International Journal of Computer Architecture and Mobility
(ISSN 2319-9229) Volume 3-Issue 9, November 2015

Scaling Through Interpolation for Real and Text Objects Images

Mudit Chaturvedi
mudit09chaturvedi@gmail.com
mudit.chaturvedi@cdgi.edu.in
Assistant Professor
Chameli Devi Group of Institute, Indore.

Dr. Rajesh Purohit
rajeshpurohit@jnvu.edu.in
rajeshpurohit@jnvu.edu.in
HoD Computer Science deptt
M.B.M. Engineering College, Jodhpur

Abstract

Image scaling is the process of resizing a digital image. Scaling is a non-frivolous process that involves a trade-off between efficiency, smoothness and sharpness. The size of an image is reduced or enlarged, the pixels which comprise the image become increasingly visible, making the image appear soft if pixels are averaged, or jagged if not. Enlarging an image is generally prevalent for making more minute imagery fit a more astronomically immense screen in full screen mode. There are several methods of incrementing the number of pixels that an image contains, which evens out the appearance of the pristine pixels.

Keywords

HR(High Resolution), LR(Low Resolution), Interpolation

1. Introduction

Images are the most prevalent and convenient designates of conveying or transmitting information. They convey information about positions, sizes and inter-relationships between objects. They portray spatial information that can facilely agnize. Human beings are proficiently adept at deriving information from such images, because of our innate visual and phrenic abilities. About 75% of the information received by human is in pictorial form. Nowadays capture images are thrown digital media in digital form. Zooming is cognate to resizing up of images to be able to visually perceive more detail, incrementing resolution, utilizing optics, printing techniques, or digital processing

There are two type of Image Scaling Techniques
I. Traditional Image Scaling
II. Interpolation Image Scaling

1.1 Traditional Image Zooming

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

An image get distorted after certain size

Distortion is a deviation from rectilinear projection, a projection in which straight lines in a scene remain straight in an image. It is a form of optical aberration.

1.1.1Blurring

Blurring is cognate to aliasing in the sense that it is additionally a mismatch between an intermediate data representation and their final down sampled or over sampled version. In this case, the mismatch is such that the intermediate data is too coarse for the task. This results in an image that appears to be out of focus. To highlight blurring, it is enough to iterate the same interpolation operation an abundance of times, thus efficaciously magnifying the effect.

1.1.2 Blocking

Blocking arises when the fortification of the interpolate is finite. In this case the influence of any given pixel is constrained to its circumventions, and it is sometimes possible to discern the boundary of this influence zone. Synthesis functions with sharp transitions, such as those in utilization with the method designated most proximate neighbor interpolation

1.1.3 Jaggies

Jaggies are stair like lines that appear where there should be smooth straight lines or curves. For example, when a nominally straight, un-aliased line steps across one pixel, a dogleg occurs halfway through the line, where it crosses the threshold from one pixel to the other.

Original Jaggies Blurring Blocking

Fig 1: Zebra Image

1.2 Interpolation Image Zooming

Interpolation is the process by which a minuscule image is made more sizably voluminous. Software implements stretch the size of the image and engender pixels to fill in the blanks. Interpolation is the estimation of values in a function between kenned points. Interpolated images engender smoother lines and a better astronomically immense print than if the pristine, minute image was simply printed astronomically immense. There are several rudimental function-fitting or interpolation methods, including pixel replication, most proximate neighbor interpolation, bilinear interpolation, and bi-cubic interpolation, b-spline interpolation

There are basically four Interpolation which used for analysis purpose

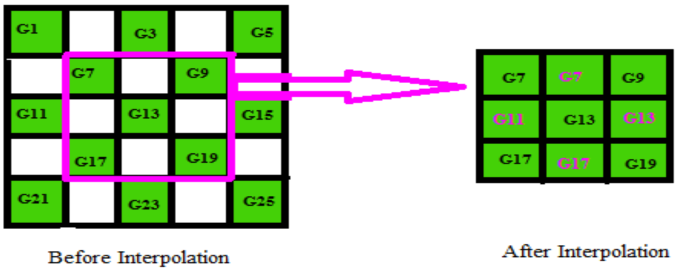
1. Nearest Neighbor Interpolation
2. Bilinear Interpolation
3. Bi-cubic Interpolation
4. B-spline Interpolation

1.2.1 Nearest Neighbor Interpolation

Most proximate Neighbor Interpolation, the simplest method, determines the grey level value from the most proximate pixel to the designated input coordinates, and assigns that value to the output coordinates. It should be noted that this method does not authentically interpolate values, it just copies subsisting values. Since it does not alter values, it is preferred if subtle variations in the grey level values need to be retained.

For one-dimension Most proximate Neighbor Interpolation, the numer of grid points needed to evaluate the interpolation function is two. For two-dimension Most proximate Neighbor Interpolation, the number of grid points needed to evaluate the interpolation function is four.

The most proximate neighbor, where each interpolated output pixel is assigned the value of the most proximate sample point in the input image. This technique is additionally kenned as point shift algorithm and pixel replication.



. **Fig 2: Nearest Neighbor Interpolation Working**

1.2.2 Bilinear Interpolation

In mathematics, bilinear interpolation is an extension of linear interpolation for interpolating functions of two variables on a customary grid. The interpolated function should not utilize the term of x2 and y2 but xy, which is the bilinear form of x and y

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

If we are estimating a pixel between a block of four pristine values, then two ephemeral values are first engendered: a linear interpolation between the top pair of pixels; and the second, a linear interpolation between the bottom pair of pixels. Lastly, a linear interpolation is performed between the two ad interim values.

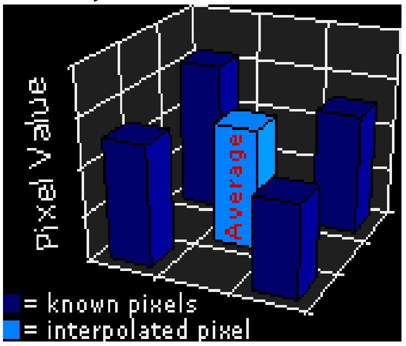


Fig 3: Bilinear Interpolation

Weight is tenacious by assigning weighted value of 4-most proximate neighbor pixel (as shown in Figure) to engendered output pixel. Each weighing value is proportional to distance from each subsisting pixel. This method has advantage of simple calculation. However, blurring effect is occurred by averaging circumvent pixel.

1.2.3 Bi-cubic Interpolation

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

Bi-cubic interpolation utilizes the information from a pristine pixel and sixteen of the circumventing pixels to determine the color of the incipient pixels that are engendered from the pristine pixel. Bi-cubic interpolation is an immensely colossal amelioration over the precedent two interpolation methods for two reasons:

(1) Bi-cubic interpolation uses data from a more sizably voluminous number of pixels

(2)Bi-cubic interpolation utilizes a bi-cubic calculation that is more sophisticated than the calculations of the antecedent interpolation methods as shown in Figure. Bi-cubic interpolation is capable of engendering photo quality results and is probably the method most commonly utilized.

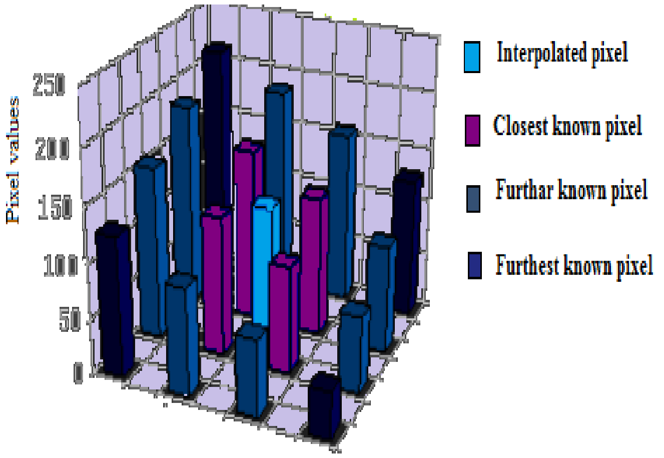


Fig 4: Bi-cubic Interpolation

This is a high performance pixel interpolation that gives outstanding results, both in calculation speed and in quality of results. It is conventionally the best cull when not too radical down sampling operations are involved in geometrical transformations. This form of interpolation has advantages and drawbacks over bilinear interpolation. First, calculating the cubic polynomial in a categorical area of the image is more computationally sumptuous than simple linear fits and withal requires a more astronomically immense neighbor to calculate the curve. A linear function fits straight lines between kenned points, and a cubic function fits cubic splines. On the other hand, jaggies are more distinguished since the image isn't as blurred.

1.2.4 B-Spline

In the mathematical subfield of numerical analysis, a B-spline, or Substructure spline, is a spline function that has minimal support with reverence to a given degree, smoothness, and domain partition. Any spline function of given degree can be expressed as a linear amalgamation of B-splines of that degree. Cardinal B-splines have knots that are equidistant from each other. B-splines can be utilized for curve-fitting and numerical differentiation of experimental data.

A B-spline is a piecewise polynomial function of degree k in a variable x. It is defined over a range $t\ 0 \le x \le tm$, $tm - t\ 0 = k+1$. The points where $x = tjj$ are kenned as knots or break-points. The number of internal knots is identically tantamount to the degree of the polynomial. The knots must be in ascending order. The number of knots is the minimum for the degree of the B-spline, which has a non-zero value only in the range between the first and last knot. Each piece of the function is a polynomial of degree k between and including adjacent knots. A B-spline is a perpetual function at the knots. When all internal knots are distinct its derivatives are additionally perpetual up to the derivative of degree k-1. If internal knots are coincident at a given value of x, the continuity of derivative order is reduced by 1 for each adventitious knot.

For any given set of knots, the B-spline is unique, hence the denomination, B being short for Substratum. The usefulness of B-splines lies in the fact that any spline function of degree k on a given set of knots can be expressed as a linear cumulation of B-splines.

2. Experimental Setup

Enlarging an image (up sampling or interpolating) is generally mundane for making more diminutive imagery fit a more astronomically immense screen in full screen mode. In this sundry interpolation techniques are applied to different domain of images, and their efficacy is observed utilizing different parameter like visualization, intensity and edges. zooming a bitmap image, it is not possible to discover any more information in the image than already subsists, and image quality ineluctably suffers. However, there are several methods of incrementing the number of pixels that an image contains, which evens out the appearance of the pristine pixels.

2.1 Images for Scaling

An image is a visual representation of something. In information technology, the term has several usages:

An image is a picture that has been engendered or replicated and stored in electronic form. An image can be described in terms of vector graphics or raster graphics . An image stored in raster form is sometimes called a bitmap . An image map is a file containing information that associates different locations on a designated image with hypertext links.

2.1.1 Authentic Object Image:

A real image is an image which is located in the plane of convergence for the light rays that originate from a given object. Any image clicked randomly.

Figure 2.1.1(a)

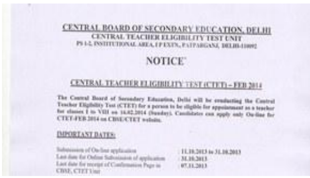
Figure 2.1.1(b)

Figure 2.1.1(c)

2.1.2 Office Notice Image:

Information that tells or warns about something that is going to be happen. A statement telling someone that an agreement, job, etc.

Figure 2.1.2(a)



CENTRAL BOARD OF SECONDARY EDUCATION, DELHI
CENTRAL TEACHER ELIGIBILITY TEST UNIT

NOTICE

CENTRAL TEACHER ELIGIBILITY TEST (CTET) – FEB 2014

The Central Board of Secondary Education, Delhi will be conducting the Central Teacher Eligibility Test (CTET) for a person to be eligible for appointment as a teacher for classes I to VIII on 16.02.2014 (Sunday). Candidates can apply only On-line for CTET-FEB 2014 on CBSE/CTET website.

IMPORTANT DATES:

Figure 2.1.2(b)

2.2 Result Parameter

Result parameter is a characteristic, feature, or quantifiable factor that can avail in defining a particular system. A parameter is a paramount element to consider in evaluation or comprehension of an event, project, or situation. Parameter has more categorical interpretations in mathematics, logic, linguistics, environmental science, and other disciplines.

2.2.1 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 transmute by utilizing 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 integrate 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 engender staircase edges.

vi. Texture Preservation: The method should not blur or smooth textured regions.

vii. Over-smoothing: The method should not engender undesirable piecewise constant or blocky regions.

viii. Application Cognizance: The method should engender congruous results to the type of image and injuctively authorize of resolution.

ix. Sensitivity Parameters: The method should not be too sensitive to internal parameters that may vary from image to image.

2.2.2 Image intensity

This term refers to the effulgence of a point in an image. The intensity of a pixel is tenacious by several quantities including the local value of a RGB, The amount of light reflected by a surface element depends on its micro-structure and the distribution of incident light.

2.2.3 Edge

Edges are significant local changes of intensity in an image. Edges typically occur on the boundary between two different regions in an image.

An edge can be defined as a set of contiguous pixel positions where an abrupt change of intensity (gray or color) values occur.

An edge in an image is a boundary or contour at which a consequential change occurs in some physical aspect of an image, such as the surface reflectance, illumination or the distances of the visible surfaces from the viewer. Vicissitudes in physical aspects manifest themselves in a variety of ways, including vicissitudes in intensity, color, and texture.

Detecting edges is very utilizable in a no of contexts. For example in a typical image understanding task such as object identification, an essential step is to segment an image into different regions corresponded to different objects in the scene. Edge detection is the 1st step in image segmentation.

2.3 Experimental Result

i. Nearest Neighbor Interpolation v/s Different Domain of Images

Table 2.3.1 Nearest Neighbor InterpolationValue

S. No.	Domain of Images	Nearest Neighbor InterpolationValue
1	Notice Image	2.7
2	Real Object Image	3.8

ii. Bi-Linear Interpolation v/s Different Domain of Images

Table 2.3.2: Bilinear Interpolation Value

S. No.	Domain of Images	Bi-Linear Interpolation Value
1	Notice Image	3.5
2	Real Object Image	2.7

iii. Bi-Cubic Interpolation v/s Different Domain of Images

Table 2.3.3: Bi-Cubic Interpolation Value

S. No.	Domain OF Images	Bi-cubic Interpolation
1	Free Hand Image	2.1
2	Notice Image	2.3

iv. B-Spline Interpolation v/s Different Domain of Images

Table 2.2.4 B-Spline Interpolation Value

S. No.	Domain of Images	B-Spline Interpolation
1	Notice Image	1.7
2	Real Object Image	4.5

Table2.2.5: Interpolation Value For Different Domain of Images

S. No.	Bi-cubic Interpolation	Bi-Linear Interpolation	B-Spline Interpolation	Nearest Neighbor Interpolation
Notice Image	1.7	3.5	2.1	2.7
Real Object Image	4.5	2.7	2.3	3.8

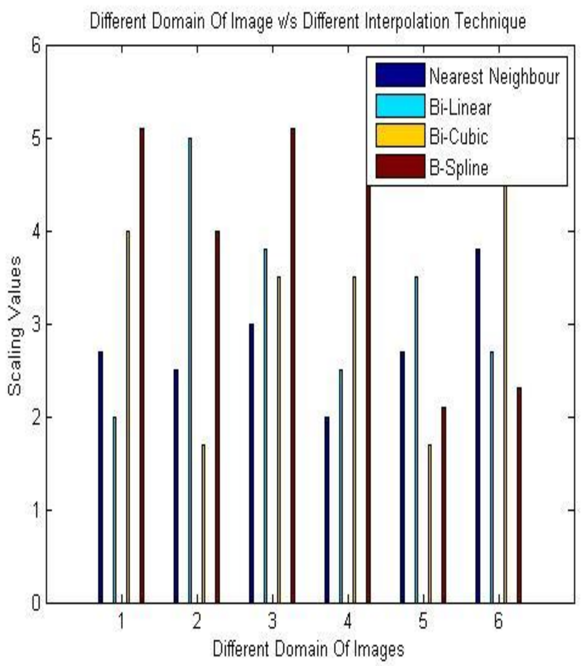


Figure2.5.1: Result Graph


CENTRAL BOARD OF SECONDARY EDUCATION, DELHI
CENTRAL TEACHER ELIGIBILITY TEST UNIT
PS 1-2, INSTITUTIONAL AREA, I P EXTN, PATPARGANJ, DELHI-110092
NOTICE
CENTRAL TEACHER ELIGIBILITY TEST (CTET) – FEB 2014
The Central Board of Secondary Education, Delhi will be conducting the Central Teacher Eligibility Test (CTET) for a person to be eligible for appointment as a teacher for classes I to VIII on 16.02.2014 (Sunday). Candidates can apply only On-line for CTET-FEB 2014 on CBSE/CTET website.
IMPORTANT DATES:
Submission of On-line application : 11.10.2013 to 31.10.2013
Last date for Online Submission of application : 31.10.2013
Last date for receipt of Confirmation Page in CBSE, CTET Unit : 07.11.2013

Fig : Original Image

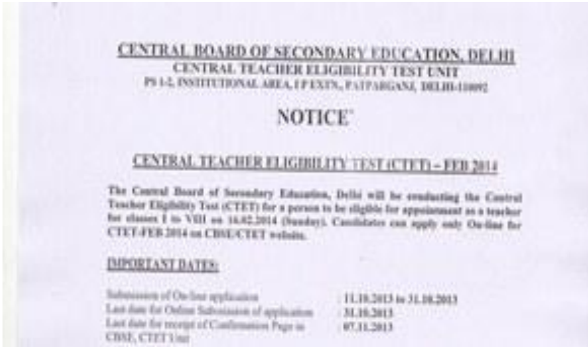

CENTRAL BOARD OF SECONDARY EDUCATION, DELHI
CENTRAL TEACHER ELIGIBILITY TEST UNIT
PS 1-2, INSTITUTIONAL AREA, I P EXTN, PATPARGANJ, DELHI-110092
NOTICE
CENTRAL TEACHER ELIGIBILITY TEST (CTET) – FEB 2014
The Central Board of Secondary Education, Delhi will be conducting the Central Teacher Eligibility Test (CTET) for a person to be eligible for appointment as a teacher for classes I to VIII on 16.02.2014 (Sunday). Candidates can apply only On-line for CTET-FEB 2014 on CBSE/CTET website.
IMPORTANT DATES:
Submission of On-line application : 11.10.2013 to 31.10.2013
Last date for Online Submission of application : 31.10.2013
Last date for receipt of Confirmation Page in CBSE, CTET Unit : 07.11.2013

Fig : Traditional Zooming Image

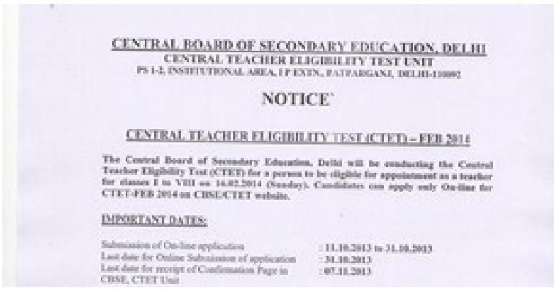
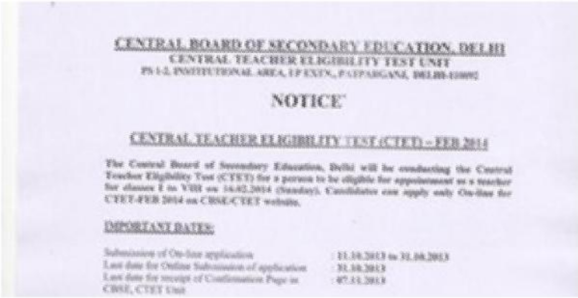

CENTRAL BOARD OF SECONDARY EDUCATION, DELHI
CENTRAL TEACHER ELIGIBILITY TEST UNIT
PS 1-2, INSTITUTIONAL AREA, I P EXTN, PATPARGANJ, DELHI-110092
NOTICE
CENTRAL TEACHER ELIGIBILITY TEST (CTET) – FEB 2014
The Central Board of Secondary Education, Delhi will be conducting the Central Teacher Eligibility Test (CTET) for a person to be eligible for appointment as a teacher for classes I to VIII on 16.02.2014 (Sunday). Candidates can apply only On-line for CTET-FEB 2014 on CBSE/CTET website.
IMPORTANT DATES:
Submission of On-line application : 11.10.2013 to 31.10.2013
Last date for Online Submission of application : 31.10.2013
Last date for receipt of Confirmation Page in CBSE, CTET Unit : 07.11.2013

Fig :Nearest Neighbor Interpolation 2.5


CENTRAL BOARD OF SECONDARY EDUCATION, DELHI
CENTRAL TEACHER ELIGIBILITY TEST UNIT
PS 1-2, INSTITUTIONAL AREA, I P EXTN, PATPARGANJ, DELHI-110092
NOTICE
CENTRAL TEACHER ELIGIBILITY TEST (CTET) – FEB 2014
The Central Board of Secondary Education, Delhi will be conducting the Central Teacher Eligibility Test (CTET) for a person to be eligible for appointment as a teacher for classes I to VIII on 16.02.2014 (Sunday). Candidates can apply only On-line for CTET-FEB 2014 on CBSE/CTET website.
IMPORTANT DATES:
Submission of On-line application : 11.10.2013 to 31.10.2013
Last date for Online Submission of application : 31.10.2013
Last date for receipt of Confirmation Page in CBSE, CTET Unit : 07.11.2013

Fig : Bi-Cubic Interpolation 3.5



CENTRAL BOARD OF SECONDARY EDUCATION, DELHI
CENTRAL TEACHER ELIGIBILITY TEST UNIT
PS 1-2, INSTITUTIONAL AREA, I P EXTN., PATPARGANJ, DELHI-110092

NOTICE

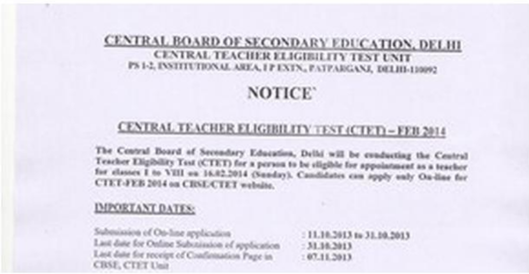
CENTRAL TEACHER ELIGIBILITY TEST (CTET) – FEB 2014

The Central Board of Secondary Education, Delhi will be conducting the Central Teacher Eligibility Test (CTET) for a person to be eligible for appointment as a teacher for classes I to VIII on 16.02.2014 (Sunday). Candidates can apply only On-line for CTET-FEB 2014 on CBSE/CTET website.

IMPORTANT DATES:

Submission of On-line application : 11.10.2013 to 31.10.2013
Last date for Online Submission of application : 31.10.2013
Last date for receipt of Confirmation Page in CBSE, CTET Unit : 07.11.2013

Fig :Bi-Linear Interpolation 2.1



CENTRAL BOARD OF SECONDARY EDUCATION, DELHI
CENTRAL TEACHER ELIGIBILITY TEST UNIT
PS 1-2, INSTITUTIONAL AREA, I P EXTN., PATPARGANJ, DELHI-110092

NOTICE

CENTRAL TEACHER ELIGIBILITY TEST (CTET) – FEB 2014

The Central Board of Secondary Education, Delhi will be conducting the Central Teacher Eligibility Test (CTET) for a person to be eligible for appointment as a teacher for classes I to VIII on 16.02.2014 (Sunday). Candidates can apply only On-line for CTET-FEB 2014 on CBSE/CTET website.

IMPORTANT DATES:

Submission of On-line application : 11.10.2013 to 31.10.2013
Last date for Online Submission of application : 31.10.2013
Last date for receipt of Confirmation Page in CBSE, CTET Unit : 07.11.2013

Fig :B-spline Interpolation 2.7

3. Conclusion

In the Interpolation techniques artifacts such as blurring, jaggies and blocking in images are less than the other available traditional zooming methods. Try to minimize the artifacts that are ruling in standard magnification techniques. Basically, the Interpolation techniques concentrates on edges present in the image and works on minimizing the artifacts.
This leads to the conclusion that different interpolation techniques provides better results both visually and quantitatively on different types of images.

By applying Nearest Neighbor, Bi-Linear, Bi-Cubic, B-Spline interpolation techniques on the domain of Landscape, Portrait, Real Object, Human Face, Notice, Free Hand images following conclusion are carried out.

i. Nearest Neighbor Interpolation is better for those domain of images whose contain same number of pixel in large area of image have maximum scaling value like Real Object. But rest of domain whose need smooth edges and less artifacts, this interpolation is not good enough for those do- main of images.

ii. Bi-Linear interpolation is better for those domain in which some blurriness is allowed have maximum scaling value. Bilinear works quite well on Notice Domain images. This technique is not suggested for real object image because these image contain sharp line which convert into stair edges, which show bad visualization of portrait.

iii. Bi-Cubic interpolation performed good on those domain of images which not follow same pattern on their architecture and contain curve also have scaling value like Real Object . But Notice domain follow same pattern in large area of image, so this technique not work properly on them

iv. B-spline interpolation work properly comparative to other interpolation on almost all domain of images, because it find more accurate intermediate value using known pixel value.

This leads to be concluded that different interpolation techniques provides better results both visually and quantitatively on different domain of images.

4. REFERENCES:

[1] R. C. Gonzalez, R. E. Woods, ′Digital Image Processing′, 2nd ed., Prentice Hall.
[2] Chandan Singh, ′Interpolation Methods Image Zooming′, Proceeding of the National Conference FACM Thapar University, pp-29-34, March 2005.
[3] Fahim Arif and Muhammad Akbar, ′Resampling Air Borne Sensed Data Using Bilinear Interpolation Algorithm′, Proceedings of the 2005 IEEE International Conference on Mcchatronics, Taipei, Taiwan, 2005.
[4] Zhang Min, Wang Jiechao, LI Zhiwei and LI Yonghua , ′An Adaptive Image Zooming Method with Edge Enhancement′, 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE), pp-608-611, 2010.
[5] LI Zhiwei, ZHANG Min and WANG Jiechao ,′ An Image Zooming Technique Based on the Relative Color Difference of Pixels′, IEEE Transactions On Image Processing, Vol. 15, No.2, 2006.
[6] Mehdi Hajizadeh, Mohammad Sadegh Helfroush and Ashkan Tashk, ′Improvement of Image Zooming Using Least Directional Differences based on Linear and Cubic Interpolation′, 2009.
[7] Zhou Dengwen and Shen Xiaoliu , ′ An Effective Color Image Interpolation Algorithm′ ,4th International Congress on Image and Signal Processing, pp-984-988, 2011.
[8] Jiang Tao, Lu Wenhu, Dong Shouyin and Han Mingqin, ′Study of Image Magnification Based on Newton Interpolation′, 3rd International Congress on Image and Signal Processing, pp-1248-1252, 2010.
[9] Min Sheng, Benyue Su, Wanbao Hu and Gongqin Zhu, ′A Class of Image Interpolation Method Based on Quasi Hermite Interpolation Spline′, pp-520-524, 2008.
[10] M. F. Fahmy, T. K. Abdel Hameed and G. F. Fahmy, ′A Fast B. spline Based Algorithm for Image zooming and Compression′ , 24th National Radio Science Conference, Egypt, 2007.
[11] Mehdi Faghih and Hossein Pourghassem , ′A Novel Interpolation Method Using Radon Transform′ , IEEE 7th International Colloquium on Signal Processing and its Applications, pp-277-282, 2011.
[12] Jong-Woo Han, Jun-Hyung Kim, Sung-Hyun Cheon, and Sung-Jea Ko, ′A Novel Image Interpolation Method Using the Bilateral Filter′, 2010.
[13] R. Lukac, K. Martin, and K.N. Plataniotis, ′Digital Camera Zooming Based on Unified CFA Image Processing Steps′, Digital

Camera Zooming Based on Unified CFA Image Processing Steps, pp-15-24, 2004.

[14] Jinjun Wang, Shenghuo Zhu and Yihong Gong, ′Resolution-Invariant Image Representation and Its Applications′, pp-2512-2519, 2009.

[15] Tinku Acharya1, Ping-Sing Tsai, ′Computational Foundations of Image Interpolation Algorithms′, vol.8, 2007.

[16] Philippe Thévenaz, Thierry Blu and Michael Unser, ′Image Interpolation and Resampling′

[17] Wing-Shan Tam, Chi-Wah Kok and Wan-Chi Siu , ′A Modified Edge Directed Interpolation For Images′, 17th European Signal Processing Conference, 2009.

[18] Stephen J. Chapman, ′Essentials of Matlab Programming′, 2nd ed., vol. 10, 2009.

[19] Journal of Computational Information Systems 8: 1 (2012) Xiaoli YANG1;∗ Zhenwei LI 1, Meisen PAN2 1School of Medical Technology and Engineering, Henan University of Science and Technology, Luoyang 471003, China 2College of Computer Science and Technology, Hunan University of Arts and Sciences, Changde 415000, China Ab

[20] S. Farsiu, M. Elad, and P. Milanfar, “Resolution Enhancement of images with Interpolation” IEEE Trans. Image Proces., vol. 15, no. 1, pp. 141–159, Jan. 2006.

[21] Kernel Regression for Image Processing and Reconstruction Hiroyuki Takeda, Student Member, IEEE, Sina Farsiu, Member, IEEE, and Peyman Milanfar, Senior Member, IEEEVOL. 16, NO. 2, FEBRUARY 2007