REMOTE SENSING SATELLITE IMAGE DATA RESTORATION PROCESSING WITHOUT MTF

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SUMMARY

We developed an image restoration method for remote sensing satellite image data without MTF. This method is useful for American TM and French SPOT remote sensing resource satellite image processing,and additionally we were able to receive improved images or super-resolution images as well. Characteristics of remote sensing blurred images are discussed,including the limited blurring set(LBS). We discuss limited blurring set analysis(LBSA). Image degradation and restoration models in LBS are a pair of general transformation in LBS. In LBS,image restoration processing has been turned to point restoration processing. Remote sensing image restoration operation based on LBS selectively applied to some blurring-related pixels of LBS in spatial domain, not the whole image. This method makes complex restoration operation simple, and processed image size remains large,for example, 8000 pixels by 6000 lines for remote sensing satellite image. We have developed a set of solutions for restoration. From image-self blurring properties we estimate image restoration. Finally we discuss and show remote sensing satellite image processing results. In addition the method would be useful for digital processing of weather satellite images, sea satellite images, resource satellite images(including Japanese ERS-1, Earth Resource satellite-1),remote sensing resample images,etc.

CHARACTERISTICS OF REMOTE SENSING BLURRED IMAGE

Remote sensing blurred satellite image $g(x,y)$ has the following characteristics:

A) The $g(x,y)$ is a discrete volume image.

B) The $g(x,y)$ is limited in that: (1) The pixel grey volumes of $g(x,y)$ are limited;for example,the maximum is 255;(2) The range of position variables (x,y) is limited.

C) The $g(x,y)$ has its mean and variance.

D) A Blurring area,which was affected by PSF(point spread function) for an ideal unblurring point, is a limited set.

We called the blurring area a limited blurring set (LBS); We define length for LBS as BL. LBS may be one dimensional,two dimensional . A raw remote sensing satellite image,generally,has a LBS which may be a arectangular area,or line,etc., and BL is from 3 to 60 pixels along

x-axis or y-axis .The g(x,y) may also be written as

$$g(x,y) = \sum_{\alpha=0}^{M-1} \sum_{\beta=0}^{N-1} f(\alpha,\beta)h(x,\alpha,y,\beta) \qquad (1)$$

This process is the remote sensing image degradation process in LBS.

If we have a linear space invariance system ,then

$h(x,\alpha,y,\beta) = h(x-\alpha,y-\beta)$

and we have the following relation from Eq.(1):

$$g(x,y) = \sum_{\alpha=0}^{M-1} \sum_{\beta=0}^{N-1} f(\alpha,\beta)h(x-\alpha,y-\beta) \qquad (2)$$

LIMITED BLURRING SET ANALYSIS FOR IDEAL REMOTE SENSING IMAGE POINT

First, we define the remote sensing image degradation operator model. If degradation operator model is one dimensional ,then

$$h = [\ a1\ a2\ \ldots\ an\ ] \qquad \text{Model(1)}$$

If degradation operator model is two dimentional,then

$$h = \begin{bmatrix} a11 & a12 & \ldots\ldots & a1n \\ a21 & a22 & \ldots\ldots & a2n \\ \ldots\ldots & & \ldots\ldots & \\ \ldots\ldots & & \ldots\ldots & \\ am1 & am2 & \ldots\ldots & amn \end{bmatrix} \qquad \text{Model(2)}$$

We then analyse LBS for a single ideal unblurring point.It is important to estimate the following parameters in LBS:

- BL of LBS;
- Blurred pixels grey volumes in LBS.
- Estimation for restoration operator model.

Length of digital degradation operator model = BL of LBS

We independently analyse LBS in x-axis and LBS in y-axis, then we have a two dimentional digital degradation operator model.

We have obtained support from physical experiment concerning LBS.In virtual satellite remote sensing image processing, using digital image enlarging processing soft or hardware devices, we may directly view if the digital image point is blurred or not. Also, we may locate single points and edge images which have LBS for SPOT and TM satellite image.

When using certain digital image processing systems,for example,the American COMTAL digital image processing system , we measure BL of LBS along x-axis(or along y-axis) and pixels grey volumes in LBS. This physical experiment is an important base for limited blurring set analysis.

Human eyes have a powerful capability of determining blurred images and pixels. This is useful tool. It is an important base for interactive restoration mode.

METHOD FOR REMOTE SENSING IMAGE RESTORATION

An Ideal remote sensing restoration image in LBS is

$$f(\alpha,\beta) = \sum_{X=0}^{M-1} \sum_{y=0}^{N-1} g(x,y)w(x,\alpha,y,\beta) \qquad (3)$$

we may estimate the restoration image $f(\alpha,\beta)$ from degradation image $g(x,y)$. Eq.(1) and Eq.(3) may be thought of as beeing a pair of general transformation equations in a LBS situation. When

$$h(x,\alpha,y,\beta) = h(x-\alpha,y-\beta)$$
$$w(x,\alpha,y,\beta) = w(x-\alpha,y-\beta)$$

this is a linear space invariance system.The restoration has been turned to the convolution operation for restoration operator model in LBS, or deconvolution for degradation operator model in LBS . We use the interactive restoration mode for image processing on TM and SPOT remote sensing satellite images.

1.We view some raw pixel on an enlarged image to locate some LBS for single isolated points Pi(i=1,2,...k) or edge image,then estimate BL.

2.Measurement of blurred pixel grey volumes in LBS for points Pi (i= 1,2,3,...,k) is obtained by hardware.

3.We estimate the digital image degradation model.

4.We estimate the digital restoration model. The following are some calculation methods:

A) An estimated degradation model $\xrightarrow{FT}$ $H(u,v)$

$$H(u,v) \rightarrow \frac{1}{H(u,v)}$$

$$\frac{1}{H(u,v)} \xrightarrow{IFT} \text{restoration operator model}$$

B) Interactive estimation mode for digital restoration model. If we have a set of digital estimated restoration models which are not exact models, we may use the interactive mode to locate optimal restoration model.According to Eq.(3),we obtain result images on the screen , and then select the optimum image.

4.According to Eq.(3),we obtain restoration images,and then display the images on the screen. We then view the result image.If the result image is not sufficient , we modify the restoration operator model in LBS in order to obtain a satisfactory image

REMOTE SENSING SATELLITE IMAGE PROCESSING RESULTS

It is important to estimate a remote sensing restoration operator model. The following are some methods:

A) Direct measurment for digital degradation model based on LBS and estimation for digital restoration model.

B) Indirect estimatation for digital degradation model and estimation for digital restoration model.

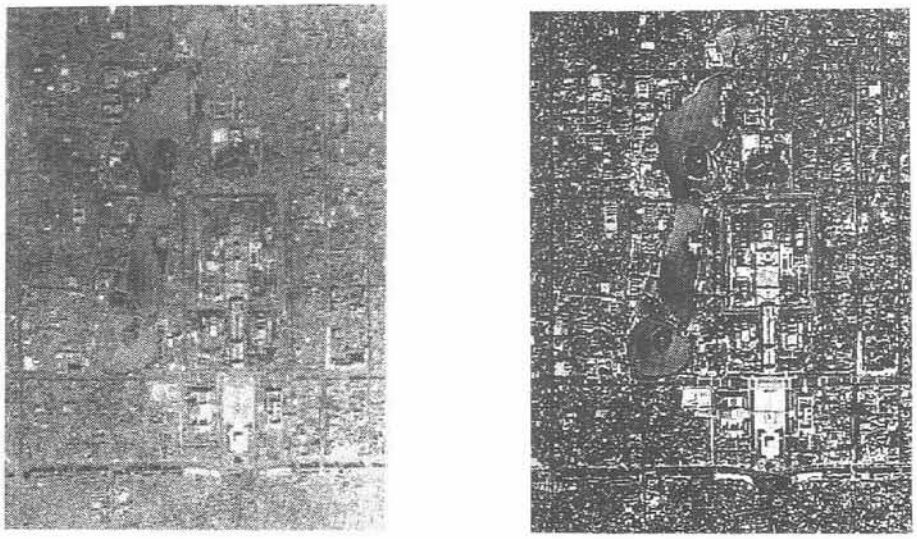
C) Interactive estimation for degradation model and restoration model.

For example:

$$w(x,y) = Mxy \sum_{x=1}^{LBx} \sum_{y=1}^{LBy} sign(x+y+kx+ky)$$

$$sign(x,y) = \begin{cases} 1 & (x+y+kx+ky)>0 \\ -1 & (x+y+kx+ky)<0 \end{cases}$$

We applied interactive estimation for the degradation and selected an artificial function family as a digital restoration operator model. Figure.1(b) was produced by the method in SPOT remote sensing satellite image.



(a)Before processing (b)After processing

Figure.1

CONCLUSION

A)The restoration processing method based on LBS is available for TM and SPOT satellite image processing, without any PSF or TMF as priori knowledge.
B)Caculation operation by this method is faster than FFT restoration opearation.
C)Processed image size is large,for example,8000 pixels by 6000 lines.
D)This method would be useful for other digital image processing, for example, weather satellite image processing, resources satellite image processing, remote sensing resample image processing,etc.

References

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