

IMAGE RESOLUTION ENHANCEMENT OF SINGLE COLOR IMAGE

A THESIS

Submitted in partial fulfillment of the
Requirements for the award of the degree of

**Master of Engineering
in
Information Security**

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "Image Resolution of Single Colored Image", in partial fulfillment of the requirements for the award of degree of Master of Engineering in Information Security Engineering submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Dr. H.S. Pannu and refers other researcher's work which are duly listed in the reference section.


The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.


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ABSTRACT

Digital Image Processing is an actively growing field which has many growing applications in Science and Engineering. The need of digital image processing is due to the improvement of pictorial information for human interpretations. Image processing may be classified into following categories: restoration, segmentation, and enhancement. Image Super-Resolution is the active field of image processing. Images and videos with high resolution are used in various fields like medicine, agriculture, pattern recognition etc. There are many applications for increasing the resolution of image but they are not very effective as they add physical artifacts such as noise or blur. There are various algorithms of image super resolution. Some algorithms do not consider the edges as the edges are most sensitive part of image. Some methods mainly focus on the edges leaving behind other part of image as it is.

In this research work, we propose a method to increase the resolution of a color image. This framework involves various steps. First step involves the interpolation of image. The interpolation is done for scaling of the image using Bicubic interpolation. Next step is feature extraction where we extract the information of high frequency pixels of image. The features are extracted from the interpolated image where features are extracted using Gradient and Laplace filters. Gradient filter act as edge detector whereas Laplace filter improves low frequency pixels. We get four images from feature extraction as output in feature extraction block, first two by applying Gradient filter horizontally and vertically. Next two, we get by applying Laplace filter vertically and horizontally respectively. Then, the Principal Component Analysis reduction is used to get the most efficient information of feature extraction. Next step is to divide the image into non-overlapping blocks so that sparse representation method is performed on each block. After that we use Sparse Representation algorithm to perform the Super Resolution. Sparse Representation method involves two dictionaries for performing Super Resolution. Dictionaries are trained using Singular Value Decomposition (k-SVD) algorithm. Dictionaries are trained from the database which contains 60 images. The database contains both high resolution and low resolution version of images. Sparse representation is done on each block. Final step is to reconstruct the image by merging the output of sparse representation and the output of bicubic interpolation. At last, we get high resolution image as an output. The performance evaluation of the proposed method is based on Peak Signal to Noise ratio (PSNR), Structure Similarity Index

(SSIM) values. The PSNR and SSIM values of our proposed algorithm are better than the Bicubic interpolation, Lanczos interpolation, k-neighbor algorithm etc. Sparse representation has better performance than various interpolation methods. The average PSNR value of proposed method exceeds that of sparse representation by 0.24 which makes it more suitable than contemporary methods.

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LIST OF ABBREVIATIONS

SR	Super Resolution
LR	Low Resolution
HR	High Resolution
PCA	Principle Component Analysis
CAT	Computerized Axial Tomography
MRI	Magnetic Resonance Imaging
CPs	Control Points
ScSR	Sparse Coding Super Resolution
PSNR	Peak Signal-To-Noise Ratio
SSIM	Structured Similarity of Index
SAI	Soft Adaptive Interpolation
SVD	Singular Value Decomposition
GPU	Graphics Processing Unit.

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INTRODUCTION

1.1 PREAMBLE:

Today is the world of digital images which are used in various fields such as medical, video surveillance, astronomy, social media, entertainment etc. We often need to zoom the image in and out to analyze images in depth for information extraction. Therefore if we can enhance the resolution of the original picture, it becomes easier for the observer to obtain any important information from the image. There are many techniques to get HR image from the original one. SR is one of the techniques used to increase the resolution of the image or video. Pixel value is the value of the brightness at any point within the image. HR image has high pixel value. There is great need for HR images because higher the pixel value enables us to enlarge the image and see the meticulous details.

1.2 IMAGE PROCESSING

It is a method to obtain a HR image or to take out some critical facts useful for further analysis by performing some mathematical operations. This is a process in which an image is given as input and the output can be HR image or some features associated.

The major three steps of image processing:-

1. Importing the image.
2. Analysis and manipulation of image.
3. Output as image or features associated.

Following are the types of image processing:-

1. Analog image processing- This type of processing is applied in hard copies like printouts and photographs.
2. Digital image processing- This type of image processing is used in soft copy of digital images.

1.3 DIGITAL IMAGE PROCESSING

Digital image processing involves a series of actions that is performed on a digital image to get the desired results. The digital images are manipulated through digital computer. The need of digital image processing is to improve the pictorial information for human interpretation or for analysis. Improvement of pictorial information includes improving the edges of an image to make it appear sharper, removing noise and motion blur from an image. To get over from these abnormalities images are to be processed. Preprocessing, enhancement and information extraction are the three main phases an image has to undergo.

1.4 SUPER RESOLUTION

SR is the technique of enhancing resolution of images or video or obtaining a HR image from one or multiple LR images. In LR image, pixel density within an image is small, therefore offering fewer details. In HR, pixel density within an image is larger, therefore offering more details. The details of the original scene can be gathered more effectively with HR images. There are various fields such as medical imaging (i.e. CAT, MRI etc), astronomy, video surveillance etc where HR images are required. The need for HR images is due to the areas where we have the need to zoom the image or to analyze it in deep. HR imaging is not always available. There are various sources of HR imaging but they are too expensive and inefficient due to sensor limitations, optics manufacturing technology.

Images can be obtained from one or multiple cameras. These images are to be associated to a regular framework. This process of association is called registration. Then SR procedures can be applicable to the particular field. Super-Resolution is successful if a reliable alignment i.e. registration and construction of the image model is done. Following are the three basic components that are used by most of the SR reconstruction algorithms:

1.4.1 Image Registration

The different view-points of the same scene can be observed by multiple LR images. The process of wrapping the surface of one or more images of same scene is called image registration. As images obtained from different sources or at different times are need to be compared for analyzing purpose or for decision making. Therefore, the misalignment between the images reduces the accuracy of analysis. So, Image registration is the process defined to align the two images geometrically. The two images are the reference image and sensed image. The reference

image is referred as source image on which algorithms of super resolution has to implement. The sensed image is called the target image. For image analysis it is a very crucial step. The data sources like image fusion, change detection, and multichannel image restoration all are combined to obtain final result. Image fusion forms an image with the combination of two or more images. Resultant fused image depicts more complete information than the single image. Change detection is the process of identifying regions of change in various images of the one same scene taken at different times. This change detection is useful in various applications like surveillance, medical diagnosing. Multiple Image Restoration is the technique to obtain the clean image from the corrupted or noisy image. This technique is different from image enhancement as image enhancement focus on the features to make image more pleasing. The very first step of super-resolution is image registration, in order to align the different images precisely. Following are some steps used in majority of registration methods:

- Detection of features: The features like edges, corners, intersections, regions are detected by means of segmentation method. These features are then represented by their representative points such as line endings or centre of gravity for further processing's. In the literature these points are called Control Points.
- Feature matching: Here the relation is established between the detected features of sensed image and those of reference image. Some similarity measures along with spatial relationships that are how features of an image are in relation to the features of reference image are used for matching.
- Transform model estimation: This mapping function provides a way to link the various parts of an image without dividing the image. The parameters of the mapping functions are computed by means of the established feature correspondence
- Image re-sampling and transformation: Transformation is done for aligning the image in correct position. This is the final step.

1.4.2 Interpolation

Interpolation is the process of finding the values of a function at positions between its samples. It is a procedure used in expanding and contracting digital images. It occurs in all

digital images at some stage of resizing, zooming, magnification or remapping your image from one pixel grid to another. Resizing an image is important when you need to increase or decrease the number of pixels. Usually resizing of image involves operations like scaling up and scaling down. Due to this resized image has low quality but it can be retained by introducing new pixels. These new pixels are introduced on the basis of prediction or approximation. Therefore, Image interpolation is the easiest way to enhance the quality of LR image. This may be achieved by curve fitting or regression analysis.

1.4.2.1 Non-Adaptive Algorithms

These algorithms use a fixed methodology to handle all the pixels in the procedure of interpolation. The algorithm performs operations on the basis of local structure of image. In this linear and fixed computation is implemented at every pixel. The computational logic for non-adaptive is fixed irrespective of image features. Interpolation of new pixel values is done by combining sum of input data and interpolation kernel. Mostly non-adaptive is used in real life applications. It include Nearest Neighbor, Sinc, Lanczos are prominent ones. Depending on their complexity, these use anywhere from 0 to 255 adjacent pixels when interpolating.

1.4.2.2 Adaptive Algorithms

Here in the adaptive techniques different methods are used to locate pixels in the throughout procedure of interpolation. Non-linear types of computations are implemented depending on the sharp edges and smooth texture. The computational logic of these techniques is dependent on the intrinsic features and content of image. These algorithms have main aim to minimize hideous interpolation artifacts. These algorithms are primarily designed to maximize artifact, therefore some of them cannot be used to distort or rotate an image. These algorithms give better results than non-adaptive but have high computational cost as they require more hardware.

1.4.3 Reconstruction Of Images

This is method of obtaining single high-resolution image either from multiple degraded still images (single static image) or from multiple degraded multi frames (collection of images related by time or view).

1.4.3.1 Blind Super Resolution

The blurring process is actually unknown in many practical applications. Due to this, blind

super-resolution algorithm is defined. The algorithm includes the identification of blur factor in SR restoration. The sensor PSF occurred due to camera lens is always ignored in the framework of blind super-resolution. This means the HR images are affected by the sensor PSF. Image registration, image restoration and estimation of PSF is combined in one framework in this technique. While suppressing noise edges are preserved by partial differential equation (PDE).

1.4.3.2 Fast And Robust Super Resolution

Estimation of HR image is not only based on LR measurements. The estimation also includes many assumptions such as noise or motion models. For estimating HR image from noisy LR images, an appropriate estimation method has to be chosen. The chosen method optimally estimates, on the basis of assumptions of data and noise models. The methods which is limited only to class of data and noise models it may or may not be the effective approach. Techniques not sensitive to models produce better and more stable results (robustness). The concept of breakdown is introduced to measure the robustness of an algorithm.

1.5 APPLICATION AREAS OF SR IMAGING

HR imaging is needed in various computer applications. The HR images are used for better performance. HR images are also used in medical area. In many areas, we need HR image to analyze the area of interest. There is a great demand for HR images and videos are needed in various fields, such as medical, engineering, computer vision, pattern recognising, video production, and so on. It is not possible to get the images and videos of suitable resolution because such images and videos are obtained from various electronic devices that uses sensors, and those sensors do not have desired resolution quality. Benefits of HR image:

- Remote sensing: It is defined as gathering of information of an object without making physical contact. Remote sensing is used in various fields such as geography or earth science discipline. Therefore, images with high spatial resolutions are required in these areas.
- Surveillance video: to increase the resolution of any video so that we can easily upscale the area of interest.
- Video standard conversion
- Medical imaging (CT, MRI, and Ultrasound etc): Most of the medical images are corrupted with noise and have LR. HR images are used for detecting any problem or analysis of specific part of body.

1.6 SUPER RESOLUTION CLASSIFICATION

1. Multiple Image Frame Super-Resolution
2. Single Image Frame Super-Resolution

These SR techniques are explained below in the subsections.

1.6.1 Multiple Images Frame Super Resolution

In multiple images SR, single SR is obtained from multiple LR images. This type of super-resolution refers to the case in which multiple images from the same scene are available. Various different “looks” of the same scene are depicted by these multiple LR images. The changes in these LR images are due to camera zoom, camera or scene motion, focus and blur. Resolution of reconstructed image is above the limits of all imaging devices by using algorithm. It means these resolved images can depict more of the original scene’s details than that of input images. The factors like blurring, geometrical transformation, and down sampling all come under degrading processes(decreasing resolution of image).The best case where SR can possible in these methods is to work when LR images have different sub pixel shifts and thus provide different information i.e. each image cannot be obtained from the others. In the basic idea of preparation of training set based on any particular algorithm is prepared and with the help of that training set we can convert LR image to HR image. It is of 3 types which are given below:

1.6.1.1 Interpolation Based Approach

The technique of up-scaling the image or resizing the image by finding out the pixel values that are unknown and lies within the sample .It occurs in all digital images where you need to resize the image or remap (i.e. taking out the pixels from one image and locating them at other positions in new image) the pixels within the image. Resizing of image involves increasing or decreasing the number of pixels within the image whereas remapping involves distorting the pixels from one grid to other grid. There are various interpolation algorithms and the result of image depends on which interpolation algorithm is used by us.

1.6.1.2 Frequency Domain Based Approach

The main aim of SR methods is to get HR image from a set of LR images. All the LR images are of the same scene. There is a method which correctly aligns high frequency and low frequency parts of the image. If there alignment of image is not perfect than this results in

irregular image. This method has many benefits. This method is very simple because it does not contain complex calculations. The relation between HR and LR image is clearly seen. We increase the resolution of LR image by finding out the high frequency details in image. This method has very low computational cost due to less calculation involved.

1.6.1.3 Regularization Based Approach

Most of the SR algorithms add blur or noise to the image. This is the main problem of SR algorithms. Their motive is to decrease the number of possible solutions to stabilize the inverse operation. In this method, we first collect the information of unknown HR image. It involves two methods:

1. Deterministic regularization approaches
2. Stochastic regularization approaches

Deterministic approaches rely on the fact that, observation model can be completely specified with the estimation of registration parameters. Inverse problem is then solved by this approach by changing some knowledge about the solution.

Stochastic methods adopt Bayesian approach, according to which the information can be extracted from the LR images about the unknown signal contained. In this method we find out PDF value of HR image with the help of observed HR image details and input LR image details.

1.6.2 Single Image Frame SR

In Single Frame Super-Resolution is based on the single LR image. In this type, we consider only one single image and processing is done on that image to convert it to HR version. The equation of single image SR can be written as

$$I_L = (I_H * b) \downarrow_s \quad (1.1)$$

Where I_L is LR image and I_H is HR image, b is blur operator which adds blurriness to the image and the subscript expression \downarrow_s denotes down sampling operation by a scale factor of s (possible value of s is positive integers).

There is a problem in single image SR, as there can be many HR images creating LR images that are identical. Single-image SR is like the interpolation, as both wants the same thing. Interpolation methods like cubic, linear etc up-scale the image by finding out the missing pixel

values. But interpolation does not consider edges as edges are the most sensitive part of the image. Therefore, this result in addition of artifacts in the image and does not give us the smooth image. The main goal of SR is to get better results. Single-image SR algorithms involve two main methods: Learning-based method and Reconstruction-based methods.

1.6.2.1 Learning Based Single Image SR

This technique of SR divides the image into patches. This is also called as Example based SR. In the method of image enhancement the input image is divided into patches where all patches have equal size. We convert LR patches into HR patches with the help of dictionary.

This method involves dictionary which is trained with the help of example images. We prepare two dictionaries one having LR patch and other having HR patch. First, match the input patch with the LR dictionary. Then, we use LR dictionary patch and HR dictionary to reconstruct LR patch into HR patch.

1.6.2.2 Reconstruction Based Single Image SR

This technique involves a process of building the relations between LR image and HR image. Its equation is:

$$L(y) = \int B(y, x) H(x) dx + E(y)$$

(1.2)

Where $L(y)$ and $H(x)$ are the continuous LR irradiance field and HR irradiance light-field on image plane, $B(y,x)$ is the blurring kernel and $E(y)$ is the noise. In the equation (1.2), it is shown that LR image is the integration of blurriness in HR image.

1.7 VARIOUS INTERPOLATION TECHNIQUES

Various SR techniques exist in image processing which are discussed as follows:

1.7.1 Cubic interpolation

It is the simplest methods of interpolation. If the value of a function $f(x)$ and its derivative $f'(x)$ is known at coordinate $x=0$ and $x=1$ than we interpolate the function on the interval $[0,1]$ using

three degree polynomial. We use 4 points to find the unknown pixels values within the image. The equation for cubic interpolation is:

$$f(k_0, k_1, k_2, k_3, x_k) = (-0.5k_0 + 1.5k_1 - 1.5k_2 + 0.5k_3)x^3 + (k_0 - 2.5k_1 + 2k_2 - 0.5k_3)x^2 + (-0.5k_0 + 0.5k_2)x + k_1 \quad (1.3)$$

Where k_0, k_1, k_2, k_3 are the values at $x=-1, x=0, x=1, x=2$ and x_k is the unknown point

1.7.1.2 Nearest Neighbor Interpolation

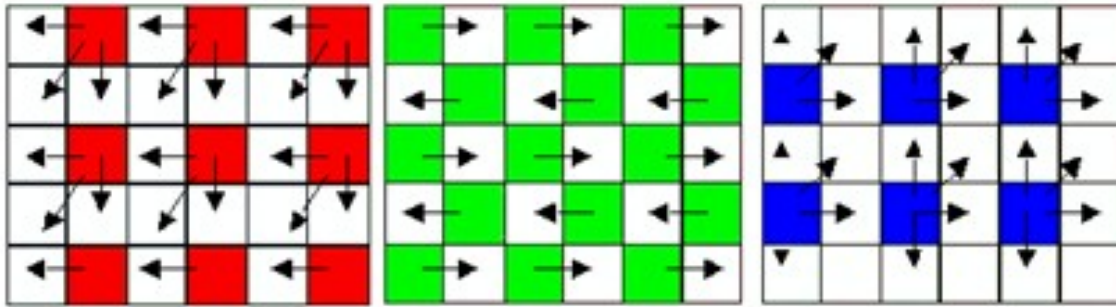


Fig 1.1 Nearest Neighbor Interpolation

The method given is very simple. It finds out the closest pixel value to specify input pixel. After that it gives that value to the output pixel. In Fig1.1, the nearest closest pixels are considered. This method does not find out new pixel values. It just copies the already present values as it does not change the values. The number of grid point needed for one-dimension nearest neighbor interpolation is two (one nearest point and one unknown point) and for 2-dimensional is four (2 for x-axis and two for y-axis). For nearest neighbor method, the equation is:

$$u(s) = \begin{cases} 0 & \text{if } s \leq 0.5 \\ 1 & \text{otherwise} \end{cases} \quad (1.4)$$

s is the distance between interpolated point and the point which is under consideration within the grid. Its coefficients $ck = f(xk)$.

1.7.1.3 Bilinear Interpolation

Bilinear interpolation is used to find out the unknown pixel values within the sample with the help of given pixel values in 2-D grid. It is advanced version of Linear Interpolation. First we do linear interpolation in one direction of image. After this, it is performed in other remaining direction. It is a re-sampling method in which we find out the average of distance weight of 4 nearest pixels to find out the new pixel value. It is used to determine value of a point by using neighboring points assuming that surface is continuous and smooth and there is highly a correlation present between the neighboring points.

In Fig(1.2), the main aim is to find the value at the dot c having green color . The point c have the coordinates tx and ty . We can find out the value of c by performing two linear interpolations in one direction i.e x axis so that we can get value of a and b . In the bilinear interpolation process, first we find out the value of a and b . In the similar way we find out c using a and b . $c00, c01, c11, c10$ are the four known pixel. c is the unknown pixel

$$b=(c_{11}-c_{01})-tx; \tag{1.5}$$

(1.6)

$$a=(c_{10}-c_{00})-tx;$$

$$c=(b-a)-ty; \tag{1.7}$$

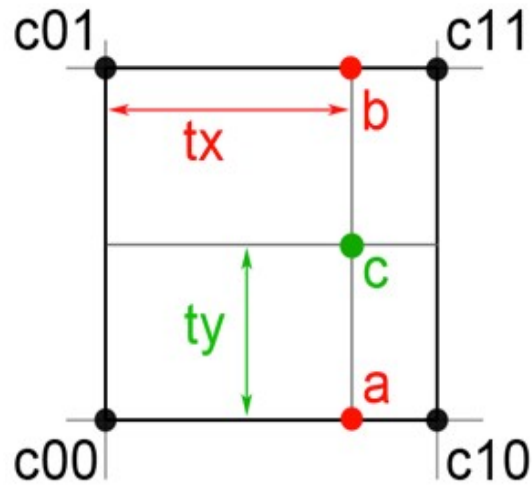


Fig 1.2 Bilinear Interpolations

1.7.1.4 Bicubic Interpolation

Interpolation involves up-scaling the image or resizing the image by finding out the pixel values that are unknown and lies within the sample. It occurs in all digital images where you need to resize the image or remap the pixels within the image

Bicubic interpolation is the improved version of cubic convolution interpolation method. Two dimensional cubic interpolations are performed easily by one dimensional interpolation on each direction. The experimental result shows that performance of this method is better than linear interpolation and k-neighbor algorithm. Bicubic interpolation works on two dimensional grids whereas cubic works on one dimensional grid. The surface we obtained in this is smoother than the surface obtained in bilinear and k-nearest interpolation algorithms. This method reconstructs the same surface between 4 starting pixels. This method provides zero artifacts. This method is hard to understand because of its tough calculation. In this information of sixteen pieces are extracted. Firstly, four horizontally 1-D cubic convolutions are used in same direction. Then one more vertically 1-D cubic convolution is performed. Therefore, we need to implement cubic interpolation in two dimensions. We need 16 grid points.

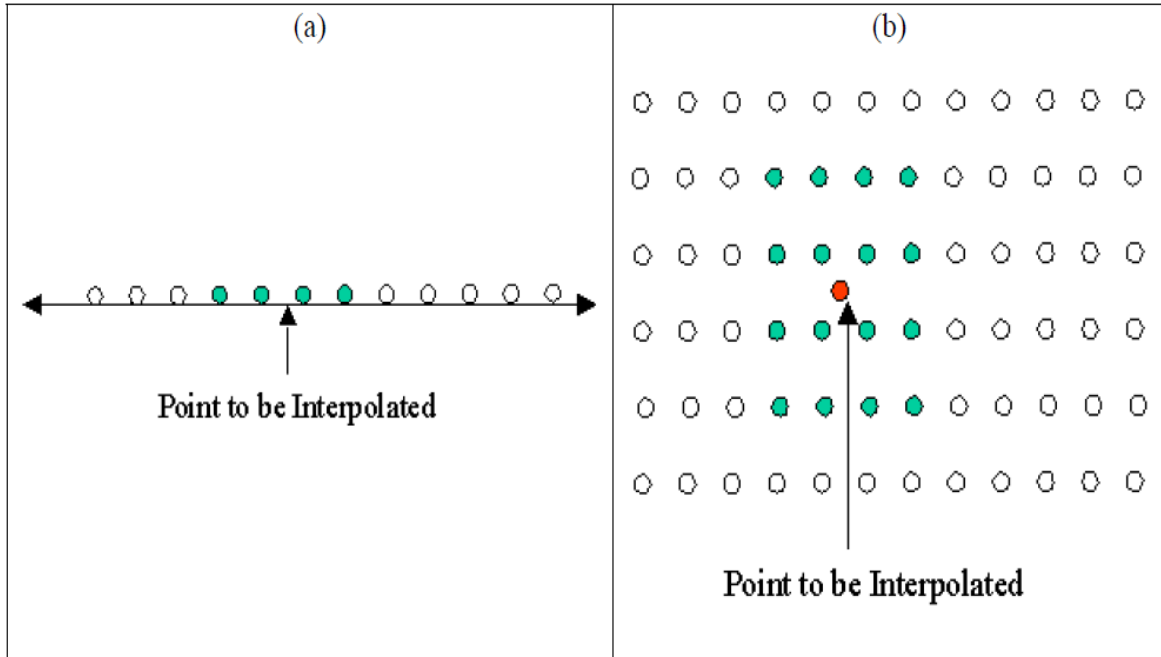


Fig 1.3 Bicubic interpolation

1.8 OUTLINE OF THE THESIS

The thesis has been organized into 6 chapters and out of that CHAPTER 1 presents Introduction. CHAPTER 2 presents the various Super Resolution techniques of image. CHAPTER 3 consists of problem statement, objective and methodology. CHAPTER 4 presents the new technique for the resolution enhancement of single color image by using bicubic interpolation, filters and sparse representation algorithm. CHAPTER 5 presents the results of proposed method and comparison of proposed method with already existing work.. Finally, followed by the conclusion and future scope of the research work for further research are provided in CHAPTER 6.

CHAPTER 2

LITERATURE REVIEW

2.1 INTERPOLATION TECHNIQUES

In [10], there is an interpolation method which is the modified version of cubic interpolation method. Bicubic interpolation works on two dimensional grids whereas cubic works on one dimensional grid. The surface we obtained in this is smoother than the surface obtained in bilinear and k-nearest interpolation algorithms. This method reconstructs the same surface between 4 starting pixels. This method provides zero artifacts. This method is hard to understand

because of its tough calculation. In this information of sixteen pieces are extracted. Firstly, four horizontally 1-D cubic convolutions are used in same direction. Then one more vertically 1-D cubic convolution is performed. Therefore, we need to implement cubic interpolation in two dimensions. We need to find 16 grid points number.

In [8], the author proposed a fusion method. The basic idea is first we interpolate the LR image by using soft adaptive interpolation (SAI is an edge preserving interpolation technique) and Bicubic interpolation. Then artifacts of SAI are estimated and those pixels are replaced by those from image which is interpolated by Bicubic interpolation. Gaussian filter may be used to reduce the artifacts of edges of Bicubic interpolated image and then a threshold value is calculated to detect the distortions caused by SAI. Gaussian filter is used to reduce the effect of noisy pixels and its performance is better than other conventional filters. Finally bilateral filter is used for smoothing the edges and the resulting HR image is achieved by weighed sum of the two HR image.

The Lancos interpolation [23] is used to scale up the image. Scaling of image is required for better view of the image and to improve its resolution. The new unknown points are calculated from given points within the sample. It is performed on digital signals. We use this method to find the signal values within the samples. We use filter's reconstruction kernel $L(x)$, called the Lanczos kernel to find out the effect of each input pixel on the interpolated pixel.

An edge directed Interpolation method is given by [9]. The result shows that this algorithm gives better performance as it preserves the edges regularity whereas bilinear or nearest neighbor interpolations does not give strong edges(does not consider edges as edges have greater pixel value than other part of image and leave them as it is). First, we find out the covariance of LR image. Then we use that value to perform interpolation at HR on the basis of geometry duality between LR and HR covariances. This method is used for interpolation of grayscale images and reconstructing color images.

2.2 VARIOUS ENHANCEMENT TECHNIQUES

Sub regions Histogram equalization (SRHE) is presented by [26]. This method improves the texture of an image. This improvement is done by changing the intensity level of the pixels. The changing is done based on the distribution of the intensity over the input image. The method divides the image based on the smoothed intensity values. Gaussian filter gives the smooth area of image. It also considers the intensity values of the neighbor pixels. Experimental result shows

that the proposed method sharpens the image.

Edge directed algorithms focus on removing artifacts from edges and paying no attention towards the smoother regions. In this paper [12] author propose an approach where edges are reconstructed but also image details are also recovered. In this approach, learning based details are combined with edge directed algorithm in a single framework. . In this approach, first edges are reconstructed in the LR input image. Than we add these details with the missing details of example image. Than learning based SR is performed. The implementation results shows that our approach has better performance than the edge directed approach as the output image is irregular in edge directed algorithms whereas it gives an image having regular texture. In [17],

there is a method of creating the dictionaries of low and high resolution patches using example images so that these dictionaries perfectly fit the training set (there is a sparse association between LR patch and HR patch). In this algorithm, first produce the sparse coding matrix using the present dictionary and then updating the dictionary atoms with the help of sparse representations. This algorithm overcomes the problem of creating and using over complete dictionary. This algorithm runs with any type of matching pursuit. The k-

nearest neighbor method given by [21] is very simple. It find out the closest pixel value to the specify input pixel. After that it gives that value to the output pixel. This method does not find out new pixel values. It just copies the already present values as it does not change the values.

In [15], Jianchao Yang et al, proposed sparse representation method for improving the resolution of an image and removing the noise. Two dictionaries are prepared from examples. Dictionaries are prepared using k-SVD algorithm (this algorithm is already explained). It involves sparse association between the HR patch and LR patch. The basic idea behind this method is to show an input vector as a weighted linear combination of small number of basis atoms. It is performed in two parts- First, training of dictionaries is done. In first phase, two dictionaries are trained. One dictionary for LR patches and one for HR patches by using example images. Then, reconstruction of HR image is performed. In reconstruction phase, the method chooses patch from the low resolution dictionary that best represent the LR patch. This algorithm depends on sparse association between image patches. The experimental result show great results in robustness to image corruption. Its performance is much better than all other SRs method like interpolation and k-nearest neighbor method because it reduces the noise and blurriness effect as

well as PSNR values of images enhanced using ScSR is greater than other conventional techniques. In [24]

Dinh-Hoan and Jean-Marie Rocchisani proposed a method sparse weighted super resolution(SWSR) and compare it with sparse coding nearest neighbor methods. The basic idea behind of this method is to show an input vector as a non-negative weighted linear combination of small number of basis atoms whereas ScSR deals with both negative and non-negative weighted linear combination. If there is negative average weight, a penalty is added. K-neighbor does not deal with noise whereas ScSR deals with only large amount of noise. SRSW deals with any amount of noise.

In [25], a new method is proposed for improving the resolution of a grayscale image. First we input the grey scale image. The LR image is interpolated using Lancos interpolation. Then we extract the features from interpolated image. Features are extracted using Lancos and Gradient filter. The PCA is used get the most efficient information of feature extraction. Dictionary is trained using k-SVD algorithm. The database used consists of images with both HR and LR version. If the size of LR images is not same as that of the HR images, we use Lancos interpolation to get the same size. We divide the image to get the block of 5*5 and the blocks are non-overlapping. Every column of block is concatenated column by column to form a vector. Than we use the “k-SVD method” to train the dictionaries. We train two dictionaries, one with LR blocks and second with HR blocks. Finally, we get both the dictionaries D_l (dictionary with LR blocks) and D_h (dictionary with HR blocks).The previous dictionary of LR blocks D_l and ScSR are used to find the sparse representation. Than the sparse representation is reconstructed using the previous value and HR dictionary D_h . At last we get the HR image.

Due to the advancement in the technologies such as 3-D imaging, the demand for HR depth images is increasing. All the traditional methods of depth super resolution reconstructs HR images by retrieving details of the image either internally from HR image or externally from the database of HR images. Therefore, H. Zheng, A. Bouzerdoun, and S. L. Phung all mutually proposed a new method [29]. This new method exploits the both internal and external HR information to obtain high resolute images. This new joint regularization method formed with different constraints, allows solving HR image and sparse code simultaneously.

Today many applications require the images with high contrast and sharpness. Therefore Guang Deng presented a generalized unsharp masking algorithm [28]. The designed algorithm

confronts the three issues: increasing the contrast and also sharpness by the residual, how to reduce halo effect with the means of an edge-preserving filter, and to solve the out-of-range problem using log-ratio and tangent operations. The properties of log-ratio approach eliminate rescaling process. In the proposed algorithm, there is availability to adjust two parameters controlling the contrast and sharpness to get the desired results.

A new scaling algorithm of super resolution is introduced in [33]. In this obtained HR image depicts more accurate details of edges. With this algorithm we can enlarge a given image to any size without uneven surface or blurring factors. Four steps are performed in the scaling process: firstly edge orientation is calculated, and then average is computed for the edge orientation, the third one is detection of edge patterns, and lastly interpolation. These all are pipelined to obtain efficient implementation. The performance is evaluated on the basis of SSIM index (Structural Similarity).

Zhaowen Wang, Ding Liu et al. discussed sparse coding model which is applied to enhance the resolution of an image is extended to improve performance of SR using key concepts of deep learning [38]. On the basis of LISTA (Learned Iterative Shrinkage and Thresholding Algorithm) network, a neural network is implemented for every step of sparse coding processing. Training is provided to the sparse coding components through back propagation. Back propagation trains the network on the basis of gradient descent.

Trinh, Luong, Dibos et al. has jointly put forward a novel example-based method [39]. They proposed the method for noise removal and to increase the pixel density of medical images. In this method, resolution is improved by using database of HR and LR patches. Their main objective is estimation of HR images from a single noisy LR image. The non-negative sparse representation is used for the estimation of input patch. Both Denoising and SR are performed on each patch. The nonnegative sparse linear representation can be found for the input taken as a nonnegative quadratic equation.

The MRI (magnetic resonance imaging) systems are affected from poor out-of-plane resolution. Post-acquisition, SR filtering is a feasible and less expensive approach. A.Souza and R.Senn introduce a new SR framework [40]. This technique is implemented to improve resolution of tissues and contrast of acquired 3D MR images. The framework models the acquired information on the basis of thickness of slice and space in between slices. The available

SR techniques have not considered the type of acquisition information that is sampling the data. This framework shows better results than existing method in the field of artificial data and MRI data of clinical knee.

Mingli Zhang et al. put forward a novel based SR algorithm [41]. This method exploits the sparse representation and nonnative similarity of patches. From this method, HR images are obtained from a technique based on ADMM (Alternating direction method of multipliers). To remove noise and artifacts from the reconstructed image an approach called back-propagation is used. Experimental results are calculated in terms of PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structured Similarity Index).

CHAPTER-3

PROBLEM STATEMENT

3.1 GAPS IN STUDIES

Most of the SR methods usually introduce over-shoots and under-shoots in the areas of sharp edges. The main need for SR algorithms is to enhance the LR image details. Filters add noise and do not give smooth image. There are many algorithms which we use to enhance the image quality. Some algorithms do not deal with the edges. The edges are the most sensitive part of the image, as the pixel value at edge is high than other neighbour pixel value. Some algorithms focus only on edges leaving rest of the image as it is which makes the image irregular. Even

interpolation used for increasing the resolution of the image does not focus on high frequency edges resulting in irregular image.

3.2 PROBLEM STATEMENT

HR images are useful in various fields. HR images are useful as it has high pixel density; it gives more clear view of image. Enhanced medical images are useful for critical examination of any body part to detect any disease and in astronomy we get information about space.

HR imaging is not always available. Sensors can be used to increase the resolution of the image. As the sensors increases, the resolution of the image also increases which result in high hardware cost. They also add physical artifacts (noise or blur) to the image. Due to these limitations, there is need of SR techniques.

Even after the arrival of various imaging sources, it is not easy task to get the image of desired resolution. This is due to the physical imaging environment and factors that decrease the quality (noise and blur). These sources give blurred and irregular image. The only solution is SR techniques that help in increasing resolution of the image.

Various interpolation methods are used to upscale the image and enhance the resolution of the image. But it gives blurred up scaled image as output. So, interpolation is not efficient method for SR.

Filters are also used to improve low frequency pixels and finding high frequency details to improve the resolution of the image. But the filters add noise in the image which gives a rough image as output.

There are many algorithms which we use for enhancing the image quality. Some algorithms do not deal with the edges. The edges are the most sensitive part of the image, as the pixel value at edge is high than other neighbor pixel value. Some algorithms focus only on edges leaving rest of the image as it is which makes the image irregular.

3.3 OBJECTIVE

The objectives of thesis are:

- (i) To achieve image super resolution by using sparse representation and interpolation.
- (ii) To achieve image resolution enhancement by using Laplace and Gradient filters.

(iii) To compare the performance of these techniques in terms of SSIM, PSNR, and visual quality with existing ones.

3.4 METHODOLOGY

The research method used in this thesis is a combination of approaches with the beneficiaries of the study prior to the design of the output product with the experimental results to follow. First method uses Bicubic interpolation to get better initial approximation. Then the Laplace and Gradient filters are applied on the interpolated image. After this, we divide the image into various non-overlapping blocks. Finally, sparse representation is performed on each block to get HR image.

CHAPTER-4

PROPOSED METHOD: SR OF COLOR IMAGE

4.1 INTRODUCTION

Image Super-Resolution is the active field of image processing. Images and videos with high resolution are used in various fields like medicine, agriculture, pattern recognition etc. Even after the arrival of various imaging sources, it is not easy task to get the image of desired resolution. But they are not very effective as they add physical artifacts (noise or blur). There are various algorithms of image super resolution. Some algorithms do not consider the edges as the edges are most sensitive part of image. Some mainly focus on the edges leaving other part of image as it is. Conventional methods such as nearest neighbor and bilinear interpolation may produce false information. They also give blurred images because they do not use any

information related to edges in the original image. Therefore we propose a method to enhance the resolution of the image. The result of the proposed method is compared with other methods (Table 5.1).

4.2 PROPOSED WORK

As there is a great demand of HR images, we proposed a method for the resolution enhancement of LR images. We design a framework which involves following steps: First interpolation is done using the Bicubic method. Then extracting important details of the image using the filters. We image is divided into various non-overlapping blocks and sparse representation method is performed on each block. Finally we reconstruct our HR image. All these steps are explained below. The block diagram of our proposed algorithm is shown below (Fig 4.2.1). The proposed SR method first use interpolation for providing a better initial approximation. After that we use sparse representation which uses two trained dictionaries for enhancing the resolution of the images.

We proposed a method in which we combine both sparse representation method and Bicubic interpolation. This method is proposed for the SR of a color image. It involves five steps:

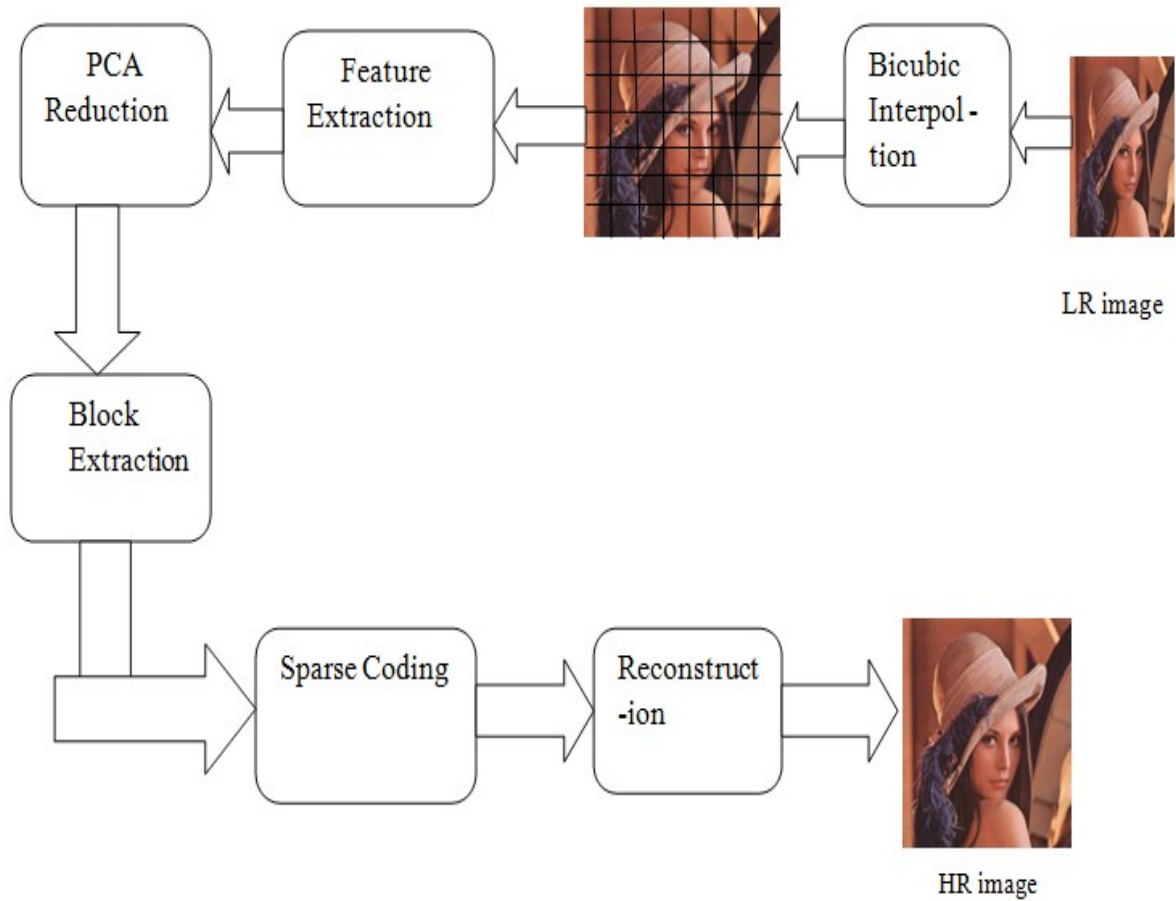


Fig 4.1 Block diagram of proposed work

Step1: First, we input the color image Y . The LR image is interpolated using Bicubic interpolation. Bicubic interpolation is the improved version of cubic convolution interpolation method. Two dimensional cubic interpolations are performed easily by one dimensional interpolation on each direction. The interpolated image is represented as X_i . Interpolation involves up-scaling the image or resizing the image by finding out the pixel values that are unknown and lies within the sample. In Bicubic interpolation, LR image is upscale up to the mention up scaling factor (factor 2). The LR image is shown in Fig 4.2 and image after Bicubic interpolation is shown in Fig 4.3.



Fig 4.2 LR Input Image



Fig 4.3 Image after Bicubic interpolation

Up scaling of image is done from LR image (Fig 4.2) by Bicubic interpolation.

Step2: After interpolation, the features are extracted from the interpolated image. Features are extracted using Laplace and Gradient filters. An image gradient is defined as the directional change in the intensity (color) of the image. Gradient filter is used for calculating change in intensity for detecting edges of the image. Laplace is a sharpening filter which allows high frequency pixels to pass and improve the low frequency pixels from the image. Feature Extraction involves extraction of important details of image. Then, features are extracted from X_i using the Gradient and the Laplacian filters, which are defined as follows:

$$G=[10-1] \quad (4.1)$$

Where G is the one dimensional Gradient filter

$$L=[10-201] \quad (4.2)$$

Where L is one dimensional Laplacian filter

Applying the G , G^T (transpose of G), L and L^T (transpose of L) to the X_i image via convolution operation. Convolution is the process in which we perform multiplication on input image and the image obtained by applying filters. We multiply the image matrix (containing the pixel values with G , G^T , L , L^T). We get four different images which give us the details of the edges. After this, we use PCA.

$$X1 = G * X_i \quad (4.4)$$

We get the intensity and edges details in horizontal direction by applying the gradient filter to the image X_i using convolution operator.

$$X2 = G^T * X_i \quad (4.5)$$

We get the intensity and edges details in vertical direction by applying the gradient filter to the image X_i to the image X using convolution operator.

$$X3 = L * X_i \quad (4.6)$$

We apply the Laplace filter and get the high frequency pixel details of horizontal direction of X_i image

$$X4 = L^T * X_i \quad (4.7)$$

We apply the Laplace filter and get the high frequency pixel details of vertical direction of X_i image.

In these way, we get four images having important details using Laplace and Gradient filters in vertical and horizontal direction.

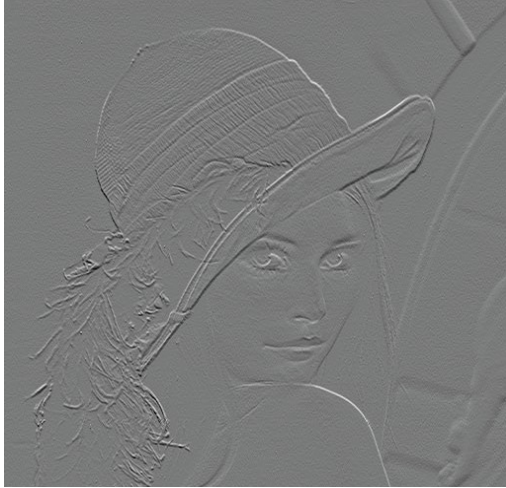


Fig 4.4 X1 image



Fig 4.5 X2 image

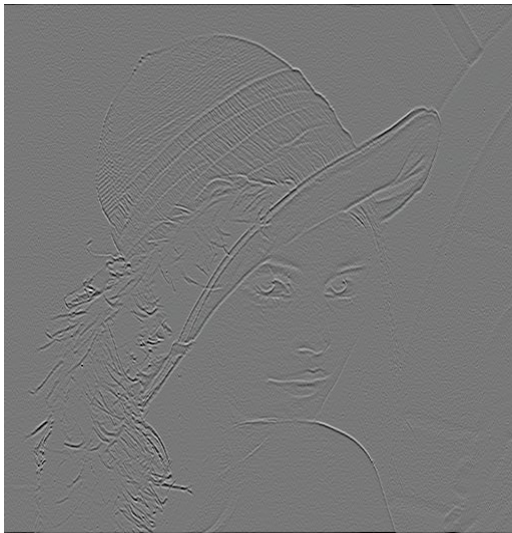


Fig 4.6 X3 image

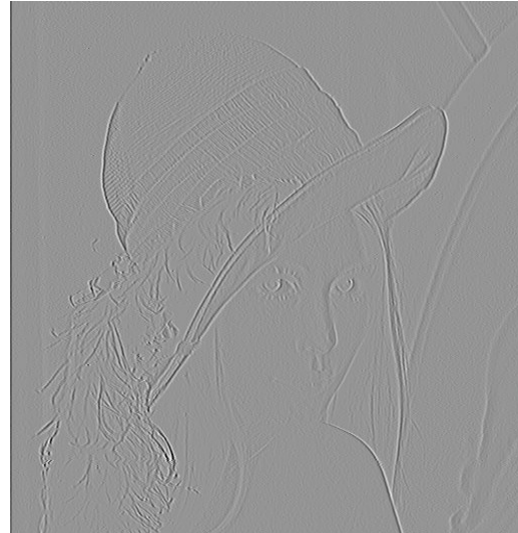


Fig 4.7 X4 image

In these images, important details are extracted with Laplace and Gradient filters.

Step3: To get the most important information of the feature extraction, we use PCA. PCA stands for principle component analysis which helps in dimension reduction of images in image processing. It takes the important details from the four images and compressed the important details into one image. The PCA is used get the most efficient information of feature extraction. Four images are reduced to one image by this PCA. The resultant image is X^R .

- Consider X as the dataset consisting of samples ignoring the class labels.

$$X = [X_1 \ X_2 \ X_3 \ X_4]; \quad (4.8)$$

- Find the mean vector.

$$x = \sum x_i / n \quad (4.9)$$

Where x is the mean of observations, $\sum x_i$ is the sum of all observations, and n is the number of observations.

- Find the covariance matrix.

$$\text{cov}(X, Y) = \sum \frac{(x_i - x)(y_i - y)}{n}$$

(4.10)

- Compute eigenvectors $[ee_1, ee_2, \dots, ee_d]$ and Eigen values $[\lambda_1, \lambda_2, \dots, \lambda_d]$.
- Sort the eigenvectors and choose eigenvectors with the largest Eigen values.
- Use this eigenvector matrix to transform the samples onto the new subspace.

Step4: Then, we divide the image X_I^R into 5×5 non overlapping blocks. We use the extractor operator E to extract each non-overlapping block at position p . E is operator which divides the image into smaller non overlapping-blocks. Image is divided into smaller blocks to perform sparse coding (in sparse coding we divide the image into smaller blocks for performing SR on each block)

$$B_p^I = E_p X_I^R \quad (4.11)$$

B_p^I is the block obtained at position p of image X_I^R .

The image X_l is also divided in non-overlapping blocks by using the operator E .

$$BI_p^l = E_p X_l \quad (4.12)$$

BI_p^l is the block obtained at position p of image X_l .

Step5: Two Dictionaries are trained using k-SVD algorithm D_l and D_h . For dictionary preparation, we use database containing 60 example images. We need two dictionaries for performing sparse coding algorithm. ScSR is an example based algorithm and these algorithms first train the example images and by using the trained example images convert the required image into HR version. The database used for dictionary construction consists of example images with both HR and LR version. Three images used in database are given below:



Fig 4.8 Training image 1



Fig 4.9 Training image 2



Fig 4.10 Training Image 3



Fig 4.11 Training image 3

We train two dictionaries D_l (containing LR blocks) and D_h (having HR block). Then, sparse representation algorithm is performed using D_l and D_h .

First, we find the low resolution patch from dictionary D_l which is similar with the B_p^l patch .

$$B_p^l = D_l * \alpha_p \quad (4.13)$$

α_p is the sparse representation vector which tells about the mismatch between B_p^l and the D_l . By using the above equation we find out the value of α_p .

By using the α_p value , we find out B_p^s which is resultant block of enhanced image.

$$B_p^s = D_h * \alpha_p \quad (4.14)$$

In this way, we perform sparse coding super resolution on all blocks and find out enhanced image blocks.

Step6: At last, the HR image is reconstructed. By adding the B_p^s (enhanced blocks we get using sparse representation method) and B_l^l (extract blocks from Bicubic image X_l), we get our final image.

$$B_p^H = B_p^S + BI_p^I \quad (4.15)$$

CHAPTER 5

IMPLEMENTATION AND TESTING

The implementation of the proposed algorithm is done in Matlab. Matlab is a high level language. It is very easy than other programming languages like C,C++,Python. It performs various tasks faster than various conventional languages.

5.1 PERFORMANCE EVALUATION

We check the performance of our algorithm by measuring PSNR and SSIM value. PSNR stands for peek signal to noise ratio. It is maximum possible noise amount removed and improvement in image reconstruction.

$$PSNR = 10 * \log_{10}(MAX_I) - 10 * \log_{10}(MSE) \quad (5.1)$$

Where MAX_I is the maximum power pixel value of the image and MSE is the mean square error.

SSIM stands for structured similarity of index. It is a method for predicting the perceived quality of images or videos. It is used to check the similarity between two images.

$$SSIM(x,y)=\frac{(2u_xu_y+c_1)(2\sigma_{xy}+c_2)}{(u_x^2+u_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \quad (5.2)$$

Where u_y the average of $\{y\}_x$;

u_x the average of y ;

σ_x^2 the variance of x ;

σ_y^2 the variance of y ;

σ_{xy} the covariance of

x and y .

We applied the proposed algorithm on various images and compared its performance with other conventional methods. Performance is calculated using PSNR and SSIM value.



Fig 5.1 Input girl image



Fig 5.2 HR by proposed method

We applied our algorithm on girl image Fig 5.1 and its output is shown in Fig 5.2



Fig 5.3 Input butterfly image



Fig 5.4 HR by proposed method

LR Fig 5.3 input Butterfly image and its HR version Fig 5.4

We applied our algorithm on various images. The results of five images: Butterfly image, Home image, Lena image, Girl image, Dog image (Fig 5.1,5.3,5.5,5.6,5.7) are shown in Table 5.1. The results of all these images are consistently better than the modern existing algorithms



Fig 5.5 Dog image

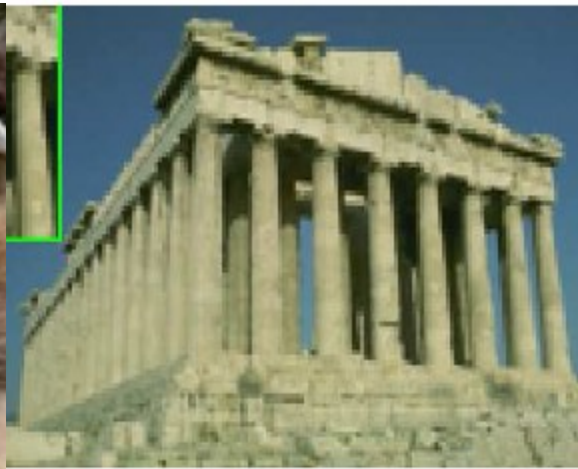


Fig 5.6 Home image

Proposed algorithm is also applied on these two images.

	Images	Sparse Representation	PSNR for proposed algorithm
1	Lena image	33.64	34.25
2	Girl image	28.02	28.16
3	Dog image	33.04	33.13
4	Home image	29.01	30.11
5	Butterfly image	30.96	31.10

Table 5.1: PSNR results of proposed algorithm for various images

5.2 COMPARATIVE ANALYSIS

Proposed algorithm is compared with Bicubic interpolation and Lanczos interpolation. The comparison on the basis of PSNR and SSIM values in table 5.2 and 5.3.

	Technique	PSNR value of Lena Image
1	Bicubic Interpolation	32.79
2	Lanczos interpolation	33.27
3	Sparse Representation	33.64
4	Proposed (1 atom)	33.65
5	Proposed (2 atom)	33.74
6	Proposed (3 atom)	34.25

Table 5.2: PSNR results for image super resolution

	Technique	SSIM value of Lena Image
1	Bicubic Interpolation	0.854
2	Lancoz interpolation	0.860
3	Sparse Representation	0.874
4	Proposed (1 atom)	0.874
5	Proposed (2 atom)	0.876
6	Proposed (3 atom)	0.889

Table 5.3: SSIM results for image super resolution

The performance of proposed algorithm is better than Lancoz and Bicubic interpolation on the basis of PSNR value and SSIM value. The image obtained in Bicubic interpolation is blurred as compared to proposed algorithm's image. The image we get is clearer than the Lancoz and Bicubic interpolation images as shown in the below figures:



Fig 5.7 LR Input Image



Fig 5.8 Bicubic interpolation



Fig 5.9 Lanczos Interpolation



Fig 5.10 Sparse Representation



Fig 5.11 Proposed algorithm

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

There is great need of HR images in various fields. The resolution of image can be enhanced by using more number of sensors. As the sensor increases the hardware cost also increases. It also adds noise in the images. So, this problem gives us to design an algorithm to increase the spatial resolution of the image. There are many methods for increasing resolution of images but still their results can be further improved.

In this paper, a resolution-enhancement technique based on sparse representation has been proposed. In comparison with other resolution-enhancement methods (Bicubic interpolation and Lancos interpolation), experiment results show better performance. The performance is calculated and comparison with other methods is done by PSNR and SSIM values. The suggested method provides good results.

The contributions of the proposed method that has given the better experiment results in comparison with other methods are as follows:

- The proposed SR method employs Bicubic interpolation, which provides a better initial approximation.
- The proposed algorithm also used filters for extracting important details of the image like high frequency edges.
- After this, it uses sparse representation to increase the resolution of the images. Two trained dictionaries are used for sparse representation.
- The time values of the proposed SR method are much less than other similar methods can obtain.

6.2 SCOPE FOR FURTHER RESEARCH

This thesis has given various opportunities for future research. This proposed can be extended to videos. This can be improved by using parallel processing to increase speed in acceleration. Further, parallel processing implementation can be achieved by using GPU hardware. This method is further used in color videos.

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VIDEO LINK

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List Of Publications

- [1] Dimple Mittal, and Husanbir Singh Pannu, “*Enhancement of Image Resolution: A Survey*”, Communications on Applied Electronics, June 2016.[Accepted]
- [2] Dimple Mittal, and Husanbir Singh Pannu, “Super Resolution Of Color Image”, 5th International Conference on Advances in Computing, Communications and Informatics, June 2016.[Communicated]

