SATELLITE IMAGE ENHANCEMENT USING ADAPTIVE SUPER RESOLUTION

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Abstract — **Satellite image processing has a crucial role in remote sensing field. The cameras or sensors embedded on satellites receive raw images which can be improved and used to various applications. To raise the resolution of acquired images super-resolution reconstruction technology is applied. In this paper a valuable satellite image enrichment using adaptive super-resolution is presented. Super-resolution reconstruction technology recreates a high resolution image using a set of low resolution images. Vandewalle motion estimation is employed to correct motion error between low resolution images. Two reconstruction methods are used to recreate a high resolution image. The quality of the recreated image is evaluated using PSNR and SSIM value. Finally, as a comparison a graph is plotted for SSIM values for the dataset images and PSNR values of the dataset images. Experimental results and graphs shows that the result is more accurate when the image is reconstructed by minimizing the error using divergence parameter.**

IndexTerms - Super-resolution reconstruction, satellite video image, motion estimation, quality evaluation.

I. INTRODUCTION

Satellite images are the images collected by imaging satellites that visualize the Earth or other planets. Applications of satellite images include meteorology, oceanography, fishing, agriculture, geology etc. Satellite images gives a better idea of what happens at each point in the world, specifically over oceans where large gaps in data occur. Wide coverage and high performance are the important features of satellite video images, which is used to obtain and update national geographic information and various geodatabases. In digital camera design image resolution is a limiting factor. It is possible to take multiple pictures in a short duration of time using most digital cameras. Low image resolution and large imaging range containing massive species are the problems associated with satellite video images. Thus by using a set of low resolution images a high resolution image can be reconstructed using super-resolution algorithm.

The spatial resolution of remote sensing images can be increased by the method of super-resolution reconstruction technology, which enhances the accuracy of target monitoring and identification, which has a great significance in military and civil fields. Image spatial resolution is a term used to measure the clarity of images. Image spatial resolution can be improved by increasing the sampling frequency without impairing the signal- to-noise ratio thus reduce the spectral aliasing. Resolution can be boosted by increasing the hardware, directly increasing the sampling frequency, and using super-resolution reconstruction technology. The first two methods have several limitations but super-resolution reconstruction technology is the most important way to improve the resolution.

Super-resolution technique recreates a high resolution image from a set of overlapping low resolution images. An image having high resolving power is the high resolution image. An image accessed by up sampling and interpolating a low resolution image cannot have a high resolution than its original. This means that image has large number of pixels but the resolving power remains the same. The interpolated image does not contain the more details than it's original. There are two major challenges in super-resolution imaging. Here we consider images which differ in planar motion. First, the difference between the low resolution input images must be known accurately. That is a precise knowledge about the motion parameter is necessary. This challenge occurs because we use images containing large amounts of aliasing. An error in motion estimation causes degradation in the high resolution image. Hence in order to create a high resolution image one of the low resolution images is interpolated. The second challenge is to affix the information from distinct registered images to recreate a sharp high resolution image.

Super-resolution algorithm is dependent on the efficiency of the model used in imaging process. For instance, if the motion calculated for some of the images is not correct, the algorithm may diminish the image rather than enhance it. Different reconstruction algorithm has different results. Furthermore, for the same reconstruction algorithm, there are variations in the reconstruction results when different number of images is used.

The paper is organized as follows. Previous works related to satellite image enrichment are discussed in Section 2. The motion estimation technique is discussed in Section 3 and Section 4 discuss about the reconstruction algorithm. The Section 5 discuss about experimental results.

II. RELATED WORKS

In 1984, Tasi and Haung first introduced the concept of super-resolution for multiple frame image restoration of band limited signals[1]. Bormon and Stevenson, Park et al. had given an analysis of current algorithms[2]. Most super-resolution method consists of two main steps: The registration step aligns all the images in the same coordinate system, and from the irregular series of samples a high resolution image is recreated. In the second step, the camera point spread function is considered. Accurate sub-pixel image registration is considered as the basic concern for good reconstruction. Image registration methods are pointed by Zitova and Flusser [3]. Registration can analyse in both frequency and spatial domain. Frequency domain methods are limited to global motion models. Planar shifts, planar rotation are the main considerations for this and scale can be expressed in Fourier domain. The best way of dealing aliasing is in frequency domain because it is easier than spatial domain.

Concepts of Planar motion estimation algorithms are stated by Reddy and Chatterji and Marcel et al [4]. By using a high pass emphasis filter they tried to emphasis high frequencies. To estimate planar shifts Kim and Su, Stone et al apply a phase correlation technique. The main advantage of this method is that almost free of aliasing to minimize errors due to aliasing. This is the low frequency part of the images. Foroosh et al showed that the signal power in the phase correlation corresponds to a polyphase transform of a filtered unit impulse response. The relation between the magnitude of Fourier transform of an image and the mirrored version of the magnitude of the Fourier transform of a rotated image are described by Lucchese and Cortelazzo [5]. The angle between the lines and the axes is equal to half the rotation angle between the two images.

For general motion models spatial domain methods are generally allowed. They are based on the whole image or on a set of selected corresponding feature vector stated by Capel and Zisseman and by Fischler and Bolles in RANSAC algorithm [6]. Keren et al in his paper a Taylor expansion based iterative planar motion estimation algorithm is proposed [7]. Pyramidal scheme increases the accuracy for large motion parameters. A hierarchical scheme was described by Bergen et al analyse motion in a multi resolution data structure. An approach to compute multiple, transparent or occluding motions in an image series are described by Irani et al [8]. The planar rotation of the input images can be calculated from the gradient field distribution by the method described by Gluckman [10]. In order to estimate planar rotation after cancellation of the rotation a phase correlation method is used. In image reconstruction stage, a high resolution image is reconstructed from the irregular set of samples obtained from different low resolution images. This can be obtained by interpolation method described by Keren et al. A frequency domain method was described by Tsai and Huang.

III. RESEARCH METHODOLOGY

The super-resolution reconstruction is explained by the following flowchart. A series of low resolution images are loaded as input to the motion estimation technique. The planar motion estimation technique calculates the rotation shift and phase shift between the low resolution input images. A median estimator technique is used for the super-resolution reconstruction technique to obtain the high resolution image. The quality of the output can be estimated by subjective evaluation or objective evaluation. Subjective evaluation is based on optical knowledge and the major limitation is that it contains large ambiguity. Objective evaluation can be done by finding the SSIM value and PSNR value.

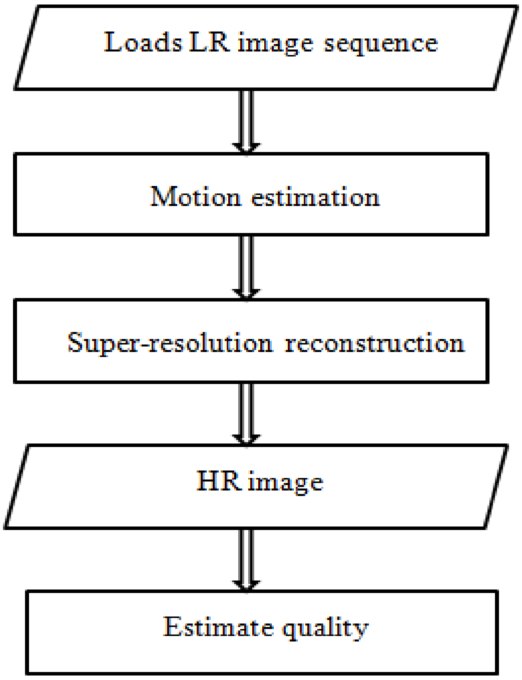

Fig. 1. Flowchart of Super-resolution reconstruction technique

3.1 Motion estimation method

Vandewalle motion estimation method is adopted for motion estimation technique. It is used to correct the motion error between a series of low resolution images. Fourier transform is used in this method to find the one-dimensional displacement of amplitude and phase. The main advantage of this method is to discard high frequency components, which may cause aliasing. In this work a planar motion estimation is preferred as it is simpler and requires less parameters, making it often robust in presence of noise. The rotation estimation algorithm is computationally efficient and work with aliased images. A frequency domain algorithm is used to estimate the motion parameter between the reference image and other images. Planar motion parallel to the image plane is only allowed in this algorithm. Horizontal and vertical shifts and planar rotation are the three parameters used to describe the motion function. To estimate the horizontal and vertical shift and the (planar) rotation separately frequency domain approach is used.

Let $g_1(x)$ be the reference signal and $g_2(x)$ be its shifted and rotated version.

$$g_2(x) = g_1(R(x+\Delta x)$$

Let $G_2(u)$ be the Fourier transform of $g_2(x)$ and $G_1(u)$ be the Fourier transform of $g_1(x)$.After another transformation the relation between the amplitude of the Fourier transforms can be computed over the same angle. Thus first estimate the rotation angle from the amplitudes of Fourier transforms. After estimating rotation, the shift can be computed from the phase difference between $G_1(u)$ and $G_2(u)$.

3.1.1 Rotation estimation

The rotation angle between $|G_1(u)|$ and $|G_2(u)|$ is computed as angle Θ for which fourier transform of the image to be registered and the rotated fourier transform of the image have maximum correlation.

3.1.2 Phase estimation

$|G_1(u)|$ and $|G_2(u)|$ are transformed into polar coordinates then the rotation angle is converted to circular shift. Then calculate the fourier transform of $|G_1(u)|$ and $|G_2(u)|$ and compute the phase shift between the two.

3.2 Reconstruction

For the reconstruction of super resolution images two method are adopted.

Method 1:
Step 1: Start with an estimate of HR image. An upsampled version of the first LR image as an initial estimate.
Step 2: Define the step size for the iterative gradient method.
Step 3: Compute the gradient of the total squared error of reassembling the HR image.
Step 4: Calculate the median of gradient and find obtain the HR image with minimum error.

Method 2:

Step 1: Start with an estimate of HR image. An upsampled version of the first LR image as an initial estimate.
Step 2: Define the step size for the iterative gradient method.
Step 3: Compute the gradient of the total squared error of reassembling the HR image.
Step 4: Calculate the median of gradient.
Step 5: Compute the divergence parameter and based on that obtain the HR image with minimum error.

IV. RESULTS AND DISCUSSION

The experiment is carried out in MATLAB platform. The dataset contains a set of LR images. Two methods are used to reconstruct the super resolution image. This results are used for quality evaluation. The original image and the reconstructed super-resolution image are subjectively calculated. The series of low resolution image in dataset are as follows. The dataset used in this work consist of four low resolution images. The rotation and shift of each of these images are estimated by using motion estimation technique. Before applying super resolution technology, an initial estimate of the high resolution image is created. For creating the initial estimate any of the four images in the dataset can be used. Here the first LR image is used to create the HR image.

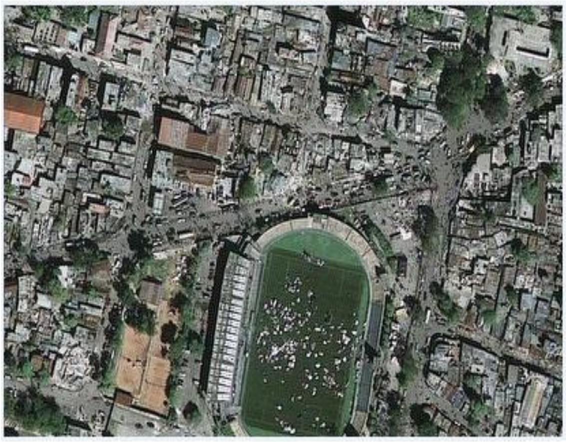

Fig.(a)

Fig.(b)

Fig(c)

Fig(c)

The reconstructed image after super resolution technology is shown in Fig.3.The pixel size of the reconstructed image increases double as compared to the original image.

Fig.3. Reconstructed image using method 1

Fig.4. Reconstructed image using method 2

The experiment is carried out using 4 images. From the SSIM comparison at different dataset images and PSNR comparison at different dataset numbers shown in Fig.5 and Fig.6 respectively it is clear that the result is more accurate when the dataset contains 3 images. It is also obvious that the reconstruction used the method 2 has a better result than method 1.

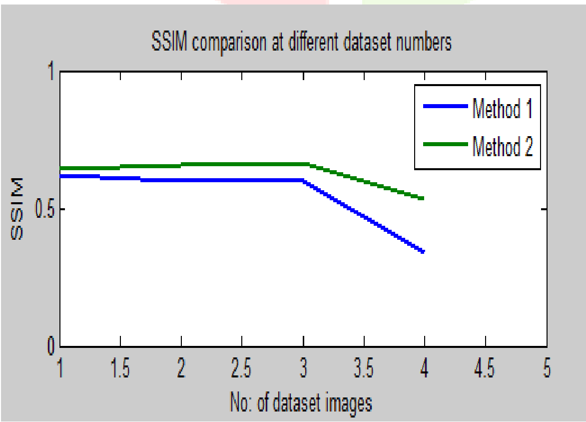

Fig.5. SSIM comparison at different dataset numbers

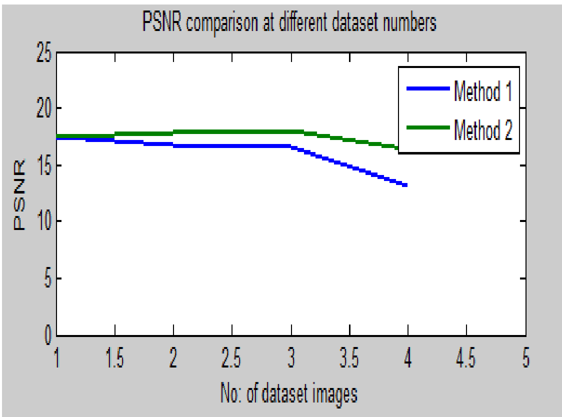

Fig.6. PSNR comparison at different dataset number

V. CONCLUSION

Super-resolution reconstruction technology is a powerful means to enhance the resolution of satellite video images. The reconstruction can be done by two methods. In order to obtain a more accurate result reconstruction based on error minimization using divergence parameter is preferred. The reconstruction result varies depending on the number of dataset images. From the experimental results it is clear that the result is most accurate when the dataset contains 3 input images.

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