Approach for image quality improvement for high-resolution sensors

Tanul Gupta, Arvind K. Singh, T.P. Srinivasan
Space Applications Centre, Ahmedabad
{tanul, aksingh, tps}@sac.isro.gov.in

***Abstract*—This paper summarizes the radiometric quality analysis and improvement of Cartosat-1 data. Striping problem observed in Cartosat images is specifically targeted and corrected using both spatial and frequency domain techniques. This includes both generic and scene based approaches. The methods proposed have been extensively tested and are giving good results without introducing any artifacts. Quantitative and Qualitative comparisons of various methods is also presented.**

Keywords—Cartosat-1, FFT Filtering, Banding, Striping, Radiometric quality improvement

I. INTRODUCTION

Satellite image data quality is affected by many factors such as electronic noise, sensor performance, thermal effects, time of imaging, atmospheric conditions and ageing of the sensor. All the factors mentioned above deteriorates the quality of the data with time due to which the problem of striping, banding, and noise/degradation in the image data gets aggravated. The objective of this paper is to summarize radiometric quality analysis and improvement of data products by removing striping present in the original images of Cartosat-1. Cartosat-1 is a stereo imaging satellite launched in May 2005 with two detector arrays viz. FORE and AFT. It has an IGFOV of 2.5 m with 10bit radiometry.

Various methods based on spatial and frequency domain techniques have been applied on the datasets [1] [3] which include both generic and scene based approaches to restore images. Four methodologies are proposed to correct for banding as well as striping. Out of these, three are based on moving average filter which works in spatial domain and remaining one works in frequency domain. These methods have been tested on Cartosat-1 datasets and is giving good results without introducing any artifacts. The results for all the techniques are presented in this paper along with their comparisons both qualitatively and quantitatively.

II. OBSERVATIONS

We have analyzed 16 different Cartosat-1 datasets acquired during the period 2010-2013. Each dataset was examined to check for the presence of noise, striping, banding or any other artifact or degradation. **Figure 1** represents 3 different datasets to show how striping problem has varied over the years. All the images present in this paper have been zoomed to 2X level. From **Figure 1**, one can observe that noise along with striping is greater in 2010 (**Figure 1A**) data set. In 2013 (**Figure 1B**) datasets, only striping is present. It is observed that the striping is wider in FORE image as compared to AFT image (**Figure 1B**).

III. APPROACH AND METHODOLOGIES

Striping correction and quality improvement of Cartosat-1 data has been attempted by both spatial and temporal domain techniques. Spatial techniques include moving average filter and different variations of the same. Temporal striping removal is carried out using FFT technique to find out repetitive frequency and then removing it [2] [4].

The Moving Average Filter has been designed to operate on mean profile of the input image. Mean profile consists of vertical average DN values of all 12000 pixels/detectors of the image. For example, if we have a 12000x12000 image then its mean profile would consist of average DN values for each pixel i.e. average of the image column wise.

The Moving Average Filter of window size 9 is applied on the mean profile of the image. This window size of 9 is selected to get a trade-off between striping correction and smoothening. With smaller window size, the striping in not completely eliminated whereas with larger window size, the image becomes smoother which leads to blurring. The offset between original mean profile and filtered mean profile is computed at each pixel location. This offset is then applied to each of the pixel of the image at every scan line.

The three different variations of moving average are (a) applying moving average separately on odd (pixel nos. 1, 3, 5…) and even (pixel nos. 2, 4, 6…) pixel data, (b) application of moving average on the entire image, and (c) a generalized moving average which uses statistical data from large sample data.

The readout of data stream is carried out separately for odd and even pixels. This results into bias between the two streams. This is the primary reason to apply moving average filter separately on odd and even pixels. The images are then merged together to form a single merged corrected image. Merged image may contain some bias between even and odd pixels. Now, Bias Correction is performed to minimize the differences between

(A)
Noise along with striping is present in this 2010 dataset

(B)
Striping is visible in both AFT and FORE cameras in 2013 dataset.

Figure 1: Cartosat-1 image

even and odd pixels. The final image obtained is devoid of unwanted striping. Another variation comprises of applying the filter on the entire image. The benefit with this kind of application is that after application of filter the image does not contain even-odd bias as in the previous case. Both of these approaches are scene based. A scene-independent generalized approach is developed which calculates Photo Response Non Uniformity (PRNU) coefficients viz. gain and bias for each of the pixel/detector. These coefficients are calculated from a varied range of images containing different signatures. **Figure 2** is the flow diagram representation of this methodology.

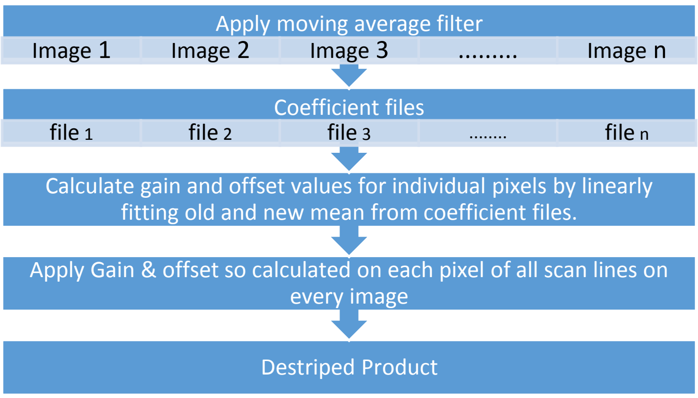

Figure 2: Flow Chart for Statistical Approach methodology to remove vertical stripes from Cartosat-1 data

The frequency based approach is based on computing the FFT of image and then eliminating high frequency components from the FFT so obtained [4]. In this approach, FFT is computed for each of the row of the image and then aggregated into a single accumulated vector. After computing the accumulated FFT, power is computed for each of the pixel/column. In the accumulated power spectrum (**Figure 3**), the frequency components of non-periodic signals are neutralized to small values (near to zero) whereas frequency components of periodic signals are accumulated to peak values other than the DC component. If there exists vertical striping with a fixed frequency spread around the whole image, then a peak is observed at that particular frequency. The locations of these peaks are detected and FFT value for those locations is made zero in each row of the image. To detect the peaks in the power spectrum automatically, a curve is fitted on the power spectrum data and an offset of $t\sigma$ is added to the curve to bring it above the mean level of the data. Where t is a constant and σ is standard deviation. On experimentation we found polynomial of order 8 fits best to the data. Also the value of t ranging between 1.3 to 1.5 sufficiently detects the peaks. Hence all those data points which are above the curve are treated as peaks and those frequencies are minimized in FFT of each row of the image. Then inverse FFT of the image is computed to get the de-striped image.

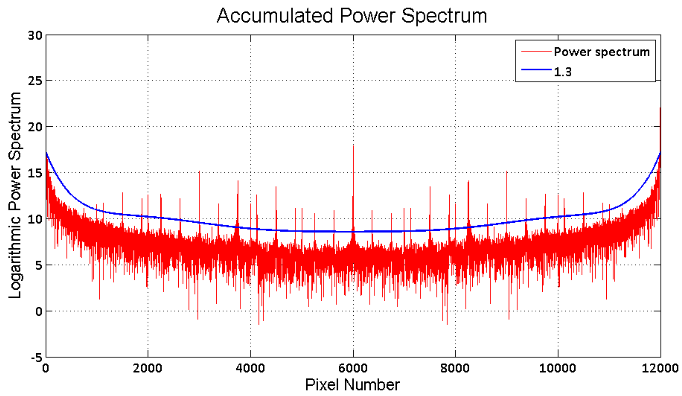

Figure 3: Power Spectrum

IV. Results and Discussion

This section summarizes the results obtained after applying all four techniques on available Cartosat-1 data sets. **Figure 4** represents cropped region of original. Striping is clearly visible in this image. On applying odd-even moving average and then bias correction, we obtained **Figure 5**. The improvement is discernible as striping is considerably removed in the corrected images. This visual improvement is justified quantitatively by comparing Mean profiles of original and even odd corrected images. In mean profiles, the vertical width, which represent deviation of DN values in neighboring pixels, has reduced considerably.

Similar kind of improvement is observed when moving average filter is applied on the full image. **Figure 6** represents the corrected image and corresponding mean profile. The decrease in vertical width is easily observable. Corrected images obtained after applying PRNU coefficients which were evaluated using the Generalized Moving Average algorithm is shown in **Figure 7**. It is observed that striping is more in brighter areas and has reduced considerably in darker areas. However, there is no visible change in width of mean profiles which is clear from **Figure 7**.

Image obtained after applying frequency removal technique is shown in **Figure 8**. It is observed that this technique de-stripes the image maintaining its sharpness as well. Also the width of the mean profile has reduced considerably showing maximum improvement in image.

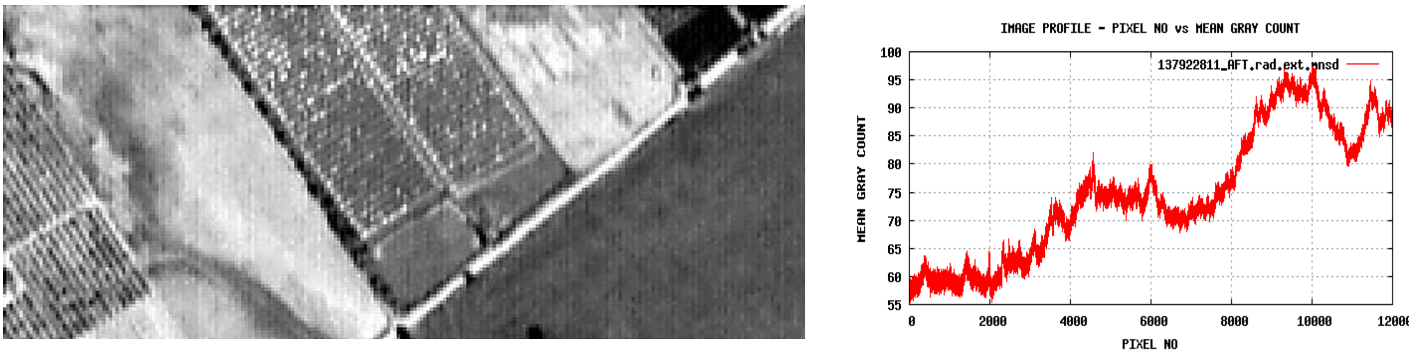

Figure 4: Original Radiometrically corrected image [LEFT] and corresponding mean profile [RIGHT]

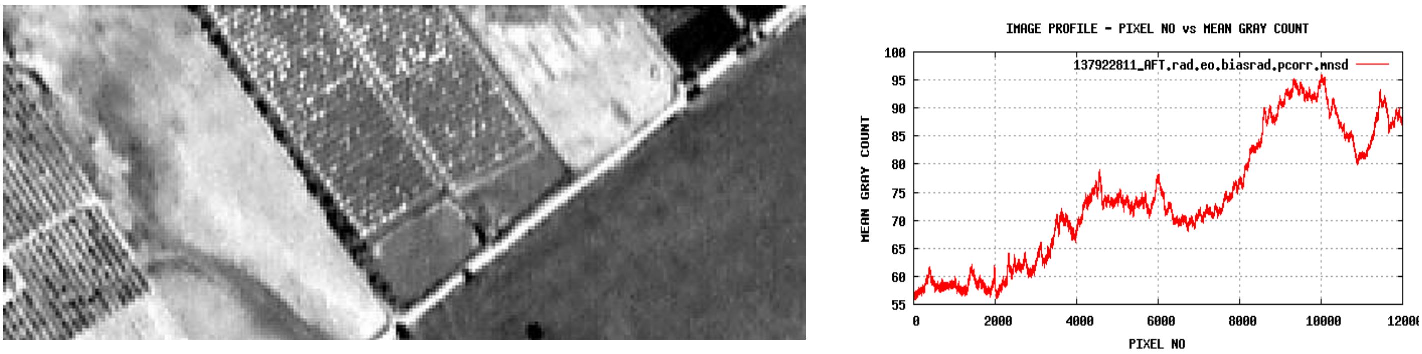

Figure 5: Image [LEFT] after applying Even-Odd Moving Average Filter and corresponding mean profile [RIGHT]

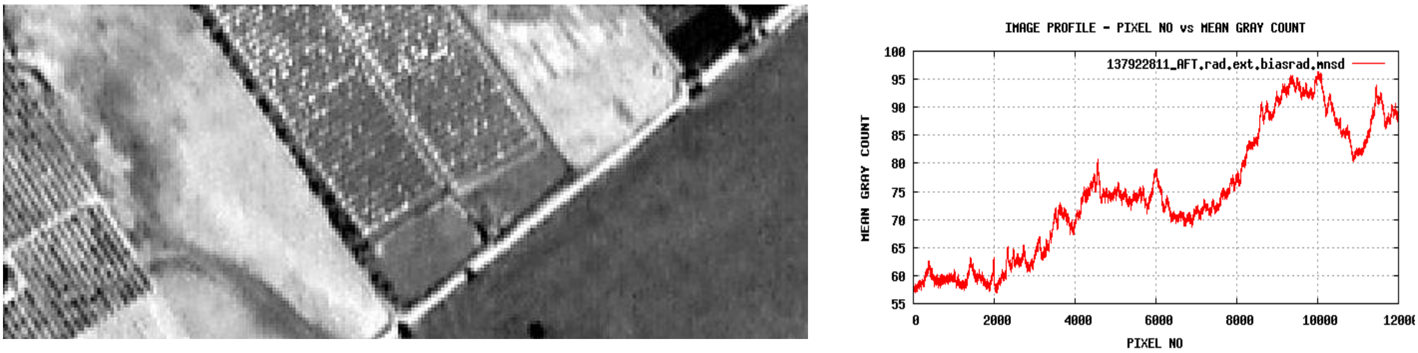

Figure 6: Image [LEFT] after applying Moving Average Filter and corresponding mean profile [RIGHT]

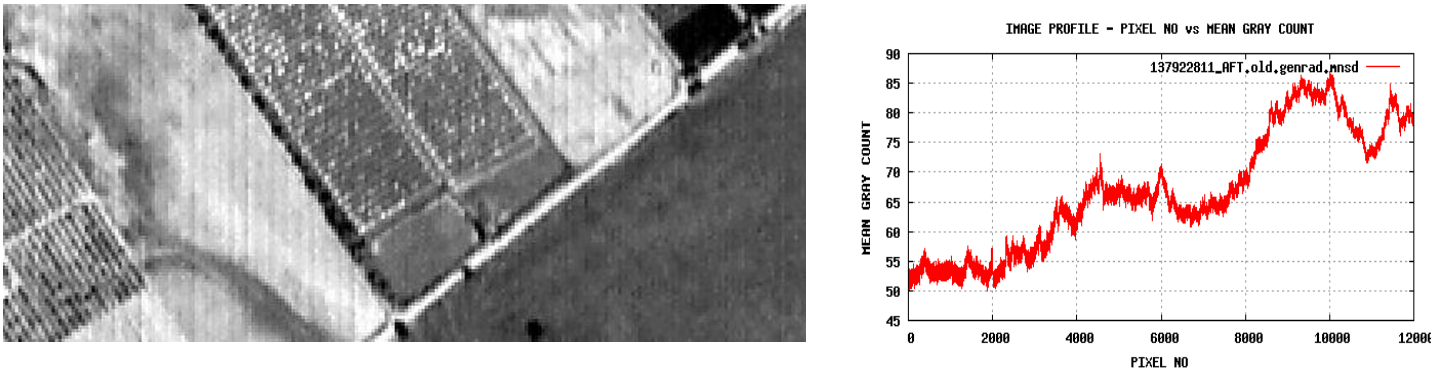

Figure 7: Image [LEFT] after applying Generalized Moving Average Filter and corresponding mean profile [RIGHT]

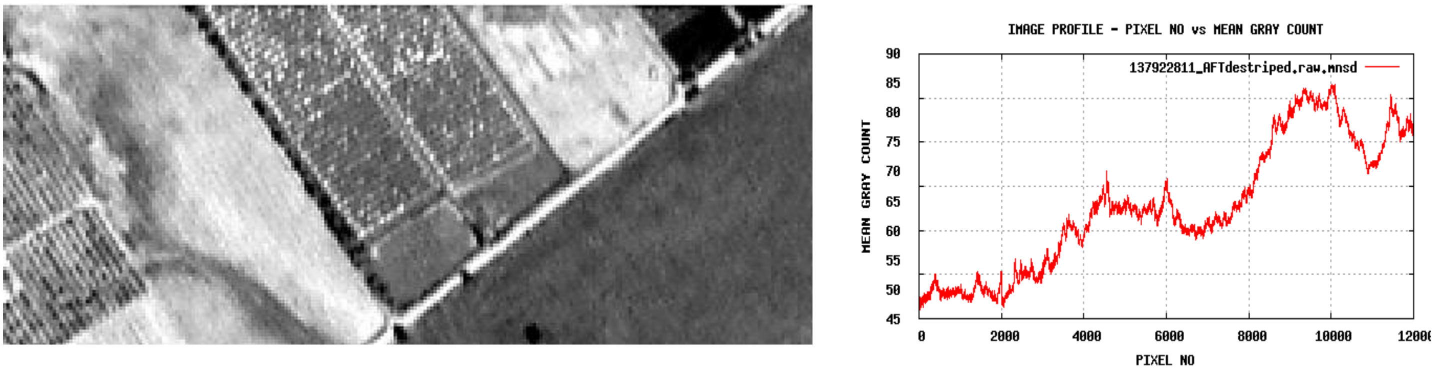

Figure 8: Image [LEFT] obtained after removing selected frequencies from Power Spectrum and corresponding mean profile [RIGHT]

A quantitative analysis of all the images was performed to evaluate the efficiency of our techniques. Parameters like minimum, maximum & mean DN values and standard deviation are tabulated in **Table 1** below.

From the parameters, one can infer that the filters are working fine and maintaining the dynamic range of the data. Also, the deviation of parameters from the original is below 1 count for every approach. Hence, it can be inferred all three approaches are having similar effect on the images. Also all three are maintaining the information content of the image as the values are very closer to each other.

Table 1: Quality Parameters for cropped regions

Parameters (Full Image)	Original Image	Moving Avg filter	Even Odd Separate	FFT analysis
Min	46	46	45	47
Max	190	189	187	188
Mean	101.871	101.834	100.876	101.872
SD	21.3635	21.3366	21.3447	21.3315

V. CONCLUSIONS

Cartosat-1 data has been analyzed both qualitatively and quantitatively. After careful analysis of the datasets we found that striping is present in datasets of 2012 and 2013. However, 2011 data has negligible striping. Scenes from 2010 consist of both striping and noise.

Applying moving average filter on the entire dataset or on even odd separately is giving good results. Striping is reduced to a significant extent without introducing any artifacts. A generalized approach of moving average filter is also applied for the full image. Striping gets reduced in darker areas whereas it increases in brighter areas when compared to original image. This is because of the limited dynamic range of the images used for computation of the PRNU values.

The results from the three approaches viz. Moving Average, Even-Odd Moving Average and FFT analysis are compared as they removed the striping quite well and comparable. Hence, any of the three can be used in the current scenario for striping correction for Cartosat-1 dataset. Moving Average filter is comparatively less computational intensive than the other two and will take less time for implementation and processing the image. In case of FFT, it is observed that it corrects the image with very less modification of the original data as the difference between the original and corrected image is minimum. Hence, this can be used if there is no restriction on computational resources.

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