"Super Resolution Image Reconstruction from Multiple Low Resolution Images"

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FOR THE DEGREE OF

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IN

INFORMATION TECHNOLOGY

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Abstract

In order to improve the resolution of a low resolution image to high resolution image, we used super resolution image reconstruction method which reconstructs a high resolution image using a set of consecutive images with small differences. Those small differences are considered to be rotation, translation and scaling. For this process we have considered image processing techniques like image registration and image reconstruction. Image registration algorithms like Keren and Fourier Mellin Transform. Interpolation is used for image reconstruction.

CANDIDATE’S DECLARATION

We hereby declare that the work presented in this project report entitled “**Super Resolution image reconstruction from multiple low resolution images**”, submitted end-semester report of 5th Semester report of B.Tech. (IT) at Indian Institute of Information Technology, Allahabad, is an authenticated record of our original work carried out from JUL 2019 to SEP 2019 under the guidance of **Prof. Vrijendra Singh**. Due acknowledgements has been made in the text to all other material used. The project was done in full compliance with the requirements and constraints of the prescribed curriculum.

Place: Allahabad
Date: 12-09-2019

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CERTIFICATE

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

Date: 12-09-2019
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1. Introduction

High-resolution (HR) images are useful in many applications such as surveillance video, video frame freezing, medical diagnostics and military information gathering, etc. Due to its high cost and physical limitations of the image sensors and high precision optics, every time we cannot get a desired HR image for every scene. So we use Super Resolution for this purpose. Here comes the concept of superresolution (SR) image reconstruction which refers to reconstruction of a high-resolution (HR) image from one or multiple low-resolution (LR) images. An image processing algorithm is used in superresolution reconstruction method which is used to enhance the spatial resolution of an image by exceeding the limiting factors of the optical imaging system. The information derived from the set of low resolution subpixel shifted images are fused to reconstruct a high resolution image. A high resolution image have higher number of pixels and has high resolving power than low resolution image. From similar pictures of the same scene, where the camera has moved very slightly, we can gather all the information necessary that will in turn enable us to reconstruct a higher resolution image.

Basic Terminology:

Low-Resolution(LR):

– It offers less details because of its small pixel density within an image.

High-Resolution(HR):

– It offers high details because of its high pixel density within an image.

SuperResolution(SR):

– It's the technique of obtaining a HR image from one or multiple LR images. .

2. Problem definition and Objectives

We are designing a model which converts low resolution images to a high resolution image using super resolution technique. Multiple sequential low resolution images are used to form a high resolution image.

Objectives:

1. To perform Image registration on input images using Keren and FMT algorithm.
2. To perform Image reconstruction after registration using Bicubic interpolation method.

3. Literature Survey

(A) Table shows Literature Survey.

S. No.	Title	Year	Journal/ Conference	Objective	Method	Challenge (s) Dealt	Future Scope
1	Super-resolution Reconstruction for License Plate Image in Video Surveillance System	2015	IEEE- Conference (Communications and Networking in China (ChinaCom))	To improve the registration accuracy of license plate image and to reconstruct a HR image from low resolution images.	FMT, Vandewalle's and POCS	Considered scaling, rotation and translation	NA
2	Video Super resolution Reconstruction Using Iterative Back Projection with Critical-Point Filters Based Image Matching	2015	ACM – Journal (Department of Communication Engineering, Xiamen University, Xiamen, Fujian, China)	To improve the spatial resolution of reconstructed images/videos.	Sliding window. Critical Point Filters (CPF) based image matching. Iterative Back Projection (IBP) algorithm.	Blurring, noise are considered during registration. Considered both rotation and translation.	NA
3	POCS Super-Resolution Sequence Image Reconstruction Based on Improvement Approach of Keren Registration Method	2006	Conference (IEEE Transactions on Intelligent Transportation Systems)	To introduce the keren sub-pixel registration method and point out its disadvantage and a new improvement approach about keren method and its iterative method	Enhanced keren sub-pixel registration method. POCS for image reconstruction.	Finding the disadvantage and improving the current method.	NA

4	A super-resolution reconstruction algorithm for surveillance images	2009	Journal (Elsevier, Signal Processing)	To enhance the resolution of region of interest from the low resolution images.	MAP estimation by using the weighted MRF regularization. Also used bilinear interpolation, GMRF, GWMRF, HMRF, HWMRF and compared the results.	Edge preserving methods.	NA
5	Super-Resolution of License Plate Images using Algebraic Reconstruction Technique	2013	Journal (Journal of Image and Graphics-JOIG)	To increase the resolution to improve the readability of the license plate numbers.	Simultaneous algebraic Reconstruction technique (SIRT). Motion estimation, transformation parameters are initialized using cross power spectrum.	New method with new algorithm	NA
S. No.	**Title**	**Year**	**Journal/ Conference**	**Objective**	**Method**	**Challenge (s) Dealt**	**Future Scope**
6	Superresolution of License Plates in Real Traffic Videos	2007	Journal (IEEE Transactions on Intelligent Transportation Systems)	To enhance license plate numbers of moving vehicles in real traffic videos.	Least squares (LS), GMRF, HMRF and DAMRF. GNC (graduated non convexity) algorithm is used.	Preservation of edges in reconstructed images.	NA
7	Real-time automatic license plate recognition for CCTV forensic applications	2011	Journal (Springer, Journal of Real-Time Image Processing)	Efficient localization of license plates in video sequence.	For feature extraction and detection, used histogram of oriented gradients and nearest mean classifier. Character segmentation using MBR on binary maps.	Multiple vehicle license plates in a real-time scenario	Enhanced super-resolution techniques.
8	Video Super Resolution using Duality Based TV-L1 Optical Flow	2010	Conference (Springer, Joint Pattern Recognition Symposium)	To compute a superresolved image of a scene from an arbitrary input video	L1 and L2 error and compared the results. They used high accuracy optic flow estimation.	Demonstrated good experimental performance on a variety of real-world examples	Simultaneously estimate the motion field and the super resolved image

9	Fast Super-resolution for License Plate Image Reconstruction	2008	Journal (IEEE, Pattern Recognition)	A fast super-resolution reconstruction algorithm for license plate recognition from LR images	Optical flow for computing motion parameters and used Fast map based sr reconstruction by minimizing cost function.	Computational cost is much lower compared with other methods	NA
10	Super-resolution Image Reconstruction	2010	Journal (IEEE, Computer Application and System Modeling (ICCASM))	To reconstruct high resolution image or video from a sequence of low resolution images	The frequency domain method, non-uniform interpolation, POCS method, iterative back projection method, Bayesian approach, regularization method.	Robust to errors in motion and blur estimation	NA

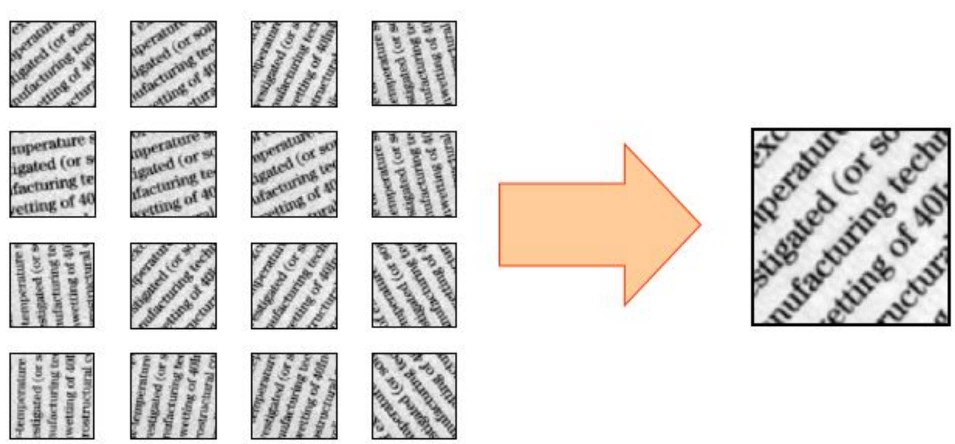
4.Proposed Approach

Basic Idea:

Given:

A set of low resolution images which are rotated, shifted and scaled.

Required:



(A) (B)

Fig. 1 Image showing (a) Low Resolution Images (b) High Resolution Images (ImageSource:[14])

When super resolution is possible?

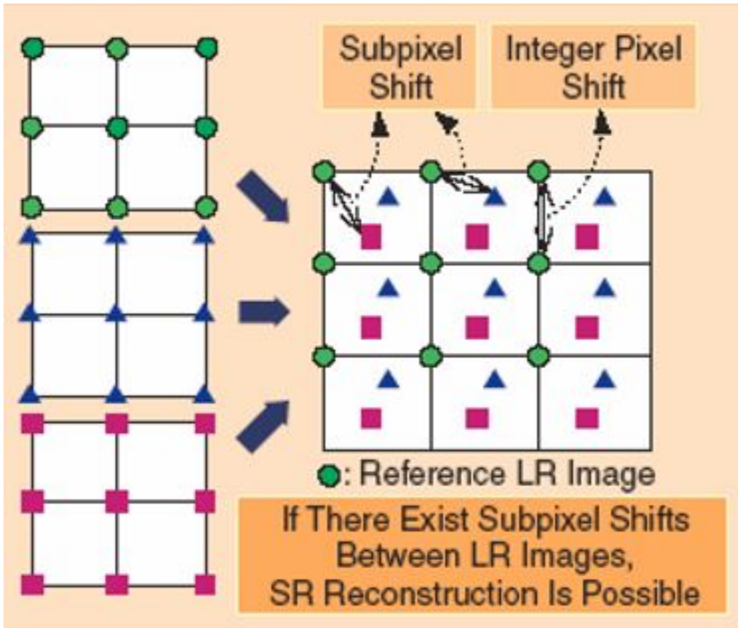


Fig. 2: Image showing when super resolution is possible. ImageSource:[14]

Super resolution is only possible when there are only subpixel shifts between the low resolution images.

Super-Resolution methods involves two steps

1) Image Registration

2) Image Reconstruction

Image Registration: It is a technique used to align multiple images of the same scene with some differences in a single integrated image. It helps to overcome issues like scaling and rotation while overlying images.

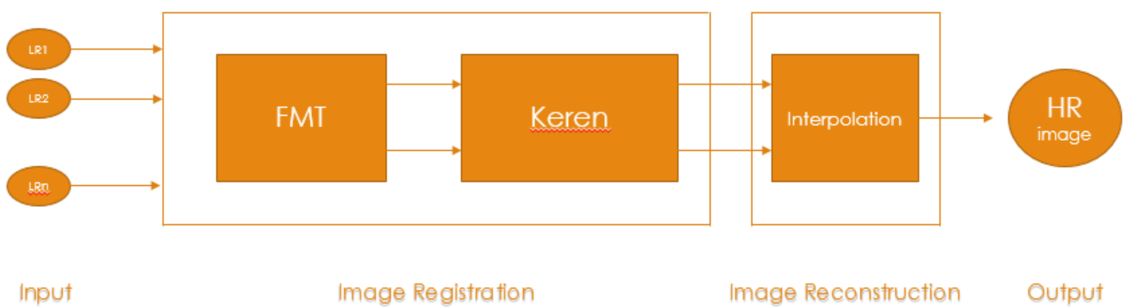
(a) (b) (c)

Fig. 3: Image showing (a) Original Image. (b) Image to be registered on original Image.

(c) After registration of image (b) on image (a). ImageSource:[14]

Image Reconstruction: It is a technique used to reconstruct an image using the details obtained from the low resolution images.

Flow Chart of our proposed methodology:



(a)

Fig. 4: Image showing (a) Figure shows the flow chart of proposed methodology

In image registration, several low resolution images which differ by rotation, scaling, translation are taken as input.

Fourier Mellin Transform (FMT) is used for scaling estimation between the low resolution images and Keren method is used for rotation and translation estimation. In keren method, there is no scaling estimation so we are considering FMT for scaling estimation. Keren is a better method when compared to FMT as keren method is able to find motion estimates even when there is subpixel shifts between the images.

Fourier Mellin Transform (FMT) Method [1][2]:

As rotation and translation parameters are found using keren algorithm, scaling parameter is found using FMT method as follows.

Let reference image be I1, and I2 be the image which is to be registered.

The relation between two images is given by the below function :

$$I_2\,(x,y) = I_1\,(xs\cos\alpha + ys\sin\alpha - t_x\,,\, -xs\sin\alpha + ys\cos\alpha - t_y)$$

(1)

Where (t_x, t_y) are shifts along x and y directions, α is the rotated angle, and s is the scaling factor.

By taking the Fourier Transform of the above equation, we get an equation in fourier domain as

$$FI_2\,(u,v) = \exp(-j2\Pi(u\,t_x + v\,t_y)) \,*$$

$$FI_1\,(us\cos\alpha + vs\sin\alpha\,, -us\sin\alpha + vs\cos\alpha) \qquad (2)$$

FI1 and FI2 denotes fourier transform of I1 and I2 respectively.

M_1 denotes spectral magnitude of FI1(u,v).

M_2 denotes spectral magnitude of FI2(u,v).

By transforming the above equation to its polar coordinates(r, θ),the relationship between Mag_1 and Mag_2 is given by

$$M_2\,(r,\theta) = M_1\,(rs,\theta - \alpha) \qquad (3)$$

where M1 and M2 are translation invariant.

Scaling is converted to translation (i.e., multiplication to addition) by transforming radial coordinate to logarithmic scale.

Consider

$$\rho = log\ (r)\ ,\ \eta = log\ (s) \tag{4}$$

$$M_2\ (\ \rho\ ,\ \theta\ ) = M_1\ (\ \rho + \eta\ ,\theta - \alpha) \tag{5}$$

By applying Fourier transformation to equation (5) , we get

$$F_{M_2}(u',v') = exp(-j2\Pi(-u'\eta+v'\alpha)) * F_{M_1}\ (u',v') \tag{6}$$

We can observe here scaling and rotation resembles as phase shifts. Finally calculating cross power spectrum of M1 and M2

$$A= F_{M_1}(u',v')* F^*{}_{M_2}(u',v')$$

$$B= F_{M_1}(u',v')* F^*{}_{M_2}(u',v')$$

$$\frac{A}{|B|} = \exp(j2\Pi\left(-u'\eta + v'\alpha\right))$$

(7)

A delta function (n,α) is obtained by computing the inverse Fourier transform of equation(7) and hence the value of n is obtained .

Now by substituting n in equation (4) we get value of s which is the desired scaling factor.

Keren Method[3]:

Keren Image Registration algorithm is used to find translation and rotation parameters namely t_x, t_y, α.

t_x represents shift in X direction,

t_y represents shift in Y direction,

θ represents rotation angle.

$$f(x,y) = Intensity\left[g\left(h(x,y)\right)\right] \tag{1}$$

Here g (x, y) is the reference image and f (x, y) is the image obtained by applying transformation function h (x, y) on g(x, y).

$$x' = xcos\alpha - ysin\alpha + tx \tag{2}$$

$$y' = ycos\alpha + xsin\alpha + ty$$

Substituting equation (2) in equation (1) we get :

$$f(x,y) = g(xcos\alpha - ysin\alpha + tx,\ \ ycos\alpha + xsin\alpha + ty) \tag{3}$$

Assuming α to be small , sine and cosine are expanded to their first two terms in Taylor series.

Equation 3 after expansion becomes,

$$f(x,y) = g(x + tx - y\alpha\ - \frac{x\alpha^2}{2},\ \ y + ty +\ x\alpha - \frac{y\alpha^2}{2}) \tag{4}$$

By applying Taylor series expansion to function f(x,y) , the above equation becomes,

$$f(x,y) = g(x,y) + \left(tx - y\alpha - \frac{x\alpha^2}{2}\right)\partial g/\partial x + \left(ty + x\alpha - \frac{y\alpha^2}{2}\right)\partial g/\partial y \tag{5}$$

Now error function (E (t_x, t_y, α)) is obtained by taking the difference of reference image and transformed image

$$E(tx,ty,a) = \sum\left[f(x,y) + \left(tx - y\alpha - \frac{x\alpha^2}{2}\right)\frac{\partial g}{\partial x} + \left(ty + x\alpha - \frac{y\alpha^2}{2}\right)\frac{\partial g}{\partial y} - f(x,y)\right]^2 \tag{6}$$

Where only overlapping part of two images is considered for summation in the above equation.

Now error function E has to be minimized, which can be done by taking the derivatives with respect to t_x, t_y, α and equating them to zero, After that some non linear terms and small coefficients are neglected. Finally we get the following linear equations:

$$AX = B \tag{7}$$

$$A = \begin{pmatrix} \sum\left(\frac{\partial g}{\partial x}\right)^2 & \sum\frac{\partial g}{\partial x}\frac{\partial g}{\partial y} & \sum R\frac{\partial g}{\partial x} \\ \sum\frac{\partial g}{\partial x}\frac{\partial g}{\partial y} & \sum\left(\frac{\partial g}{\partial y}\right)^2 & \sum R\frac{\partial g}{\partial y} \\ \sum R\frac{\partial g}{\partial x} & \sum R\frac{\partial g}{\partial y} & \sum R^2 \end{pmatrix}, X = \begin{pmatrix} tx \\ ty \\ \alpha \end{pmatrix}$$

$$B = \begin{pmatrix} \sum\frac{\partial g}{\partial x}(f-g) \\ \sum\frac{\partial g}{\partial y}(f-g) \\ \sum R(f-g) \end{pmatrix}, R = x\frac{\partial g}{\partial y} - y\frac{\partial g}{\partial x}$$

By multiplying both sides by C^{-1} in equation (7), we get:

$$X = A^{-1}B \tag{8}$$

Keren Algorithm[3]:

Step 1: A 3 layer Gaussian pyramid is constructed for both reference and input image. Initial the layer variable n to 3.

Step 2: K denotes the no of iterations and initialise i to zero and the original four parameter variable $X_0^1 = [0\ 0\ 0\ 0]^T$.

Step 3: Calculate A_i^n, B_i^n and then find X_i^n using the equation (8)

Step 4: if (i==K) , then jump to (7)

Step 5: Resample g_n (x, y) according to X_i^n and the formula (10).

Step 6: increment k by 1, and jump to (3)

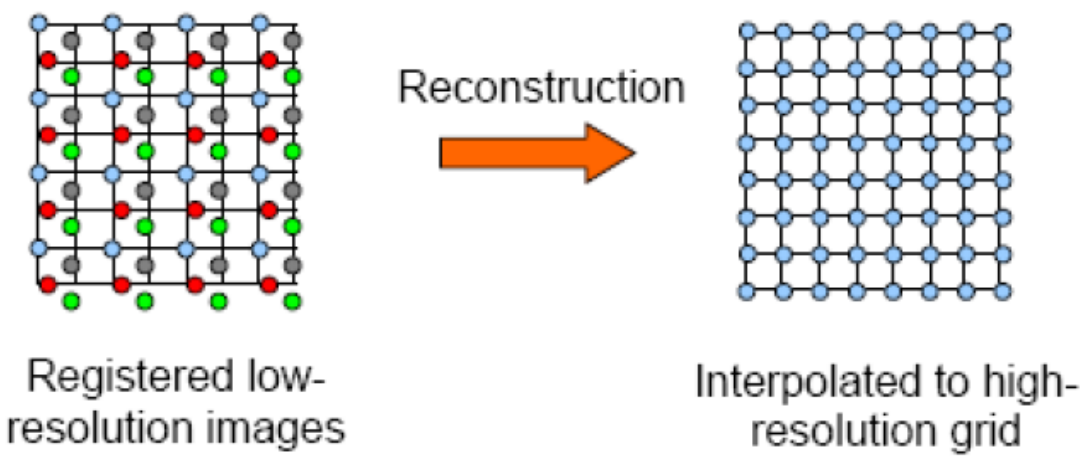
Step 7: if (n<3), in that case make $X_0^{n+1} = X_i^n$, and increment 'n' by 1 and go to (2). Otherwise, program ends.

After the parameters has been detected by the above algoritthms, we align all the images with respect to reference image. Now we need to perform image reconstruction to get a high resolution output.

Image reconstruction is done by Interpolation method which are used to enhance the image resolution.

IMAGE RECONSTRUCTION:

After Image Registration, we have rotation and shift parameters of every image with respect to reference image. Now we have to construct a new grid image with new pixel values such that some of the pixels of the new image are found by applying their respective shift and rotation parameters to the old pixel values of every image. For example, consider an image for which we have shift and rotation parameters and the scaling factor(size of output image w.r.t input image), now for every pixel coordinate, a new pixel coordinate is found by using those parameters and mapping the pixel value to the found coordinates of respective pixel. By repeating this process for every image we get some pixel coordinates and its values and for finding pixel values of remaining coordinates **bicubic interpolation** is used.



(a) (b)

Fig. 5: Image showing (a) Figure shows pixel representation of registered low resolution images.

(b) It shows high resolution grid of Image after Interpolation. ImageSource:[13]

INTERPOLATION:

It is a method of finding the unknown values by using some known values. There are different types of interpolation linear interpolation, cubic interpolation for single dimension and bilinear and bicubic interpolation for two dimensional data. But bicubic interpolation gives more accurate values when compared to bilinear. Hence we use bicubic interpolation for finding the pixel intensities of unknown pixel coordinates.

When we fill the pixel values of input image in scaled output image some pixel values are left unfilled, there we use interpolation to find the unknown pixel values.

BICUBIC INTERPOLATION:

It is an extension to cubic interpolation which is performed for single dimensional data. In bicubic interpolation also unknown values are found using cubic equation. In this 16 known points are considered around the unknown point which is to be calculated.

Equation for bicubic interpolation is given below:

$$\begin{aligned} p(x,y) = {} & a_{00}x^0y^0 + a_{01}x^0y^1 + a_{02}x^0y^2 + a_{03}x^0y^3 + \\ & a_{10}x^1y^0 + a_{11}x^1y^1 + a_{12}x^1y^2 + a_{13}x^1y^3 + \\ & a_{20}x^2y^0 + a_{21}x^2y^1 + a_{22}x^2y^2 + a_{23}x^2y^3 + \\ & a_{30}x^3y^0 + a_{31}x^3y^1 + a_{32}x^3y^2 + a_{33}x^3y^3 \end{aligned} \tag{9}$$

In the above equation, we have 16 coefficients which are not known and we have 16 equations by putting each of the 16 points in that equation. So we have 16 unknowns and 16 equations which can be solved to get intensity of pixel at that particular point. Hence we can find pixel values at every missing coordinates.

After image reconstruction we are applying image enhancement techniques like image sharpening which enhances edges of the objects in the image.

5. Hardware and Software Requirements

Programming Tools:

Matlab

Dataset:

Datasets are taken from Multi-Dimensional Signal Processing Research Group (MDSP)

Dataset Link:

https://users.soe.ucsc.edu/~milanfar/software/sr-datasets.html

9.Conclusion

In this project, we implemented an algorithm to increase the resolution of low resolution images. In Image Registration, we have used keren method for estimating rotation and translation parameters and FMT method for estimating scaling parameters. For Image Reconstruction, bicubic interpolation is used. The results in the validation also shows that we got better values of blur metric, PSNR and SSIM.

10. Future Scope

Our algorithm takes an assumption that all the input images are differed by small changes (i.e., translation, rotation and scaling). If there are large changes between images then it would be better to take the region of interest in every image and apply this algorithm to those images to get better results.

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