Estimation of System MTF of EO Satellite by Slanted Edge Method

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Abstract: - Image Quality of spacecraft sensors vary between ground pre-launch measure, after launch and over satellite lifetime due to launching vibration and space harsh environment. Due to the inaccessibility of the satellite on orbit, it is mandatory to use indirect method in order to estimate satellite performances. The aim of this work is to estimate the Image Quality of satellite by using the sharp edge characteristics of image in order to obtain Image Quality parameter estimation such Modulation transfer function. The Edge based Selected Method is implemented and tested in view to learn more about its advantages and drawbacks.

Key-Words: -MTF, ESF, Satellite, Slanted Edge, Satellite, LSF

1 Introduction

The geometric characteristics of a spatial imaging system can be expressed by a single number or a simple interpretation. The Modulation Transfer Function (MTF) is a very good approach to determine the spatial quality of an imaging system. Despite that there are several ways to measure the MTF, in this work we have examined the most widely used methods in this area to characterize the properties of on-board cameras. Then we will look specifically at one of them.

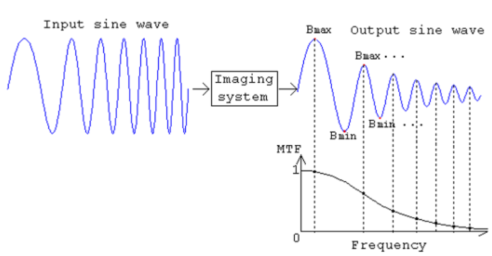

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Figure 1. Low pass effect on frequencies of (satellite) cameras

A recording of a natural scene by observation satellite provides images degraded by the atmosphere, optical system and sensor [1]. The observation of a more quality product as faithful reality and original scene request further processing of the image [3].

Furthermore the development of universal tools for the systematic evaluation of image quality is very useful when the number of image is very important. This is for example the case when it comes to optimizing the characteristic parameters of a system of an embedded imaging system.

2 Non Reference Estimation of MTF

To summarize the steps of images acquisition on-board Earth observation satellite we must remember that light from the observed scene through the atmosphere primarily affected by the optical system which acts mainly by diffraction and aberrations. The intensity image thus formed at the sensor is blurred. It then undergoes a sample by integration over photosensitive elements (pixels) sensor.

As the integration is not instantaneous, the image is affected by the motion of the instrument. The light is then converted into electricity which is then contaminated by noise of various origins. This current is submitted to quantification stage before forming an image. This is the stage of measurement, which further contributes to the degradation.

Taken in a more pragmatic understanding pulse response of the satellite camera is reduced to estimate the quality or degradation of images delivered. The community of remote sensing describes this activities by calibration/validation (Cal/Val) or Quality Assurance of satellite images[8].

After exploring state of art of methods and algorithms proposed for blind deconvolution, there is none that can be directly applied successfully on satellite or aerial images which can applied directly on image and give original scene.

The method that comes closest to the assumptions such as posed here is to observe an already known scene under the assumption that the observation of such a scene can then help to deconvolve obtained scene[1] [4].

The in aeronautics and space industry can not be satisfied with too coarse results. It is therefore necessary to formulate new approaches, taking into account the specific data to be processed. Adaptation of the tools described is equally fundamental. The concepts of support reducing space and positivity do not provide significant improvement in Earth observation. Due to the intrinsic characteristic of satellite imagery; the scene continues well beyond the bounds of the image. Lack of uniform background motivating the use of boundary constraints. The approach adopted in a purely spatial. The large images model generally used is inadequate as long as the observed natural scenes have details on all scales. The spectral characteristics are not all taken into account. Finally A bad model spectrum gives a FTM poorly estimated.

3 Edge Method

The abrupt luminance transitions called knife edge are useful targets to evaluate the spatial response as allows stimulating the imaging system response at all spatial frequencies. The algorithm proposed by [3] first determines the locations of the edge in sub-pixel accuracy. This requires the alignment of all the rows of pixels from the location of the boundary. Then data are interpolated and averaged to obtain a distribution function. The ESF is then differentiated to obtain the PSF. Then, applying the Fourier transform and the normalization of the PSF gives the MTF profile and value at 50% MTF or Nyquist frequency.

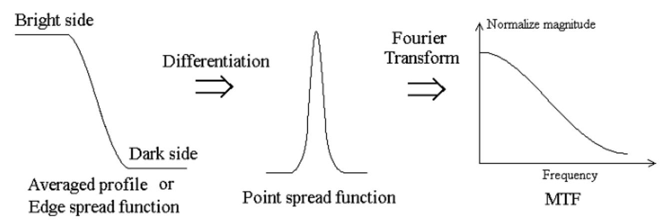

Figure 2. from the edge to the MTF

4 Methodology

As the major constraint of this method is how to avoid noise and oversampling, selection of suitable edge to compute realistic MTF profile must respect severe criteria.

From the set of available satellite images, thumbnails were extracted. The selection of the edges follows the rules already established and inspired by existing methods like in [2] and [12]. Eligible edge must represent sharp passages in term of radiometric transition. Edge must be relatively slanted with regard to the vertical. Suitable edge must include and reflect overall dynamics of the image. Edge must be long enough.

Once the edge obtained from image, then the maximum slope of each contour line is calculated. We have applied and tried to adapt the Edge Method procedure as described by [2] and [3] on section of Barcelona (Spain) Spot5 PAN Image and UK-DMC Bejaia (Algeria) images.

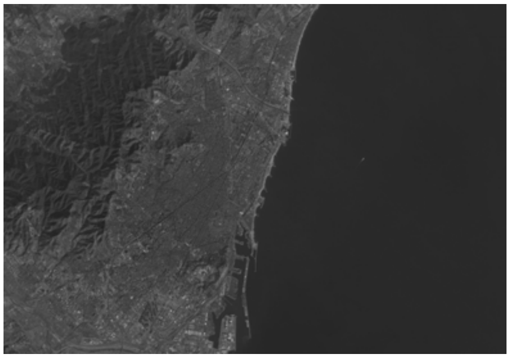

Figure 3. View of Barcelona Spot-5 Image in Panchromatic Modality

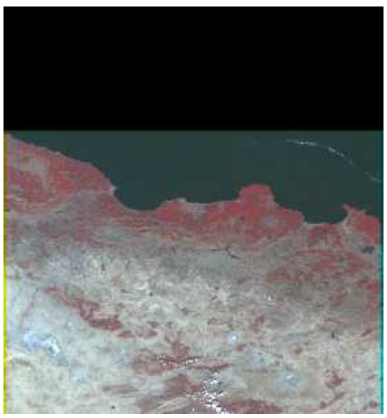

Figure 4. View of Bejaia UK-DMC image MS Modality

The first step is to determine the exact limit of the edge. The positions of the edge were determined line by line using the pixel Digital Number.

4.1 Edge Selection and Fitting

One a suitable edge is selected manually. Edge location is determined with sub-pixel accuracy. Differentiation is applied on set of lines composing the studied edge. The eligible edge was chosen as part of feature of UKDMS Bejaia airport as shown in the figure 07 bellow:

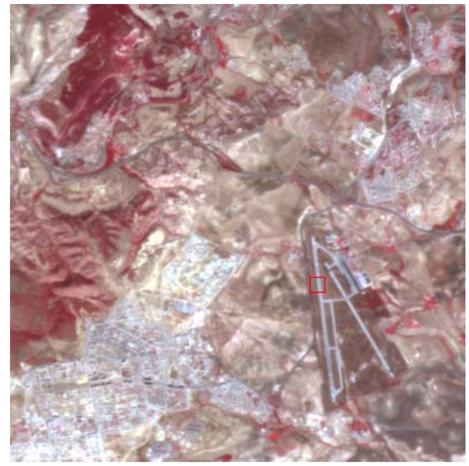

Figure 5. Zoom on of Bejaia Airport UK-DMC image MS Modality

After choosing ROI surrounding eligible edge implemented procedure allows us to illustrate the gridded area as shown in the figure. Meanwhile differentiation of ROI edge image and least square fitting gives a line passing a cross the sharp variation of each line of ROI. We use cubic polynomial function to obtain such line to have sub-pixel accuracy.

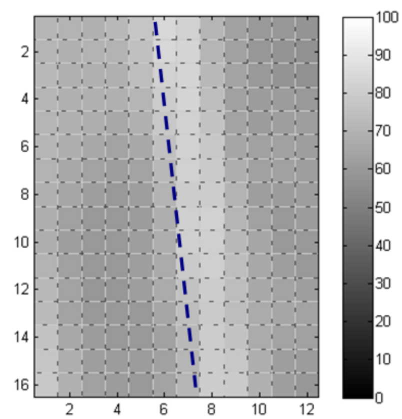

Figure 6. Zoom on of Bejaia Airport UK-DMC image MS Modality

4.2 Edge Spread Function Determination

After the fitting line is determined for each row i different straight lines are then constructed perpendicular to the edge and crossing the edge pixel in several pixel positions. Piecewise cubic spleen interpolation allows to construct and obtain edge spread function ESF.

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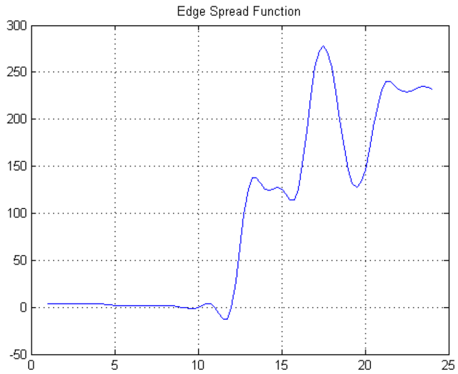

Figure 7. Example of obtained ESF

As shown in the figure above obtained LSF may represent lobes due to noise. A fitting of such data become hence mandatory.

4.3 ESF Fitting & FERMI Function

In order to avoid noise a fitting of the average of ROI line must be performed. Fermi logistic function is widely used as in CRESPI et al and Ryan et al. We used a combination of 3 logistic functions such as:

$$F(x) = d + \sum_{i=0}^{2} \frac{a_i}{\exp[(x - b_i)/c_i] + 1}$$

The Fermi function implemented allows an automatic fitting of the averaged line of edge. By using K-means clustering the data set is divided on 3 parts according to the mean of the part. The lower mean equal the bottom of curve (B) (cf. figure) and the higher the top (A° of the same curve. The coefficients c_i b_i a_i are chosen like in Ryan et al.

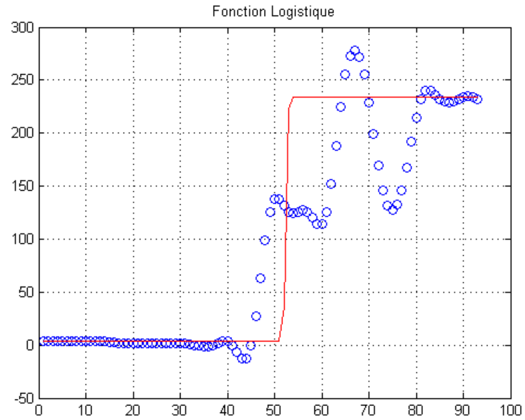

Figure 8. Fitted ESF by logistic function

Here it is important to say that the use of k-means clustering of data may produce occurring some problem of convergence of the k-means algorithm even when built in Matlab is used. We tuned the kmeans function in Matlab such to obtain always the same result when running the code of Fermi function many times:

```
[ODX,CC]=
kmeans(M,3,'emptyaction','singleton','
Replicates',100);
K1ind=find(ODX==1);
K2ind=find(ODX==2);
K3ind=find(ODX==3);
Bottom_Edge=min([mean(M(1,K1ind)),mean
(M(1,K2ind)),mean(M(1,K3ind))]);
Top_Edge=max([mean(M(1,K1ind)),mean(M(
1,K2ind)),mean(M(1,K3ind))]);
```

4.4 Line Spread Function Determination

A differentiation of fitted edge spread function gives Line Spread Function profile. In our case windowing is not applicable since we observed very flat side of the fitted logistic function with no noise.

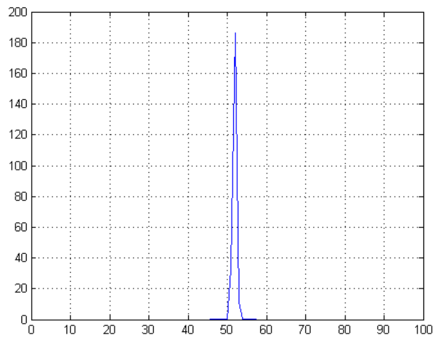

Figure 9. Example of obtained ESF

4.5 MTF Construction

Performing Discrete Fourier transformation on LSF allows us to obtain Modulation transfer function value and the value at Nyquist.

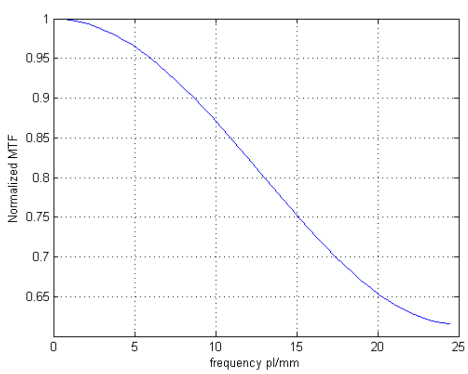

Figure 10. Example of obtained ESF

On other data set of image we selected four edges of the same image of Barcelona. Spot 5 spatial resolution of 2,5 m allows to select buildings edges. Also High/low transition quality is so good and the general noise intensity is acceptable with regards to data. We obtain MTF profile as illustrated in the figure 7.

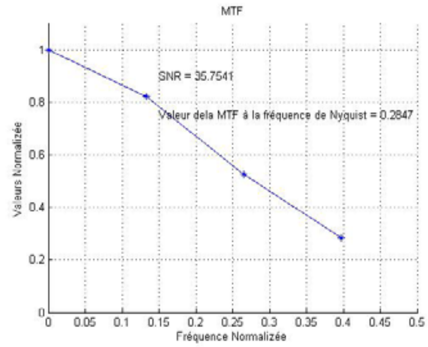

Figure 7. Obtained MTF profile

Table1 shows that over the four edge profile selected and processed the mean MTF obtained is about 0.27 meanwhile Spot 5 Panchromatic MTF as known is about 0.25.

Edge ID	**1**	**2**	**3**	**4**
Edge Length	221	221	221	221
MTF @nyquist	0.2847	0.2942	0.2542	0.2665
MTF @nyquist (avr)	0.27			

Table 1. Comparison of obtained results

5 Conclusion

In our work we deliberately omitted the steps of filtering the noise. We selected suitable edges. In order to quickly explore the technique we choose simple reductive approach. The expected result even already known have no great originality but allows understanding the method and constructs our own views in relation to limitations. Obtain the real edge among a considerable amount of noise constitute a real challenge.
Automation of the *good edge* selection may constitute a future continuity of this work.

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