it refers to a reduction in size, called minification.

Image zooming is among the fundamental image processing operations. Methods like JPEG are usually an acceptable standard while it is among lossy methods, but still has a good quality outcome. Zooming is related to resizing up of images to be able to see more detail, increasing resolution, using optics, printing techniques, or digital processing [5,1]. The applications of image interpolation range from the commonplace viewing of online images to the more sophisticated magnification of satellite images. With the rise of consumer-based digital photography, users expect to have a greater control over their digital images. Astronomical images from rovers and probes are received at an extremely low transmission rate (about 40 bytes per second), making the transmission of High Resolution (HR) data infeasible. In medical imaging, neurologists would like to have the ability to zoom in on specific parts of brain tomography images. Zooming can be used to resize a video frame to fit the field of view of a projection device, which may help to reduce blurring. Finally, the most obvious application of image zooming is to simply allow one to enjoy a larger version of a favorite image obtained from any commercially available digital imaging device such as a camera, camcorder or scanner.

Traditional image zooming techniques use up-sampling by zero-insertion followed by one-dimensional filtering to interpolate the HR samples. The main drawback of this approach is that the frequency content of the high-resolution image is the same as the Low-Resolution (LR) image. This is due to the fact that linear techniques are incapable of introducing new information into the image. The lack of new high frequency content results in a variety of undesirable image artifacts such as blocking, staircase edges and blurring.

1.2.1 Interpolation in Image Zooming

Image zooming is an important process in image processing. It is a process to recover image from distorted to its original image. The restoration of degraded images can be applied in many application areas that are needed to repair images. Image interpolation is one part of image restoration. Very often data is specified on a regular grid (values are written at the vertex position of a 2D or 3D grid) or on a line (in the 1D case) but the program needs to evaluate values at random position on that grid [1].

Interpolation (sometimes called resampling) is an imaging method to increase (or decrease) the number of pixels in a digital image [4]. It is applied in diverse areas ranging from computer graphics, rendering, editing, medical image reconstruction, to online image viewing. Interpolation is done by approximating the required function using simpler functions such as, polynomials. It is a link between the discrete world and the continuous one. This permits input values to be evaluated at arbitrary positions in the input, not just those defined at the sample points. The goal of image interpolation is to produce acceptable images at different resolutions from a single LR image. The actual resolution of an image is defined as the number of pixels, but the effective resolution is a much harder quantity to define as it depends on subjective human judgment and perception.

The image quality highly depends on the used interpolation technique. Image interpolation works in two directions, and tries to achieve a best approximation of a pixel's color and intensity based on the values at surrounding pixels. The following example illustrates how resizing / enlargement works.

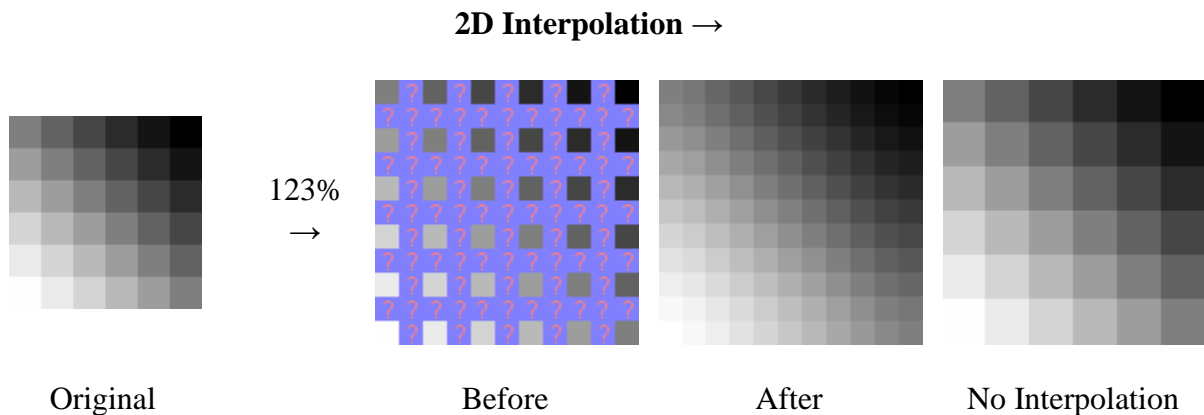


Figure 1.2: Resizing / enlargement works

Digital image interpolation is the recovery of a continuous intensity surface from discrete image data samples. For instance, HR cameras digitized scenes at a much finer scale and so contain more information than LR cameras. All pictures and images cannot be stored at HR due to equipment, memory, in the case of the Internet, bandwidth limitations.

A need for LR images in interpolation algorithms give end-users magnified images of higher resolution for viewing, printing, and editing, creating.

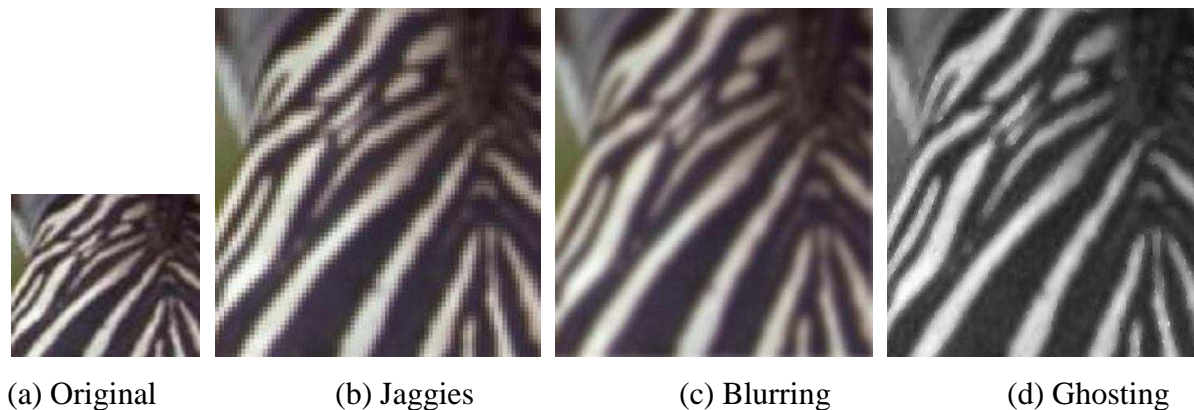


Figure 1.3: Zebra image

The above figure shows the three major artifacts while zooming an image. These artifacts are shown in figure 1.3. jaggies- blocks are formed due to replication of pixels, blurring- unclarity of the image, ghosting- distortion of the image. The interpolation algorithms attempt to solve these artifacts in many ways. Some factors must be kept in mind while making an algorithm like speed (zooming should not take much time for enlarging an image), memory requirement (the algorithm should not take much memory space) [2].

1.2.2 Zooming as Number

Magnification is the process of enlarging something only in appearance, not in physical size. This enlargement is quantified by a calculated number also called "magnification". In general, magnification is divided as:

- i. Linear or transverse magnification — For real images, such as images projected on a screen, size means a linear dimension (for example, in millimeters or inches).

- ii. Angular magnification — placement of the object closer to the eye than the eye could normally focus. Strictly speaking, one should take the tangent of that angle (in practice, this makes a difference only if the angle is larger than a few degrees).

1.3 Motivation

Study on image zooming has been done in various literature in variety of ways. Instead of so much work in this field there are very few image zooming software's which provide adaptive zooming methods. Even the latest software uses the traditional linear magnification algorithm. However such software's are recently brought into market.

Many interpolation algorithms currently used in consumer products produce magnifications that include undesirable artifacts like "blurring", "jaggies" and "ghosting" shown in Figure 1.3. Digital zooming has a role in picking up clues and details in surveillance images and video. The consumer, presented with the magnification, will be unsatisfied with the unrealistic image upon seeing the artifacts. As it is a non-trivial process that involves a trade-off between Efficiency, smoothness and sharpness of edges and freedom from artifacts are two critical factors in the perceived quality of the interpolated image [3]. More advanced magnification methods such as learning-based algorithms require specific training data, large running times, or extensive user input. Still there is a need for a more general interpolation technique that can minimize these flaws.

The motivation of this research is to create a magnification algorithm that creates realistic real-world image magnifications that do not require a large amount of user input. A realistic real world image would be an image that is free from artifacts such as blurring, ghosting and jaggies. The image must include smooth contours and also rapid edge transitions in areas of the image where sharp edges are found in the LR image. Proposed algorithm can produce magnifications with these properties.

1.4 Description of Thesis

The thesis basically consists of the techniques of zooming of images. As already a lot of work has already been done. But still our approach is to study all the work earlier done and find a better zooming algorithm. We have started from the literature survey of the earlier techniques. We realized that most of the algorithms focus on the traditional methods, but we have changed

our path to adaptive methods. The traditional methods have many artifacts, but we have tried to resolve them.

Firstly, we started from the literature survey. Most of the methods using the interpolation based techniques which is quite useful but it is non adaptive in most of the cases. We have described each and every interpolation based techniques with visual examples. Secondly, the problem statement has been defined [3,4]. Here, in depth description of the problem is given. In next section, the proposed algorithm is explained. The proposed algorithm is an adaptive based algorithm which basically focuses on the edges. Later, the result has been evaluated with the help of proper mathematical methods like *MSE* and *PSNR*. Finally, the conclusion has been given with the benefits as well as disadvantages of the proposed algorithm.

Chapter 2

Literature Survey

2.1 Image Zooming Techniques

There are various zooming techniques. Some of them are given as follows:

In literature, most of the image interpolation techniques have been developed by interpolating the pixels based on characteristics of local features such as edge information, nearest neighbor criteria, etc.

Zhiwei L. et al [5] proposed a new Mathematical Technique for Image Interpolation using the nearest neighbor interpolation and bilinear interpolation together for magnifying images based on relative color difference of pixels. The method is more suitable for non word images than word images.

Hajizadeh M. et al [6] proposed a new method that uses least directional differences of neighbor pixels, based on bilinear and bicubic interpolation methods for images. This improves zooming results even for low resolution images in both qualitative and quantitative aspects.

Dengwen Z. et al [7] , a novel edge-directed interpolation method for color images which is an extension of the standard bicubic convolution (CC) interpolation method is proposed, which extends the classical bicubic convolution interpolation that preserve the edges and textures, and noticeably suppress common artifacts such as blurring, blocking and aliasing in interpolated images. The experimental results demonstrate that it outperforms significantly the bicubic interpolation in terms of both objective and subjective measures.

Tao J. et al [8], a new method using Newton interpolation for image magnification ,and used the Matlab to implement this algorithm. The algorithm save more high frequency information of the image based on the characteristics of pixel and reduce the fuzzy degrees of the image. Experiments can be concluded that this method is better than the traditional method when it is used in high-magnification image. It loses less high-frequency than the bilinear interpolation method to solve the fuzzy shortcoming, and also reduce the sawtooth shape and Mosaic phenomenon of the nearest neighbor method.

Sheng M. et al. [9], presents a method for image zooming using quasi Hermite interpolation spline, which provides a smaller interpolation error, and reasonable computing times. Moreover, the method can preserve the contours or edges of images by adjusting the corresponding local parameters. The theoretic analysis and the experimental results show that the interpolation effects by the proposed approach are slightly better than those by the existing interpolation approaches. Also the run-times of this method are evidently superior to the method by normal cubic interpolation spline.

Fahmy M. et al. [10], A fast computationally efficient method is proposed for computing the output of non-causal digital systems. The method is efficiently used for evaluating the B_spline coefficients fitting a given data. Next, a decimated number of these coefficients are optimally chosen to reconstruct the original image using reduced number of data. Image compression is achieved through compressing the coefficients using efficient compressing techniques. Illustrative examples demonstrate the far superior results of the proposed technique when compared to other conventional methods. This in turn results in lower bit rates. The fit rate can be further reduced, through making the compression scheme adaptive.

Faghih M. et al. [11], an improved scheme of radon transform is used to convert image from dot domain into line domain. In the line domain, enlargement and interpolation is carried out and then interpolated image returns to dot domain. Comparison between conventional methods: bilinear, and bicubic were done and the power of method to interpolating diagonal straight lines with respect to last methods were shown. However the process cost of this method is more than last methods but this method presents better quality in numerous images and opens new ways to develop new interpolation methods for zooming digital images in the future.

Han J. et al. [12], a novel image interpolation method is proposed to obtain HR images. In the method, the image is decomposed using a bilateral filter into the detail and base layers which represent textual and structural information of images, respectively. Then, the detail layer is interpolated and amplified to obtain a clear edge without blurring. To evaluate the performance of the proposed method, the conventional bi-linear and local gradient based interpolation methods are compared with the proposed method. Since the base layer contains the structural information of the image, this layer is enlarged by an edge-preserving interpolation method to reduce jaggling. Experimental results show that the proposed algorithm performs the conventional methods in terms of blurring and jaggling.

Lukac R. et al. [13], a unified camera image processing system that performs zooming and full color image reconstruction for single-sensor digital cameras is introduced. The scheme employs a small number of reusable, low-complexity operations and a consistent color model throughout to achieve high-quality zoomed output that is practical for hardware implementation. The experimental results supported the proposed methodology by producing superior output, both objectively and subjectively, when compared to other schemes.

Wang J. et al. [14], present a Resolution-Invariant Image Representation (RIIR) framework that includes the methods of building a set of multi-resolution bases from training images, estimating the optimal sparse resolution-invariant representation of any image, and reconstructing the missing patches of any resolution level. The method discuss three interesting applications: (i) a strategy to built a compact RIIR base set and the RIIR framework is applied to Multi- Scale Image Magnification and a strategy to built a compact RIIR base set; (ii) the RIIR framework is extended to conduct Continuous Image Scaling where a new base at any resolution level can be generated using existing RIIR set on the fly; and (iii), the image content-based zooming concept is combined with RIIR framework to perform Content-Based Automatic Zooming. Experimental results show that RIIR based method outperforms existing methods in various aspects.

2.2 Algorithm Subdivision

Common interpolation algorithms can be grouped into two categories: adaptive and non-adaptive. Adaptive methods change depending on what they are interpolating, whereas non-adaptive methods treat all pixels equally.

2.2.1 Non-Adaptive Algorithms

Non adaptive interpolation, interpolates by fixed pattern for all pixels has the advantage of easy to perform and low calculation cost [3]. Depending on their complexity, these use anywhere from 0 to 256 (or more) adjacent pixels when interpolating. The more adjacent pixels they include, the more accurate they can become, but this comes at the expense of much longer processing time. These algorithms can be used to both distort and resize a photo. The zoomed image of Figure 2.1(a) using non-adaptive algorithm is shown in Figure 2.1(b). Non-adaptive algorithms are :

1. Nearest Neighbor
2. Bilinear
3. Bicubic Smoother
4. Bicubic
5. Bicubic Sharper
6. Lanczos
7. Bilinear b/w blur

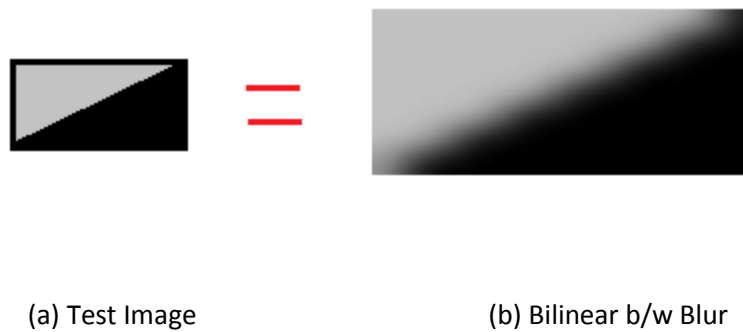


Figure 2.1: Enlarged Image using Non-Adaptive Algorithm

2.2.2 Adaptive Algorithms:

Adaptive interpolation estimates lost pixel values using feature of surround pixel can get better image than non adaptive algorithm [15]. However, it has a lot of calculations. Many of these apply a different version of their algorithm (on a pixel-by-pixel basis) when they detect the presence of an edge aiming to minimize unsightly interpolation artifacts in regions where they are most apparent. These algorithms are designed to maximizing the artifact-free detail in enlarged photos, so some cannot be used to distort or rotate an image. The zoomed image of Figure 2.2(a) using adaptive algorithm is shown in Figure 2.2(b). Adaptive algorithms are:

- i. Nearest Neighbor
- ii. Bicubic
- iii. Genuine Fractals
- iv. Photo Zoom
- v. Smart Edge



(a) Test Image

(b) Smart Edge

Figure 2.2: Enlarged Image using Adaptive Algorithm

2.3 Interpolation Methods

Interpolation is the process by which a small image is made larger. Software tools stretch the size of the image and generate pixels to fill in the blanks. Interpolation is the estimation of values in a function between known points. Interpolated images produce smoother lines and a better large print than if the original, small image was simply printed large. There are several basic function-fitting or interpolation methods, including pixel replication, bilinear interpolation, and bicubic interpolation.

2.3.1 Pixel Replication

Pixel replication is the simplest interpolation from a computational standpoint is the nearest neighbor, where each interpolated output pixel is assigned the value of the nearest sample point in the input image. This technique is also known as point shift algorithm and pixel replication. The interpolation kernel for the nearest neighbor algorithm is defined as the frequency response of the nearest neighbor kernel is

... (1)

The kernel and its Fourier transform are shown in Figure 2.3

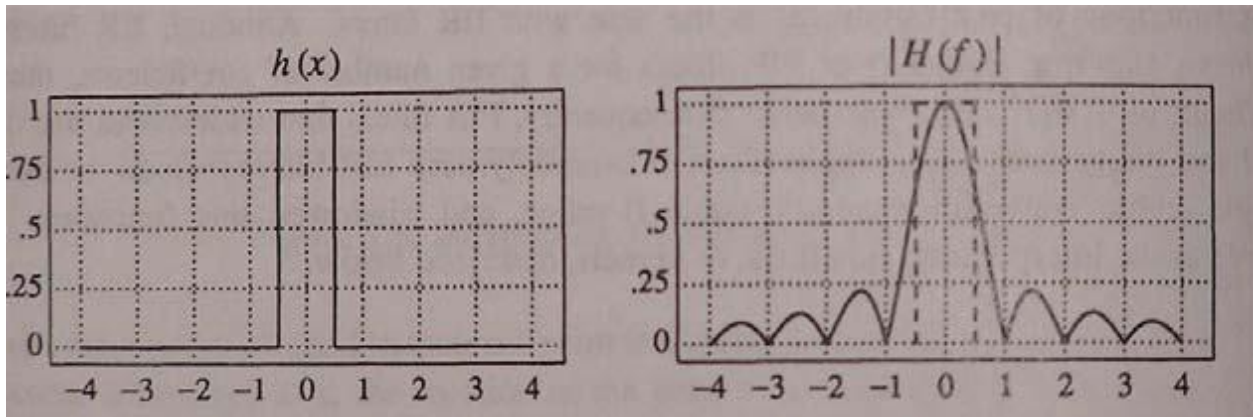


Figure 2.3: kernel and its Fourier transform



(a) Down sampled image (b) 3× Pixel Replication image (c) Original Image

Figure 2.4: Pixel Replication Example

A type of up sampling of a digital image, effected by increasing the number of pixels in an image, but without adding any data or detail. In Figure 2.4, original image Figure 2.4(c) down sampled by a scale of three Figure 2.4(a) then magnified 3× by using pixel replication. The new colored pixels are often interpolated using the original pixels. Image quality is not often very high when images are enlarged in this manner. As shown in Figure 2.4(b), images made with pixel replication are extremely jagged. Hence the higher resolution image is blocky and jagged, since the original pixels have grown by exactly the magnification scale.

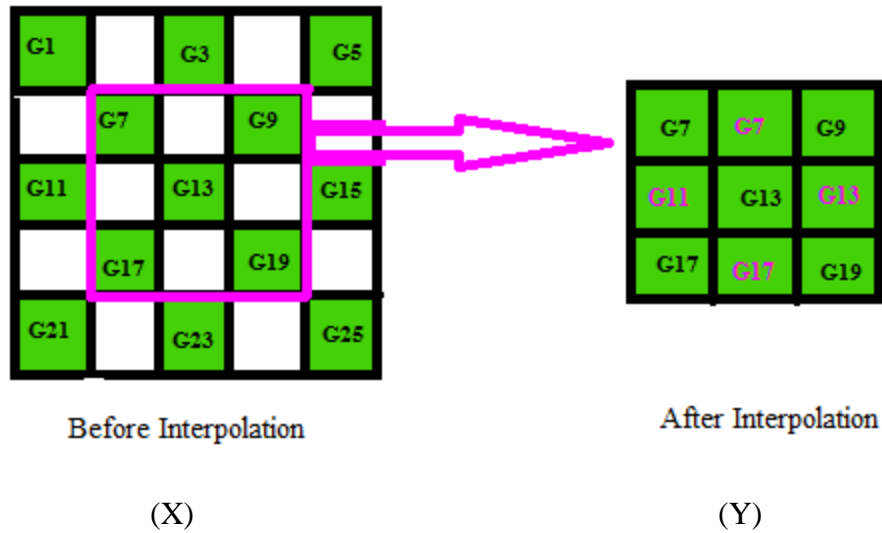


Figure 2.5: Pixel Replication Working

The above Figure 2.5 shows how pixel replication actually works. A selected part of X image is $2\times$ magnified in the particular pattern and hence we got the image Y.

2.3.2 Bilinear Interpolation

In mathematics, bilinear interpolation is an extension of linear interpolation for interpolating functions of two variables (e.g., x and y) on a regular grid. The interpolated function should not use the term of x^2 and y^2 but xy , which is the bilinear form of x and y

Bilinear interpolation considers the closest 2×2 neighborhood of known pixel values surrounding the unknown pixel. It then takes a weighted average of these 4 pixels to arrive at its final interpolated value.

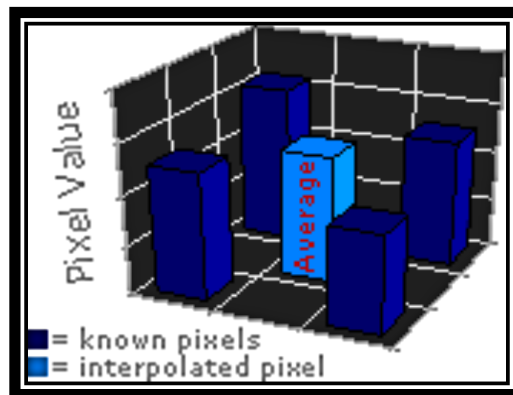


Figure 2.6: Bilinear Interpolation

This results in much smoother looking images than nearest neighbor.[16] Weight is determined by assigning weighted value of 4-nearest neighbor pixel (as shown in Figure 2.6) to generated output pixel. Each weighing value is proportional to distance from each existing pixel. This method has advantage of simple calculation. And output image using bilinear interpolation is better than nearest neighbor replication. However, blurring effect is occurred by averaging surround pixel. Figure 2.7 gives an example of linear interpolation in one dimension. As can be seen from the figure, unknown pixel values in the HR grid are estimated to exactly lie on the line that fits between two original pixel values.

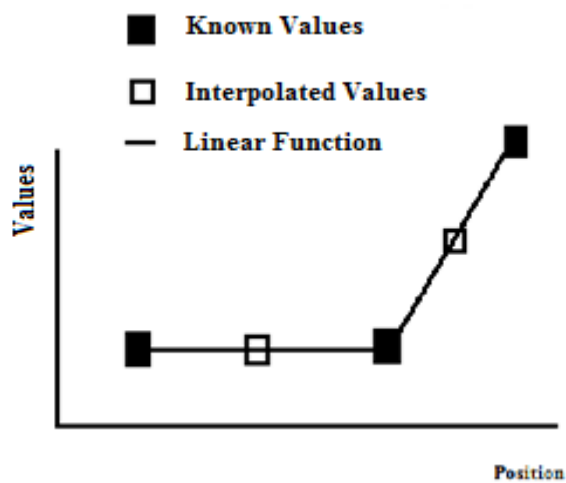


Figure2.7: Linear Interpolation

A linear function is fit between known values and all interpolated values fall on the fitted line. For example, in 2x magnification in one dimension, there would be only one unknown pixel between known pixel values. The pixel value would be calculated by taking half of the first known pixel plus half of the second known pixel. By this, interpolation is performed in one dimension. Linear interpolation extends easily into two dimensions.

Bilinear interpolation can be described as linear interpolation in one dimension followed by linear interpolation in the other. For example, if we are estimating a pixel between a block of four original values, then two temporary values are first created: a linear interpolation between the top pair of pixels; and the second, a linear interpolation between the bottom pair of pixels as shown in Figure 2.8. Lastly, a linear interpolation is performed between the two temporary values.

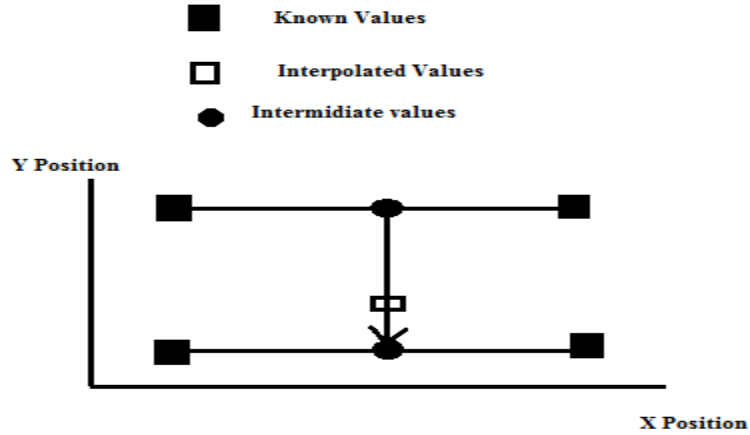


Figure 2.8: Bilinear Interpolation



Figure 2.9: Pixel Replication and Bilinear Interpolation.

In Figure 2.9, original image Figure 2.9(d) down sampled by a scale of three Figure 2.9(a) then magnified $3 \times$ bilinear interpolations Figure 2.9(b). Bilinear interpolation results in much smoother looking images than nearest neighbor. This can be seen in Figure 2.9. Due to the

interpolation process, the image becomes slightly blurred since pixel values are spread throughout the HR grid.

2.3.3 Bicubic Interpolation

Bicubic interpolation is an extension of cubic interpolation for interpolating data points on a two dimensional regular grid. The interpolated surface is smoother than corresponding surfaces obtained by bilinear interpolation or nearest-neighbor interpolation.

Bicubic interpolation uses the information from an original pixel and sixteen of the surrounding pixels to determine the color of the new pixels that are created from the original pixel. Bicubic interpolation is a big improvement over the previous two interpolation methods for two reasons: (1) Bicubic interpolation uses data from a larger number of pixels and (2) bicubic interpolation uses a bicubic calculation that is more sophisticated than the calculations of the previous interpolation methods as shown in Figure.2.10. Bicubic interpolation is capable of producing photo quality results and is probably the method most commonly used.

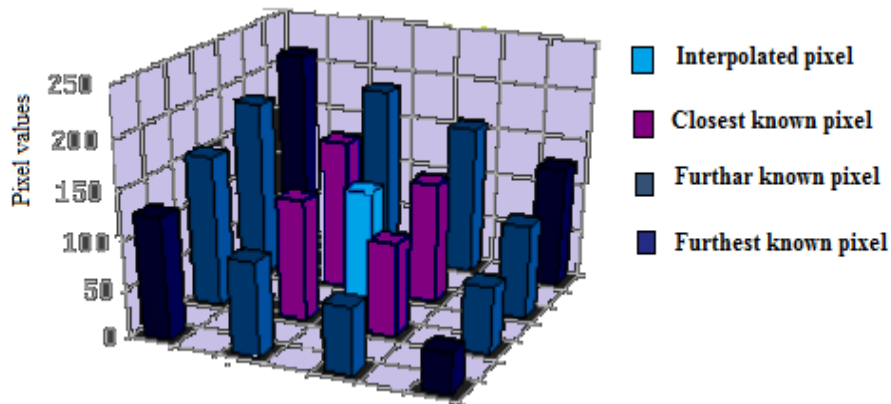


Figure 2.10: Bicubic Interpolation

Bicubic interpolation works same as bilinear interpolation, except using a cubic function instead of a linear function to estimate pixels between known values as in Figure 2.11. This is a high performance pixel interpolation that gives outstanding results, both in calculation speed and in quality of results. It is usually the best choice when not too radical downsampling operations are involved in geometrical transformations. This form of interpolation has advantages and drawbacks over bilinear interpolation. First, calculating the cubic polynomial in a specific area of the image is more computationally expensive than simple linear fits and also requires a larger neighbor to calculate the curve. A linear function fits straight lines between known points, and a

cubic function fits cubic splines. On the other hand, jaggies are more distinguished since the image isn't as blurred.

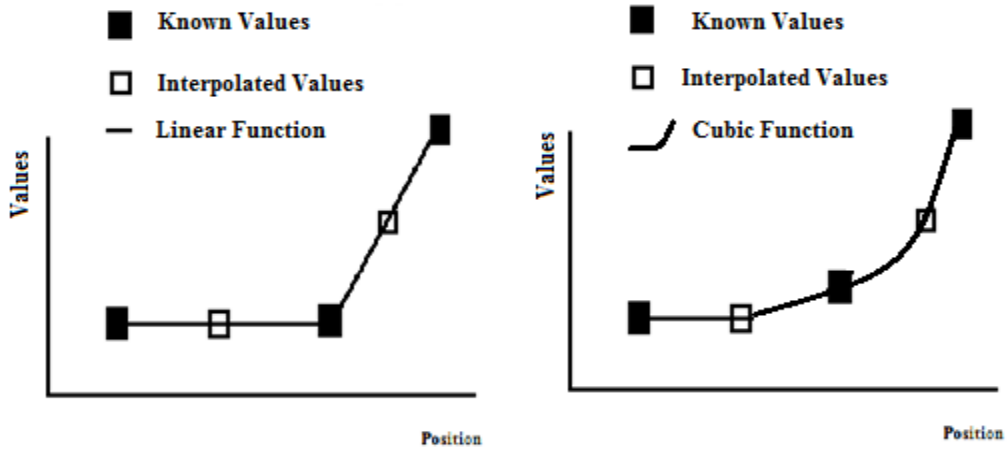


Figure 2.11: Linear vs Bicubic Interpolation



Figure 2.12: Bilinear vs Bicubic Interpolation.

A comparison of bilinear and bicubic interpolation is shown in Figure 2.12. In Figure 2.12, original image Figure 2.12(d) down sampled by a scale of four as shown in Figure 2.12(a) then magnified $3 \times$ bicubic interpolations in Figure 2.12(c). Bicubic interpolation produces magnifications, which are sharper and more jagged (Lena for example) than bilinear interpolation.

2.4 Filtering Methods

Some other magnification techniques use filtering approaches for LR images. Filter-based methods use sampling theory to attempt to create perfect interpolations of images. By convolving these pixel points with a sinc function in the spatial domain, a perfect reconstruction of sampled points is accomplished.

Due to these approximations, errors are introduced causing both blurring and jaggies. Another drawback of using filter based methods is the increase in computational cost. Even with a truncated sinc function, the kernel can be quite large. For instance, the Lanczos filter is a windowed form of the sinc filter. The sinc function is infinite in extent, and thus not directly usable in practice. Instead, one uses approximations to the filter, called windowed forms, and the Lanczos filter is one such windowing. The windows vanish outside of a range, and using larger ranges allows one to improve accuracy in exchange for more computation like the Lanczos2 and Lanczos3 filter's kernel is 16×16 , makes the algorithm much computationally expensive than bicubic interpolation. We use these techniques in this thesis work for comparing the results with proposed algorithm.

2.5 Visual Properties of Interpolated Images

The first 8 are visual properties of the interpolated image the last is a computational property of the interpolation method:

- i. **Geometric Invariance:** The subject matter should not change by using interpolation methods in order to preserve the geometry and relative sizes.
- ii. **Contrast Invariance:** The method should preserve the overall luminance values of in an image and contrast of the image.
- iii. **Noise:** The method should not add noise or other artifacts to the image.

- iv. **Edge Preservation:** The method should preserve edges and boundaries and sharpen them where possible.
- v. **Aliasing:** The method should not produce staircase edges.
- vi. **Texture Preservation:** The method should not blur or smooth textured regions.
- vii. **Over-smoothing:** The method should not produce undesirable piecewise constant or blocky regions.
- viii. **Application Awareness:** The method should produce appropriate results to the type of image and order of resolution.
- ix. **Sensitivity Parameters:** The method should not be too sensitive to internal parameters that may vary from image to image.

Chapter 3

Problem Statement

Image zooming is used in many applications like scientific visualization, multimedia applications and image analysis tasks.[23] A generic image zooming algorithm takes as an input a digital image and provides an output a picture of required size preserving as much as possible the information context of original image. Several good zooming techniques are now days available. The interpolation techniques: pixel replication, bilinear and bicubic are the most popular choices and implemented in commercial digital image processing software.

After going through the literature, we have found that artifacts occurs when the image is zoomed using the interpolation techniques. These artifacts can be of many types such like jagging- blocks are formed due to replication of pixels and blurring. One of the reasons of the artifacts is the presence of edges in an image. When an image having edges is zoomed, these edges are not resized properly. These may cause the blurring in the zoomed images. So there is the need to consider the presence of image edges while zooming the images

Chapter 4:

Proposed Method

4.1 Background Introduction

Assume the original image is

Triple the size of the image I by inserting 0s between all the known elements to form X .

4.1.1 The Nearest Neighbor Interpolator

Take a unit sample function of a matrix of dimensions L having all elements of same value. L is the Magnification. For instance, we have unit sample function having $L=3$

Then in MATLAB, a pre-defined function `conv2(x, h1, 'same')` is utilized to perform two-dimensional convolution of x and $h1$. To compute it we use following algorithm: first rotate $h1$ 180 degree, the element in the lower right corner of rotated $h1$ coincides with the element in the upper left corner of x , and their multiplication forms the (1, 1) element of $y1$. To compute (1, 2) element of $y1$, just move rotated $h1$ one element right and sum all the multiplications of coincided elements. All the other elements can be computed in the similar way. The parameter `'same'` means returning the central part of `conv2(x, h1)`, which corresponds to x and replace 0s in x to generate

From the above output image, it is clear that the superiority of this method lies in its simple algorithm and easy to implement in hardware, while its drawbacks are having obvious box phenomenon.

4.1.2 The Bilinear Interpolator

A unit sample function of a triangle sequence with dimension of $(2L_1-1)*(2L_2-1)$, where the lateral magnification (L_1) and longitudinal magnification (L_2). Let $L_1=L_2=3$, then the unit sample function is

—

It is a 180-degree symmetric matrix and thus uses this function to compute two-dimensional convolution. So, `conv2(x, h2, 'same')` is used, in the MATLAB to obtain output image, and to generate

The above output image performs better than the method of repeat interpolation, with the transitional phenomenon replacing the obvious box phenomenon. However, it requires hardware to perform addition, multiplication and division, resulting in a much higher calculation cost.

4.2 The Proposed Method

In this section, we shall give a detailed description of the adaptive zooming method using Bit-Depth and Adaptive Edge Enhancement (*AEE*). A, B, C, D and M , shown in Figure 4.1, are five regions of pixels to be interpolated and $f(i,j), f(i+n,j), f(i,j+n), f(i+n,j+n)$ taking $n=3$ are the known pixel values corresponding to the original image.

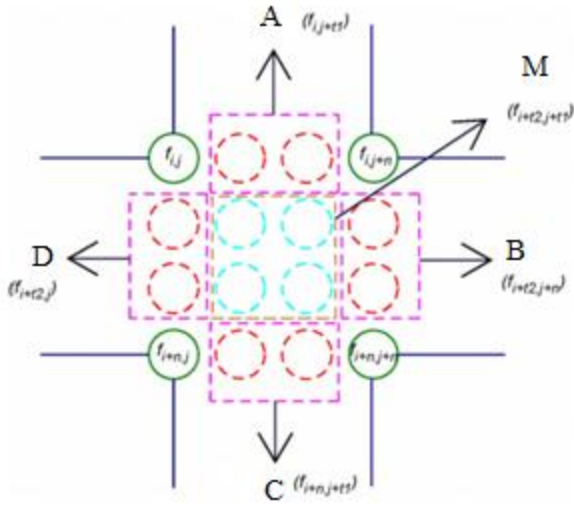


Figure 4.1: Pixel Layout After Enlargement

Step 1: Determine pixel values in *A*, *B*, *C* and *D* regions.

The values of the pixels in these four regions are determined by the differences of the values of the adjacent pixels in their directions. This is an adaptive algorithm where *M* is dependent on *A*, *B*, *C* and *D* region. We can call it in another way that every pixel bit depth is 8 and we can use it as weight.

Bit_Depth = 8

$$Wt = \quad / 2$$

To calculate *A*, the difference of the values of its two adjacent pixels in the horizontal direction is firstly calculated. This difference is denoted by dA and $dA \geq TH$. If $dA \geq TH$, where *TH* denotes a threshold value and is setted with fixed values 128, the nearest neighbor interpolator will be applied to determine the pixel values in *A*, otherwise the bilinear interpolator will be used. The methods for determining the pixel values in *B*, *C*, *D* is similar.

, and . If all the pixel values in any one region are determined by the nearest neighbor interpolator, this region will be called a nearest neighbor region. If the pixel values in any one region are determined by the bilinear interpolator, this region will be called a bilinear region.

Step 2: Determine pixel values in M

Since M is adjacent to the pixel values of A, B, C and D regions, it will be determined by all pixel values in A, B, C, D regions.

If all or three of A, B, C, D are nearest neighbor regions, then M will also be a nearest neighbor region. If all or three of A, B, C, D are bilinear regions, then M will also be a bilinear region.

If A and C are nearest neighbor regions and D and B are bilinear regions, the following formula is used for generating pixel values for M :

$$\begin{array}{ccc} & - & - \\ - & & \\ - & - & \end{array} \dots(2)$$

If A and C are bilinear regions and D and B are nearest neighbor regions, the following formula is used for generating pixel values for M :

$$\begin{array}{ccc} & - & - \\ - & & \\ - & - & \end{array} \dots(3)$$

If A and D are nearest neighbor/ bilinear regions and C and B are bilinear/ neighbor regions, the top-left region of M , including the minor diagonal, is a nearest neighbor/ bilinear region. The bottom-right region of M , excluding the minor diagonal, is a bilinear/ neighbor region.

If A and B are nearest neighbor/ bilinear regions and C and D are bilinear/ neighbor regions, the top-right region of M , including the principal diagonal, is a nearest neighbor/ bilinear region. The bottom-left region of M , excluding the principal diagonal, is a bilinear/ neighbor region as shown in Figure 4.2.

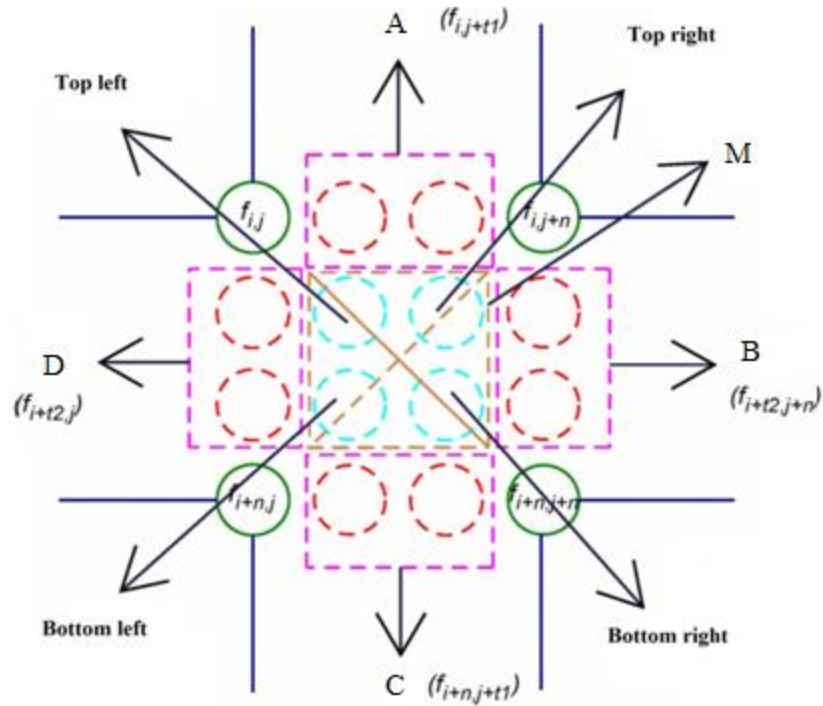


Figure 4.2: Illustration for Proposed Method

4.3 Results

4.3.1 Visual Comparisons

The first qualitative analysis of adaptive algorithm is a series of image comparisons that are presented in the thesis. By the visuals of the output of proposed algorithm, it is clear that it is better than the other existing techniques. The visual results of image comparisons are shown in Figure 4.3 and Figure 4.4 using different interpolation techniques.



Figure 4.3(a): Downsampled



Figure 4.3(b): Nearest Neighbor



Figure 4.3 (c): Bilinear



Figure 4.3 (d): Bicubic



Figure 4.3 (g): AEE



Figure 4.3 (h): Proposed Method



Figure 4.3 (i): Original

Figure 4.3: Barbara



Figure 4.4 (a): Downsample



Figure 4.4 (b): Nearest Neighbor



Figure 4.4 (c): Bilinear



Figure 4.4 (d): Bicubic



Figure 4.4 (e): Lanczos 2



Figure 4.4 (f): Lanczos3



Figure 4.4 (g): AEE



Figure 4.4 (h): Proposed Method



Figure 4.4 (i): Original

Figure 4.4: Bouquet

4.3.2 Quantitative Comparisons

We use two different quantitative measurements on ten real world images. In order to obtain these, an image was first downsampled by factor of three. This LR image was then magnified by a factor of three using a variety of magnification of interpolation techniques for zooming and then compared with the original image. All the measurements reflect the accuracy of the zoomed image. The measurements used in the thesis are *MSE* and *PSNR*.

4.3.3 Accuracy Measurement

The quantitative measurements were gathered by comparing the magnified image with the original image using several metrics which are *MSE*, *PSNR*. These metrics are defined as:

$$\frac{1}{n} \sum_{x,y} (I(x,y) - \hat{I}(x,y))^2 \quad \dots (4)$$

Where \hat{I} is the magnified image, I is the original image, n is the total number of pixels and x, y are the corresponding average pixel value in each image.

$$\frac{1}{n} \sum_{x,y} \max(I(x,y) - \hat{I}(x,y))^2 \quad \dots (5)$$

In equation (5), MAX is a function that finds the maximum value of array. When the pixels are in 8 bits per sample, this is 255. SUM is the function that finds the sum of array and \square^2 – it multiplies the array element by element by itself.

The manner in which the images are down sampled is also worth noting, since we are down sampling an image, magnifying this LR image using the two techniques and comparing it to the original image. Here, we use Matlab [18] to downsample the image by 3 and to implement these techniques. Here all the magnified images are compared with the original images; results of the analysis are shown in Table 4.1. & Table 4.2 and graphical results are shown in Figure 4.5(a) and 4.5(b).

Table 4.1: PSNR For Gray Images

Method Images	Nearest	Bilinear	Bicubic	Lanczos2	Lanczos3	AEE	Proposed Method
Barbara	22.5014	23.9281	23.6366	23.6288	23.3668	25.9033	25.9105
Boat	22.3283	23.7320	23.5235	23.5159	23.2968	26.1055	26.1497
Clown	23.1548	24.7562	24.6266	24.6208	24.4400	27.8268	28.0019
Couple	22.4232	23.7563	23.5500	23.5414	23.3209	25.7076	25.7436
Pepper	24.3867	25.8066	25.5856	25.5815	25.3645	28.6858	28.7485

Table 4.2: PSNR For Colored Images

Method Images	Nearest	Bilinear	Bicubic	Lanczos2	Lanczos3	AEE	Proposed Method
Baby	20.9460	22.3577	22.1814	22.1737	22.0175	24.9847	25.0276
Bouquet	16.5882	18.0280	17.8083	17.8025	17.5946	20.1603	20.1935
College	23.2622	24.6541	24.4463	24.4389	24.2217	26.7160	26.7532
Hema	18.6346	20.3059	20.1747	20.1672	19.9958	23.8668	23.9427
Minnie	14.9292	15.5089	16.3603	16.3517	16.1826	18.6136	19.0479

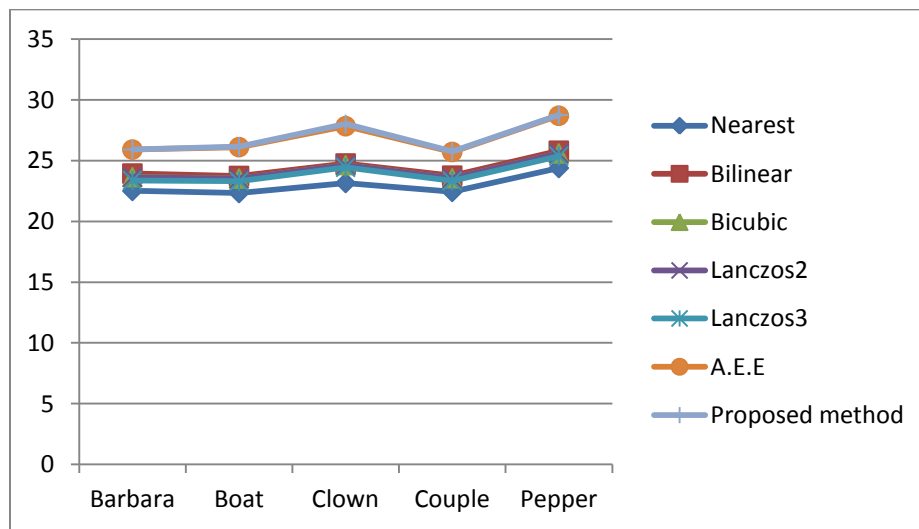


Figure 4.5(a): PSNR for Gray Images

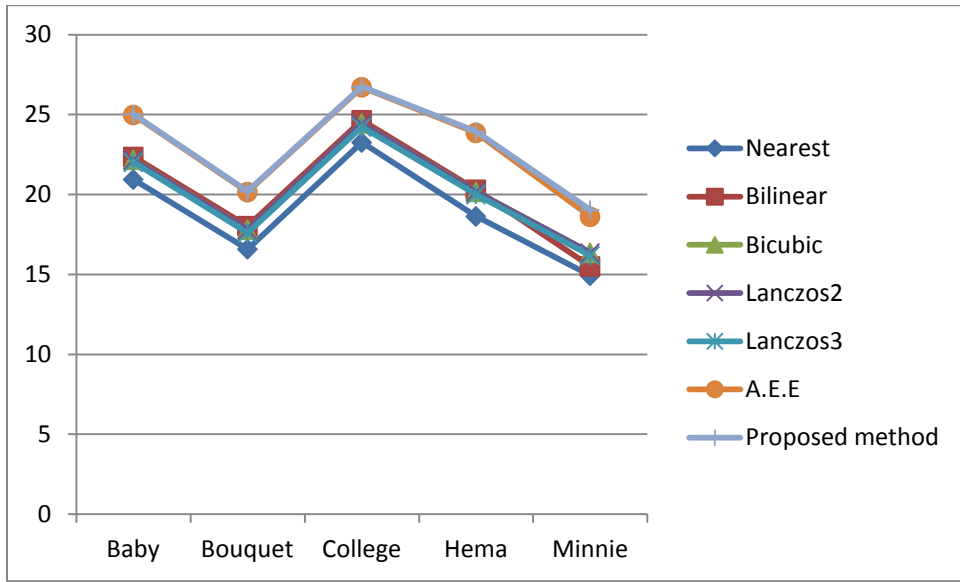


Figure 4.5(b): PSNR for Colored Images

Chapter 5

Conclusions and Future Work

5.1 Conclusion

In this thesis, we have proposed an adaptive image zooming algorithm based on different interpolation techniques. The algorithm has been compared with other interpolation methods according to visual and quantitative measurements.

When the results shown in Table 4.1 and 4.2 are analyzed, the *PSNR* of proposed algorithm is higher than the interpolation methods, which conclude quality of resultant image of proposed algorithm is better than the other interpolation methods.

The accuracy measurement alone is not sufficient to determine an image quality. Visual inspection is also necessary. When the visual results shown in Figure 4.3 and Figure 4.4 are analyzed, the proposed visual results are better than existing methods. In the proposed algorithm artifacts [3] such as blurring and jaggies in images produced are less than the other interpolation methods. The algorithm attempts to minimize the artifacts that are ruling in standard magnification techniques. Basically, the proposed algorithm concentrates on edges present in the image and works on minimizing the artifacts.

This leads to the conclusion that proposed algorithm provides better results both visually and quantitatively.

5.2 Future Work of Research

The future work would involve the improvement of the proposed algorithm for the images and also improve its processing speed. The weight factors used in the proposed algorithm can be combined with other existing algorithms and the results can be improved visually as well as quantitatively.

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APPENDIX:



A.1: Barbara original Image



A.2: Bouquet Original Images