Single Leaf Image Super Resolution using NEDI Technique and Improved by PSO Algorithm

Antim Patel[1] Kishori Shekokar[2]
[2]HOD
[1]Department of Master of Computer Engineering [2]Department of Computer Engineering
[1]Navsari, Gujarat, India [2]Sigma Institute of Engineering, Bakrol, Vadodara

Abstract— The concept of superresolution is for increasing the input image resolution. The paper focuses to study the iterative curvature based methods on single diseased leaf image having low resolution. For agricultural countries like India, Crop plays a vital role in country's economic growth. Plants gets viral, bacterial or fungal diseases which have a significant reduction quantity as well as quality of agricultural products. The traditional approach of expert's naked eye observation is time consuming. For this leaf identification system, leaf diseases detection system, plant diseases diagnosis system are developed which demands high resolution leaf images as input for better recognition rate. The use of superresolution technique which is related in both with the statistical relationship between high resolution output and low resolution input images and with the human perception of image quality can be considered as cheapest solution. However superresolution algorithms are being affected by artifacts such as over smoothed, jaggies, blurred or over sharped. The paper has described NEDI: New Edge Detection Interpolation with PSO Algorithm which outputs the superresolved image for a single leaf image with less memory requirement then NEDI or FCBI: Fast Curvature Based Interpolation. Fine edges in SR images are preserved without applying complex mathematical algorithms based on wavelet, fast curvelet etc. The concept can be useful for agricultural expert to help farmers for exact leaf disease detection and further accurate remedial actions for the same. The experimental result shows the best visible result of an infected leaf along with statistical comparing parameters: Mean Square Root (MSE) and Peak Signal to Noise Ratio (PSNR).

Key words: Mean Square Root (MSE) and Peak Signal to Noise Ratio (PSNR)

I. Introduction

For better performance in image analysis, a common need arises of high resolution. High pixel density is offered by high resolution image and thereby the image has more details then the original image.

The central aim of Super-Resolution (SR) is to generate a higher resolution image from lower resolution images. High resolution image offers a high pixel density and thereby more details about the original scene. The need for high resolution is common in computer vision applications for better performance in pattern recognition and analysis of images. High resolution is of importance in medical imaging for diagnosis. Many applications require zooming of a specific area of interest in the image wherein high resolution becomes essential, e.g. surveillance, forensic and satellite imaging applications.

However, high resolution images are not always available. This is since the setup for high resolution imaging proves expensive and also it may not always be feasible due to the inherent limitations of the sensor, optics manufacturing technology. These problems can be overcome through the use of image processing algorithms, which are relatively inexpensive, giving rise to concept of super-resolution. It provides an advantage as it may cost less and the existing low resolution imaging systems can still be utilized.

Super-resolution is based on the idea that a combination of low resolution (noisy) sequence of images of a scene can be used to generate a high resolution image or image sequence. Thus it attempts to reconstruct the original scene image with high resolution given a set of observed images at lower resolution.

The general approach considers the low resolution images as resulting from resampling of a high resolution image. The goal is then to recover the high resolution image which when resampled based on the input images and the imaging model, will produce the low resolution observed images. Thus the accuracy of imaging model is vital for super-resolution and an incorrect modeling, say of motion, can actually degrade the image further.

The observed images could be taken from one or multiple cameras or could be frames of a video sequence. These images need to be mapped to a common reference frame. This process is registration. The super-resolution procedure can then be applied to a region of interest in the aligned composite image. The key to successful super-resolution consists of accurate alignment i.e. registration and formulation of an appropriate forward image model. The figure 1 below shows the stages in super-resolution process.

II. Literature Review

A. *Super Resolution Techniques*

As per the super resolution imaging analysis is concerned, there are two main domains i.e. Frequency domain and spatial domain approach for image registration. In our case, the results of the spatial domain are very much better in visual quality as well as in analytical parameter also than the frequency domain, which typically failed to adequately register images. By the nature of frequency domain, Fourier transform methods are limited to only global motion models. In the early stages, most of the research work is carried out under frequency domain approach but as more general degradation models were considered; later research has tended to concentrate almost exclusively on spatial domain formulations.

Basically, image super resolution can be obtained in two categories- Non-adaptive SR & Adaptive SR in spatial domain approach.

1) *Non-adaptive Image SR*

Non-adaptive image SR techniques are based on direct manipulation on pixels instead of considering any feature or content of an image. These techniques follow the same pattern for all pixels and are easy to perform and have less calculation cost. Various non-adaptive techniques are nearest neighbour. bilinear and bicubic. But these techniques having some drawbacks such as problems of blurring of edges or artifacts around edges. It stores only low frequency component of an original leaf image also produces blurry images quality. Mainly it misses the required information from super resolved infected leaf image. To overcome these, we approached for Adaptive Image SR for our agricultural information for more accuracy.

2) Adaptive Image SR

This technique considers image features like intensity value, edges as well as texture information. It also provides better visual image quality result as it preserves high frequency components from an original infected leaf image, so it is much easier for detection and classification accuracy. Various adaptive SR techniques are NEDI, DDT, FCBI, Learning based approach. Only main drawback is it requires much more computational time. So, here, we have worked over this problem while maintaining the SR quality of an infected leaf image. So, as far as infected leaf image problems are concerned, adaptive image SR approach is much better in practice and advantageous. Machine learning based detection and recognition of plant diseases can provide clues to identify and treat the diseases in its early stages. Comparatively, visually identifying plant diseases is expensive, inefficient, and difficult. Also, it requires the expertise of trained botanist. There are several methods for measuring leaf area, however, in practice, it is used mainly three: the human evaluation, the method of leaf dimensions and the methods which use devices such as plan meter and area integrator. Nevertheless, these methods require extensive work and are time-consuming. Moreover, they have some degree of inaccuracy. And, the measurement techniques are not performed in the most cases by a farmer, but by an expert (agronomist), which delays the diagnosis. With the advances in computing, especially in the graphics processing, it is possible to develop alternative methods for determining the damaged leaf area. Plant diseases have turned into a dilemma as it can cause significant reduction in both quality and quantity of agricultural products.

B. Fast Curvature Based Interpolation (FCBI)

The method is similar to the Data Dependent Triangulation, but instead of obtaining the new pixel values by averaging the two opposite neighbours with lower difference, we compute second order derivatives in the two diagonal directions and interpolate the two opposite neighbours in the direction where the derivative is lower. In detail, if we consider the first interpolation step, we compute the local approximation of the second order derivative I_{11} and I_{22} along the two diagonal directions using a 12 pixel neighbourhood.

In second technique, the energy term is sum of the curvature continuity, curvature enhancement and isolevels curves .First we compute, for each new pixel, the energy function U(2i+l; 2j+l) and the two modified energies U+(2i+l;2j+l) and U-(2i+l;2j+l), i.e. the energy values obtained by adding or subtracting a fixed value called threshold value to the local pixel value 1(2i+l;2 j+l) [14] and assign this intensity value to pixel. This procedure is iteratively repeated until the sum of the modified pixels at the current iteration is lower than a fixed threshold value.

C. FCBI Algorithm Steps

1) Steps for FCBI technique are as follows

Step 1: Put original pixels in the enlarged grid at locations 2i, 2j.

Step 2: Insert pixels at locations 2i+l, 2j+l with the FCB! Method.

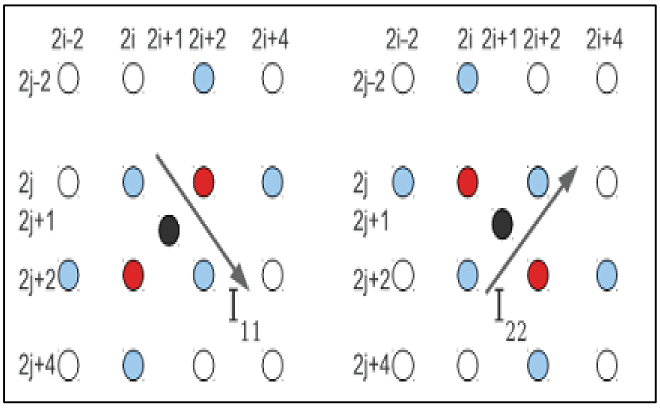


Fig. 1: The average of the two neighbors in the direction of lowest second order derivative (I_{11}or I_{22})

Step 3: Apply iterative correction until the image variation is above a given threshold.

Step 4: Insert pixels in the remaining locations with the FCB! Method.

Step 5: Apply iterative correction to the added pixels.

Step 6: Repeat the whole procedure on the new image for further enlargements.

D. New Edge-Directed Interpolation

NEDI technique is a combined approach of bilinear interpolation and covariance based adaptive interpolation. In linear interpolation techniques have blurred edges and artifacts. Mainly two purposes to introduce NEDI technique: first is to produce better visual quality then linear interpolation techniques (Bilinear and Bicubic) and second is to reduce the computational complexity of covariance based adaptive interpolation technique. Same grid shown in fig. 1 is used here also.

1) Algorithm Steps

Step 1: Calculate linear interpolation coefficient.

$\acute{\alpha} = R\_1\ \acute{r}$…………………………………(1)

Where R, r are local covariance

Step 2: Calculate HR covariance from LR image.

$\acute{\alpha} = (CTC)\_1(CT\acute{y})$ ………………………..(2)

Where y: data vector and C:data matrix

Step 3: Replace value of covariance.

$\acute{Y}_{2i+1,2j+1} = \sum_{k=0}^{1} j \sum_{l=0}^{1} \alpha_{2k} + lY2(i+k), 2(j+l)$…....(3)

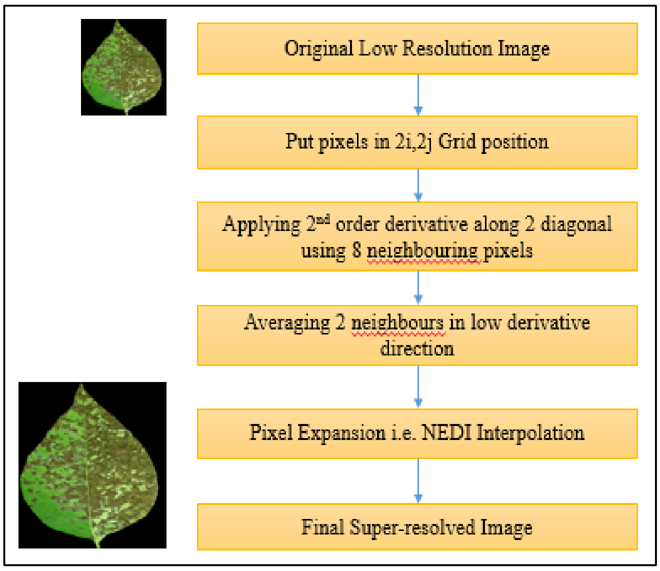


Fig. 2: Proposed NEDI Technique Workflow

E. Plant Diseases Analysis and Its Symptoms

The RGB image feature pixel counting techniques is extensively applied to agricultural science. Image analysis can be applied for the following purposes [3]:

- To detect plant leaf, stem, and fruit diseases.
- To quantify affected area by disease.
- To find the boundaries of the affected area.
- To determine the colour of the affected area
- To determine size & shape of fruits.

1) Bacterial Disease Symptoms

The disease is characterized by tiny pale green spots which soon come into view as water- soaked. The lesions enlarge and then appear as dry dead spots as shown in figure 3(a), e.g. bacterial leaf spot have brown or black water-soaked spots on the foliage, sometimes with a yellow halo, generally identical in size. Under dry conditions the spots have a speckled appearance. Infected plants have brown or black water-soaked spots on the foliage, sometimes with a yellow halo, usually uniform in size. The spots enlarge and will run together under wet conditions. Under dry conditions the spots have a speckled appearance. As spots become more numerous, entire leaves may yellow, wither and drop. Members of the Prunus family (stone fruits, including cherry, plum, almond, apricot and peach) are particularly susceptible to bacterial leaf spot. The fruit may appear spotted or have sunken brown areas.

(a)

(b)

(c)

Fig. 3: Leaf disease symptoms. (a) Bacterial disease banyan tree leaf image (b) Fungal disease image (c) Viral disease mug leaf image

2) Viral Disease Symptoms

Among all plant leaf diseases, those caused by viruses are the most difficult to diagnose. Viruses produce no telltale signs that can be readily observed and often easily confused with nutrient deficiencies and herbicide injury. Aphids, leafhoppers, whiteflies and cucumber beetles insects are common carriers of this disease, e.g. Mosaic Virus, Look for yellow or green stripes or spots on foliage, as shown in figure 3(b). Leaves might be wrinkled, curled and growth may be stunted. Pathogen-caused leaf spot diseases, particularly those of stone fruit trees and such vegetables as tomatoes, peppers, and lettuce are of two types, those caused by bacteria and those caused by fungus. Leaf spotting of either kind is generally similar in appearance and effect. Prevention and treatment of both kinds often involve the same practices.

3) Fungal Disease Symptoms

Among all plant leaf diseases, those caused by fungus some of them are discussed below and shown in figure 3(c), e.g. Late blight caused by the fungus Phytophthora. It first appears on lower, older leaves like water-soaked, gray-green spots. When fungal disease matures, these spots darken and then white fungal growth forms on the undersides. Early blight is caused by the fungus Alternaria solani. It first appears on the lower, older leaves like small brown spots with concentric rings that form a bull"s eye pattern. When disease matures, it spreads outward on the leaf surface causing it to turn yellow. In downy mildew yellow to white patches on the upper surface. These areas are covered with white to greyish on the undersides as shown in figure 1(c).

III. PROPOSED SYSTEM

Existing system is based on ICBI and FCBI, while proposed system is based on ICBI and NEDI pixel expansion. Here pixel is taken and fitted in the grid at a particular location. Neighbors are considered to generate the new pixel. Two diagonal directions are considered and one which is having lower order is chosen. Chosen diagonal is taken to generate new pixel. This procedure is repeated for next pixel until the desired resolution is not obtained. Proposd work focuses on implementing an image superresolution method that will provide high resolution image for given low resolution image for leaf for agricultural application. However it is observed that the output HR image is blurred because of over pixelization or is over sharped. To avoid such noise in the super resolved final image the proposed system is focusing on PSO algorithm[5].The proposed work implements the PSO algorithm that is used to improve the results of NEDI technique. PSO algorithm is considering the each pixel from image as a single particle. Proposed method will generate a cost value from super resolved image and threshold value from original image. By comparing the cost with threshold necessary correction will be applied by PSO algorithm. Finally corrected SR image is generated without blurring, over smoothed and over sharped noise.

A. Idea of Improvement

The existing FCBI with ICBI algorithm is replaced by NEDI and ICBI pixel expansion algorithm. As the superresolved images incurred over smoothing or over sharpening noise, proposed approach is using PSO algorithm to overcome the noise.

B. New Edge-Directed Interpolation

This method is already explained in II. Literature review part B. This method is directly used in proposed work.

C. PSO Algorithm

The PSO algorithm was first described by Kennedy and Eberhart in 1996. The basic PSO (BPSO) algorithm begins by scattering a number of “particles” in the function domain space. Each particle is essentially a data structure that keeps track of its current position x and its current velocity v. Additionally, each particle remembers the “best” position it has obtained in the past, denoted. The algorithm maintains a population of particles, where each particle represents a potential solution of the optimization. Each particle is assigned a randomized velocity. The particles are then flown through the problem space.

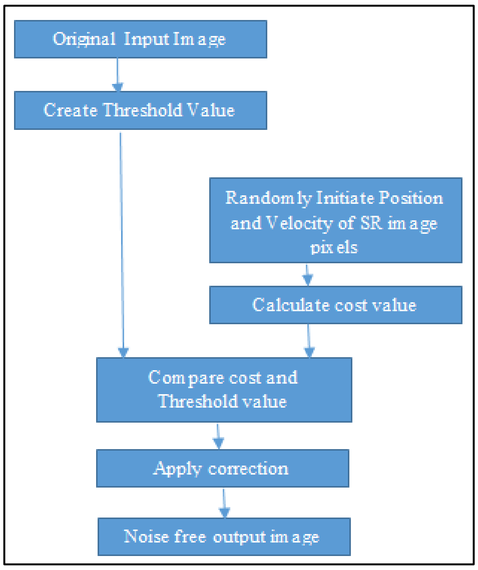


Fig. 4: PSO Algorithm

The aim of PSO is to find the particle position that results in the best evaluation of a given fitness function. Each particle keeps track of the following information in the problem space: xi, the current position of the particle; vi, the current velocity of the particle; and yi, the personal best position of the particle which is the best position that it has achieved so far. This position yields the best fitness value for that particle[6]. The fitness value of this position is called pBest. There is another parameter simulated by PSO, called global best (gBest). For gBest, the best particle is determined from the entire swarm. The best value tracked by the global version of the PSO is the overall best value (gBest), obtained so far by any particle in the population. The PSO changes the velocity of each particle at each time step so that it moves toward its personal best and global best locations.

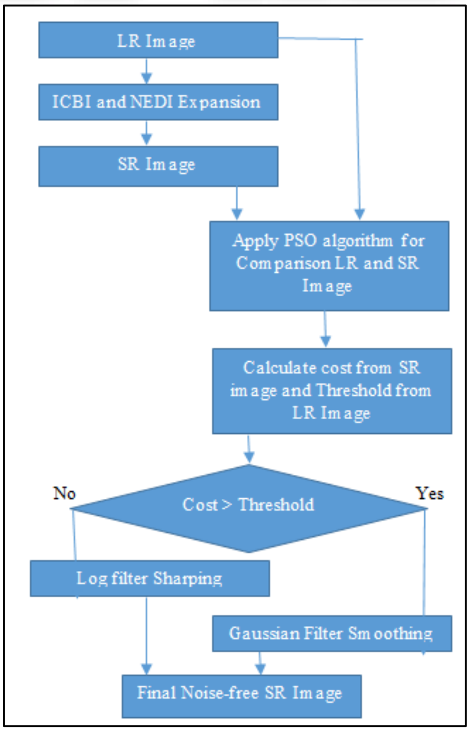


Fig. 5: Proposed System Workflow

IV. EXPERIMENTAL RESULTS

A. *Performance Metrics*

The analytical parameter such as MSE and PSNR can be calculated for comparing the original LR image with the output SR image of considered leaf taken. Other comparative measures are calculated on Proposed work. The parameters gives a magnitude which can be shown graphically for better understanding.

1) 1 Mean Square Error (MSE)

Mean Square Error [1] can be defined as

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(x_{i,j} - x'_{i,j}\right)^2 \quad \text{..................(4)}$$

Where,
$X_{i,j}$: Original input image,
$X'_{i,j}$: SR output image,
MxN: SR image dimensions.

2) 2 Peak Signal to Noise Ratio (PSNR)

PSNR[1] avoids many problem of measuring image quality by scaling the MSE according to the image range. It is defined by the below equation

$$PSNR = 10\log\frac{255^2}{MSE}dB \quad \text{.....................(5)}$$

3) 3 Root Mean Square Error (RMSE)

Root mean square error can be calculated as follow

$$RMSE = \sqrt{MSE} \quad \text{..(6)}$$

4) 4 Structural Similarity (SSIM)

SSIM[33],[34] can be calculated from below equation

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad \text{..(7)}$$

Where,
μ_x: Mean of x.
μ_y : Mean of y.
σ_x^2: Variance of x.
σ_y^2: Variance of y.
σ_{xy}: Covariance of x and y.
$C_1=(k_1L)^2$, $C_2=(k_2L)^2$ two variables to stabilize division with weak denominator where L: dynamic range of pixel values($2^{\text{bits per pixel}}$-1) and k_1=0.01 and k_2=0.03.

5) 5 Improvement Signal to Noise Ratio (ISNR)

ISNR[30] [32] is given by following equation

$$ISNR = 10\log10\left(\frac{\sum\sum(g(x,y)-f(x,y))2}{\sum\sum(f(x,y)-\hat{f}(x,y))^2}\right) \quad \text{.....(8)}$$

Where,
f(x,y): Input image,
g(x,y): Corrupted image,
$\hat{f}(x,y)$: Observed image of original image.

6) 6 Feature SIMilarity (FSIM)

FSIM[31] is calculated as follow

$$FSIM = \left(\frac{\sum_{x\in\Omega}S_L(x).PCm(x)}{\sum_{x\in\Omega}PC_m(x)}\right) \quad \text{....................(9)}$$

Where,
PC_m: Phase congruency,
S_L: Similarity of f(x,y),
f(x,y): Original image,
Ω: Spatial domain of whole image.

B. *Result Analysis*

I have implemented Fast Curvature Based Interpolation with Iterative Curvature Based Interpolation pixel expansion technique along with the New Edge Detection Interpolation with Iterative Curvature Based Interpolation Technique for pixel expansion on Acer laptop having AMD Quad Core processor A8-4500 with Turbo CORE Technology up to 2.80 GHz processor on Windows 8.1 with the help of Matlab 2013a.

Result of FCBI with ICBI is shown in table 1 followed by a graph while the result of NEDI with ICBI techniques id shown in table 2 with a graph. The result of proposed approach is shown in table 3 and graphically also. Finally table 4 shows the comparison of all the mentioned techniques where one can visualize that the proposed work is better than the other systems. Table 5 is showing the comparison for memory requirement for taken LR leaf image with SR leaf image. The proposed work is having better result is shown graphically also. The results are shown graphically for ease of understand. For experiments shown for all methods and proposed work is conducted on same images. However the proposed work is tested on 500 leaf images containing normal leaf image from and following diseased leaf images:

- Bacterial Blight
- Fungal early blight
- Late blight
- Leaf spots
- Sun burn
- Mosaic virus infected leaf
- Powdery mildew
- Leaf mold
- Septoria leaf spot

And many other diseases infected leaf images were taken and successfully tested.

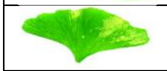
Datasets	PSNR	MSE
	37.1107	12.6474
	36.2376	15.4639
	37.7526	10.9099
	30.7834	54.2924
	35.2592	19.3716

Table 1: FCBI with ICBI Results

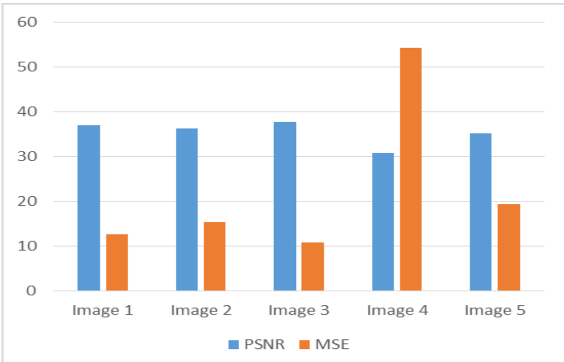


Fig. 6: Graphical Analysis of FCBI with ICBI Technique Results

Datasets	PSNR	RMSE	SSIM	ISNR	FSIM
	43.71	6.58	0.667	21.96	0.850
	45.10	6.08	0.705	23.21	0.789
	41.44	7.65	0.709	20.89	0.789
	37.71	69.48	0.728	16.80	0.818
	41.21	7.78	0.659	20.22	0.834

Table 2: Proposed NEDI with ICBI Results

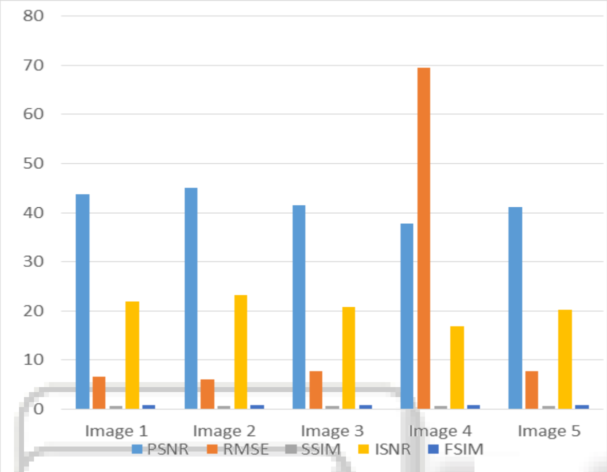


Fig. 7: Graphical Analysis of Proposed NEDI with ICBI Technique Results

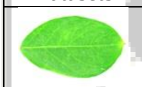
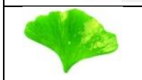
Datasets	PSNR	RMSE	SSIM	ISNR	FSIM
	52.94	3.69	0.869	22.60	0.890
	55.60	3.19	0.836	24.45	0.862
	49.62	4.76	0.897	21.66	0.883
	45.17	7.45	0.895	17.82	0.856
	49.33	4.89	0.894	21.20	0.885

Table 3: Proposed Work Results

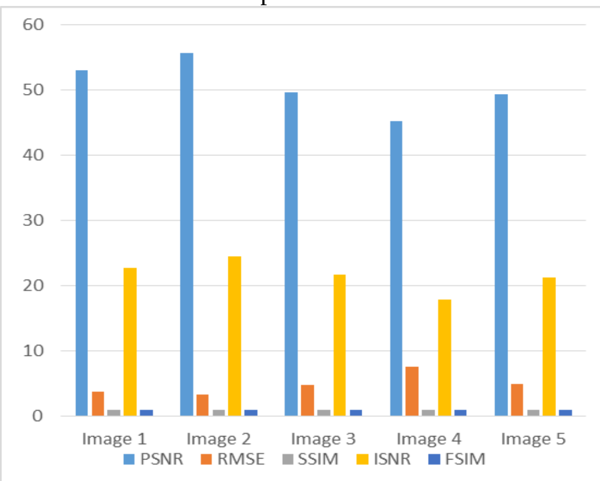


Fig. 8: Graphical Analysis of Proposed Work Results

Datasets	Methods	PSNR	MSE
	FCBI + ICBI	37.1107	12.6474
	NEDI + ICBI	43.7149	17.4417
	Proposed Work	52.9431	10.4417
	FCBI + ICBI	36.2376	15.4639
	NEDI + ICBI	45.1076	12.6568
	Proposed Work	55.6051	5.6568
	FCBI + ICBI	37.7526	10.9099
	NEDI + ICBI	41.4411	29.4422
	Proposed Work	49.6201	22.4422
	FCBI + ICBI	30.7834	54.2924
	NEDI + ICBI	37.7118	69.4857
	Proposed Work	45.1730	62.4857
	FCBI + ICBI	35.2592	19.3716
	NEDI + ICBI	41.2183	30.9918
	Proposed Work	49.3302	23.9916

Table 4: Results Comparison between Proposed Work and Other Systems

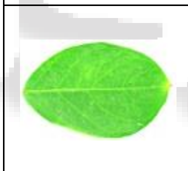
Datasets	Original Memory (kb)	Methods	Super-resolved Memory (kb)
	20.5	FCBI + ICBI	5.17
		NEDI + ICBI	4.90
		Proposed Work	4.90
	18.9	FCBI + ICBI	4.24
		NEDI + ICBI	4.21
		Proposed Work	4.21
	23.2	FCBI + ICBI	6.81
		NEDI + ICBI	6.52
		Proposed Work	6.52
	27.1	FCBI + ICBI	8.96
		NEDI + ICBI	8.77
		Proposed Work	8.77
	22.4	FCBI + ICBI	6.59
		NEDI + ICBI	6.30
		Proposed Work	6.30

Table 5: Results Comparison between Proposed Work and Other Systems for memory requirement

V. CONCLUSION

Plants are economical important for agricultural countries like India which is affected normally by bacterial, viral or fungal diseases that appears on leaf and stem. The agricultural application need HR images for their better functioning of detection and classification. The proposed Image Superresolution method will provide high resolution noise-free image of leaf image for agricultural applications. The experimental results proved that the proposed work is better then the NEDI with ICBI Technique and the FCBI with ICBI Technique used previously. The increment in the values of PSNR, SSIM, FSIM, and ISNR while decrement in the values of MSE and RMSE shows that the proposed work is better. Results are also shown graphically also. The proposed work also requires less memory then the previously used techniques however the NEDI with ICBI have same memory requirement as the proposed work because NEDI with ICBI is directly taken in proposed work. The proposed work is very useful for agricultural applications such as leaf identification system, leaf diseases detection system, plant diseases diagnosis system and such others.

REFERENCES

[1] Sanket B. Kasturiwala, S. A. Ladhake," Adaptive Image Superresolution for Agrobased Applicaion", International Conference on Industrial Instrumentation and Control, IEEE-28 May 2015.
[2] Antim Patel, Kishori Shekoker, "A Survey on Adaptive Techniques of Image Superresolution", International Journal of Advance Research and Innovative Ideas in Education, Volume-1, Issue-5, 2015.
[3] K. Sreedhar Reddy, K. Rama Linga Reddy, "Enlargement of image based upon Interpolation Techniques", International Journal of Advanced Research in computer & Communication Engineering, 2013.
[4] G. Rangamma, V. Anuradha, "Computational efficient scheme for Realtime Artifact-Free Image Up-Scaling", International Journal of Scientific Engineering & Technology Research, 2014.
[5] Vaishali Patel, Prof. Kinjal Mistree, "A Review on Different Image Interpolation Techniques for Image Enhancement", International Journal of Emerging Technology and advanced Engineering, Volume-3, Issue-12, December 2013.
[6] Yin Dong yu, Wang Gan Quan, Kuang Ding Bo, "Super-Resolution image reconstruction using Iterative NEDI- based Interpolation", International Symposium Photoelectronic detection and Imaging, july-2013.
[7] Jinyu Chu, Ju Liu, Jianping Qiao, Xiaoling Wang, Yujun Li, "Gradient-based Adaptive Interpolation in Superresolution Image Restoration", International Journal of Computing Applications, 2010.
[8] Xin Li, Michael T. Orchard, "New edge- Directed Interpolation", IEEE Transactions on Image Processing, Vol 10, Number 10, October 2001.
[9] Pradeep Gaidhani, "Super Resolution", from Education Information UK, CVonline.
[10] Sung Cheol Park, Min Kyu Park, Moon Gi Kang, "Super-Resolution Image Reconstruction: A Technical Overview", IEEE Signal Processing Magazine, May 2003.
[11] Vivek Chaudhari, C. Y. Patil, "Disease Detection of Cotton Leaves Using Advanced image Processing",IEEE International Journal of Advanced Computer Research, Volume-4 Number-2 Issue-15 June-2014.
[12] Ratih Kartika Dewi, R. V. Hari Ginardi, "Feature Extraction for Identification of Sugarcane Rust Disease", IEEE International Conference on Information, Communication Technology and System, 2014.
[13] Ms. Kiran R. Gavhale, Prof. Ujwalla Gawande," An Overview of the Research on Plant Leaves Disease detection using Image Processing Techniques", IEEE Journal of Computer Engineering-Jan 2014.
[14] Xiaojing Niu, Meili Wang, Xianqiang Chen, Shihui Guo, Hongming Zhang, Dongjian He, "Image Segmentation Algorithm for Disease Detection of Wheat Leaves", International Conference on Advanced Mechatronic Systems, Kumamoto, Japan, IEEE August 10-12, 2014.
[15] Shanwen Zhang, Chuanlei Zhang, "Orthogonal locally discriminant projection for classification of plant leaf diseases", IEEE Ninth International Conference on Computational Intelligence and SecurityI, 2013.
[16] S. Arivazhagan, R. Newlin shebiah, S. Ananthi, S. Vishnu Varthini, "Detection of unhealthy region of plant leaves and classification of plant leaf diseases using texture features", Department of Eletronics and Communcation Engineering-March 2013.
[17] Ms. Kiran R. Gavhale and Prof. Ujwalla Gawande, "An Overview of the Research on Plant Leaves Disease detection using Image Processing Techniques", IOSR Journal of Computer Engineering-Jan 2014.
[18] Sachin.B.Jadhav, Prof.Dr.Sanjay B Patil, "Grading of Soybean Leaf Disease Based on Segmented Image Using K-means Clustering", International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume-4, Issue-6, January 2015.
[19] Viraj A. Gulhane, Dr. Ajay A. Gurjar, "Detection of Diseases on Cotton Leaves and Its Possible Diagnosis", International Journal of Image Processing, Volume-5, Issue-5, 2011.
[20] Khushal Khairnar , Rahul Dagade, "Disease Detection and Diagnosis on Plant using Image Processing – A Review", International Journal of Computer Applications- 2014.
[21] S. Patil, V. Kumbhar, D. Yadav, N. Ukirade, " Detection of Leaf Diseases by Image Processing", International Journal of Advanced Research in Electronics and Communication Engineering-2015.
[22] Vijai Singh, Varsha, A K Misra, "Detection of unhealthy region of plant leaves using Image Processing and Genetic Algorithm", International Conference on Advances in Computer Engineering and Applications-2015.
[23] Santanu Phadikar and Jaya Sil, "Rice Disease Identification using Pattern Recognition Techniques", Proceedings of 11th International Conference on

Computer and Information Technology, IEEE-Dec 2008.
[24] Dheeb Al Bashish, Malik Braik, and Sulieman Bani-Ahmad, "A Framework for Detection and Classification of Plant leaf and Stem Diseases", International conference on signal and Image Processing, Chennai, India- Feb 2012.
[25] P. Revathi, M. Hemalatha, "Cotton Leaf Spot Diseases Detection Utilizing Feature Selection with Skew Divergence Method", International Journal of Scientific Engineering and Technology-Jan 2014.
[26] Alexey lukin, Andrey S. Krylov, Andrey Nasonov, "Image Interpolation by Super-Resolution", Moscow State of University, Dec-2012.
[27] Wan-Chi Siu, He He, "Single image Super-Resolution using Gaussian Process Regression", International Journal of Electronics and Information Engineering, Dec-2013.
[28] Xin Li, Michael T. Orchard, "New edge- Directed Interpolation", IEEE Transactions on Image Processing, Vol 10, Number 10, October 2001.
[29] Sonali Shejwal, A. M. Deshpande, "Comparative Analysis of Edge based single Image Superresolution", International Journal of Computer Trends and technology, Volume 10, Issue 5, April-2014.
[30] Mohammad Poumahmood, Amin Mohammadpour, Easa narimani, "Estimation of Image corruption Inverse Function and image restoration suing a PSO-Based Algorithm", International Journal of Computer Applications, Volume 13, Number 1, January 2011.
[31] Lin Zhang, Lei Zhang, Xuanqin Mou, David Zhang, "FSIM: Feature Similarity Index for Image quality Assesment", IEEE Transactions for Image Processing, Volume 20, Number 8, August 2011.
[32] Mark R. Banham, Aggelos K. Katsaggelos, "Digital Image Restoration", IEEE Signal Processing Magazine, March 1997.
[33] Zhou Wang, A. C. Bovik, H. R. Shaikh, E. P. Simoncelli, "Image Quality Assessment from Error Visibility to Structural Similarity", IEEE Transaction on Image Processing, April 2004.
[34] Dosselmann, Richard, Xue Dong Yang, "A Comprehensive Assessment of the Structural Similarity Index", Signal, Image and Video Processing, Springer, Volume 5, Issue 1, March 2011.