



Satellite Image Gap Filling Technique

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Abstract

In the current research work a useful gap filling method was presented. Images over Al Mosel city in Iraq were used as tested images. The linear algorithm for high resolution (H.R.) image interpolation were based. The difference between the proposed algorithm and conventional nearest neighbor algorithm is that the concept applied, to estimate the missing pixel value, is guided by the nearest value rather than the distance. In other words, the proposed concept selects one pixel, among four directly surrounding the empty location, whose value is almost equal to the value generated by the conventional bilinear interpolation algorithm. The experimental results show that the proposed method demonstrated higher performances in terms of H.R. and thus is applicable to gray level satellites images.

Keywords: Gap filling, image inpainting, remote sensing, and missing data filling

تقنية ملء الفجوات في صور الأقمار الصناعية

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الخلاصة

في البحث الحالي تم تحضير طريقة مفيدة لملء الفجوات. اضافة الى بعض صور الاقمار الصناعية العالمية تم اختيار صورة للموصل فوق العراق كصورة اختبارية. خوارزمية بسيطة وكفوءة لاستكمال الصور تم اعتمادها. الفرق بين الخوارزمية المقترحة وخوارزمية الجار الاقرب التقليدية بان المبدأ المطبق هو لتخمين قيمة البكسل المفقود منقاد الى القيمة الاقرب وليس الجار الاقرب. بعبارة اخرى، ان المبدأ المقترح يختار بكسل واحد من بين اربعة مواقع محيطة بالموقع الفارغ، والذي دائما تكون قيمته مساوية الى القيمة المتولدة باستخدام خوارزمية الاستكمال الثنائية. النتائج العملية توضح ان الطريقة المقترحة استعرضت اداء عالي وحتى على الصور العالية الدقة وهذا يعني انها قابلة للتطبيق لصور الاقمار الصناعية ذات التدرج الرمادي.

1. Introduction

Reconstruction of missing or damaged portions of images is an ancient practice used extensively in artwork restoration. Also known as inpainting or retouching, this activity consists of filling in the missing areas or modifying the damaged ones in a non-detectable way by an observer not familiar with the original images. Applications of image inpainting range from restoration of photographs, films and paintings, to removal of occlusions, such as text, subtitles, stamps and publicity from images. In addition, inpainting can also be used to produce special effects [1].

Gap filling (inpainting) in satellite images aims at filling gaps occur due to instrumentation

error, losses of image data during transmission; such area involve reconstruction in satellite image referred as gapped area in satellite images. Gap filling in satellite images can be classified as single source, multi-source and hybrid methods. Multi-source methods involve more than one image for reconstruction. Single source methods use same image information to fill gaps. Hybrid method combines both of the above approach. There is ongoing research in the field of inpainting also aimed at reconstruction of images in plausible way. Inpainting methods can be classified as based on PDE, based on exemplar based inpainting and based on classification of blocks [2].

The thematic mapper satellite ETM + Scan Line Corrector (Scan Line Corrector, referred to as SLC) failure. Since then, only in the ETM+SLC-Off mode of operation, it provided with a slit on the image data. The image is difficult to normal use. For the "SLC-Off" data points in the data, its accuracy and geometric accuracy of radiation almost no influenced of SLC failure. Landsat-7 is still running track, in addition to SLC other than damage to the device performance is still intact, the main work of scanning mirror also has the ability to provide useful image data. Therefore, ways to repair the SLC data gaps caused by failure to make normal use of image data can be, the international remote sensing has become a hot research field [3].

2. Related works

Soon after SLC failure, a joint United States Geological Survey/National Aeronautics and Space Administration (USGS/NASA) Landsat team explored a number of different options for filling in the data gaps in the SLC-off images. One method developed was a local linear histogram-matching method using one or more SLC-off or SLC-on images [4]. This method applies a local linear histogram matching in a moving window of each missing pixel to derive the rescaling function. This re-scaling function is then used to convert the radiometric values of one input scene into equivalent radiometric values of the scene being gap-filled, and the transformed data are then used to fill the gaps of that scene. This method is very simple and easy to implement, and can resolve many of the missing-data problems if the input scenes are of high quality (e.g., negligible cloud and snow cover) and represent comparable seasonal conditions [4].

Geostatistics based methods have also been employed (Pringle, et al.) [5], in which kriging or co-kriging techniques have been used to fill the data gaps. The case studies showed that these geostatistical methods can also be very effective for interpolating the missing pixels in the SLC-off imagery. While the above methods can restore the un-scanned gaps in ETM+ SLC-off imagery, sometimes with very good results, it should be noted that the above methods also suffer from a number of limitations that have precluded their widespread use, especially for quantitative application [5].

The geostatistical interpolation methods also have two major drawbacks. First, these methods do not predict the reflectance well at the pixel-level, and thus are not optimal for small and

discrete objects. Secondly, these geostatistical approaches are very computationally intensive, which limit their implementation for mass production (Pringle, et al.) [5]. Based on the shortcomings in the above methods, the aim of this study is to demonstrate the application of a simple and effective method to fill the gaps in SLC-off ETM+ imagery. This new method, which we will refer to hereafter as the Neighborhood Similar Pixel Interpolator (NSPI), has the potential to interpolate the value of pixels located in the gaps accurately, especially improving results in heterogeneous landscape areas. In this paper, we will first describe this approach and the algorithm, and later on we will demonstrate its use and performance on simulated and actual SLC-off images.

3. Proposed method description

Many algorithms have been proposed for gap filling in satellite images. The existing gap filling algorithms for satellite image gap filling can be characterized as multi source, single source and hybrid. In the first category gap areas are constructed using other useful sources. The second category mostly is based on within image pixel similarities/dissimilarity rules where gapped areas are constructed using non-gapped areas in the image itself.

In general the proposed method could be considered from 2nd type. It's dependent on the single image (distorted) and fills the missed pixel depending on the neighboring pixels.

The implementation of proposed gap filing method illustrated in details in the following lines:

1- Load the Picture as array (for faster operation)

2- Create a Mask picture Mask array (Mask_{x,y}) using following function:

Move Thru the Picture in X and Y coordinates scan for missed\black pixel.

$$Mask_{x,y} = \begin{cases} True, & \text{pixel}_{x,y}=0(\text{missed}) \\ False, & \text{otherwise} \end{cases}$$

3- Move Thru the Picture in X and Y coordinates scan for missed\black pixel.

4- mCounter(for missed pixels)= 0; If Mask_{x,y} = True, then we found a missed pixel, then mCounter:= + 1

5- Check if there is a Colored Pixel around missed pixel, If yes then add the color cCounter(for colored pixels)= 0, this done as follow (see fig.2).

- If not Mask_{x-1,y} then Buff-Pixel:=Pixel_{x-1,y}; cCount=+1

- If not Mask_{X + 1, Y} then Buff-Pixel:= Buff-Pixel + Pixel_{X+1,Y} ; cCount==+1
 - If not Mask_{X,Y-1} then Buff-Pixel:= Buff-Pixel + Pixel_{X,Y} ; cCount==+1
 - If not Mask_{X+1, Y} then Buff-Pixel:=Pixel_{X+1, Y} : cCount:=+1
- 6- If we have 2 or more colored pixels around?
If yes then fill the missed pixel with a combination: If cCount > 1 Then
New-Pixel_{X, Y}= Buff-Pixel/ cCount
we removed a transparent pixel
Mask_{X, Y}= False; mCounter= - 1
End If
Buff-Pixel=0
7. If there is still a transparent pixel then
RESTART ; Loop Until mCounter < 1

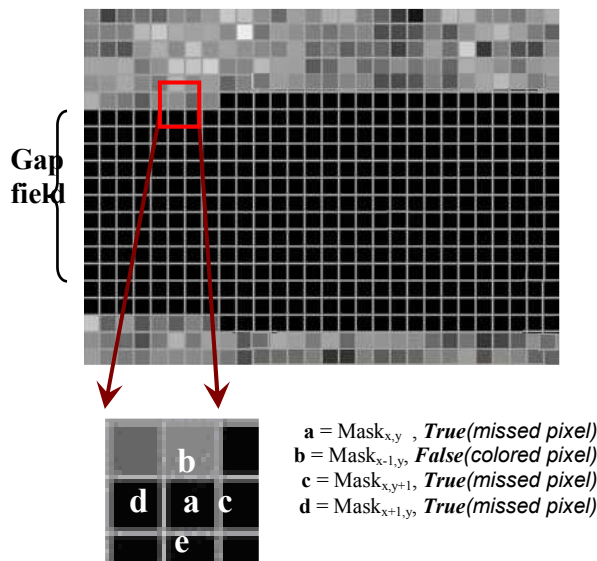


Figure 2- Illustration Of Mask_{x,y} Window In The Scan Gap.

4. Tested Results

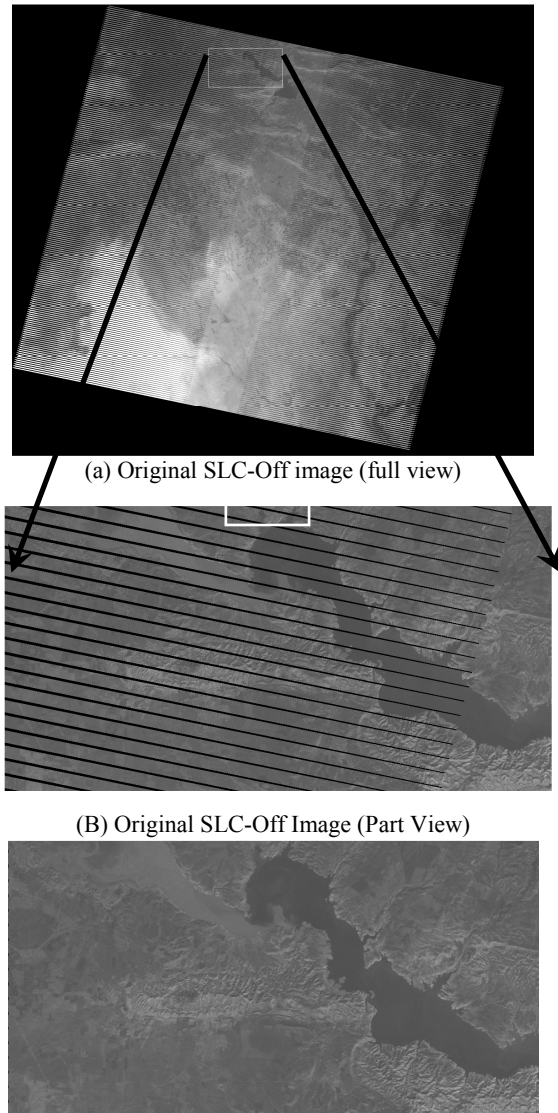
Two test scenes, along with two compatible fill scenes, were selected for analysis, see fig3. In addition to the visual comparisons of the gap-filling methods, we performed quantitative evaluation over the numerical phantom results as well.

We evaluated the results of the numerical phantom dataset by calculating the mean square error (MSE) in the image domain. %MSE represents the percentage ratios between the MSE values calculated as, [6]:

$$MSE(f_{EST}(x,y), f_{GAP}(x,y)) = \frac{\sum_{x=1}^M \sum_{y=1}^N [f_{EST}(x,y) - f_{ORIG}(x,y)]^2}{\sum_{x=1}^M \sum_{y=1}^N [f_{GAP}(x,y) - f_{ORIG}(x,y)]^2}$$

where $f_{ORIG}(x,y)$, $f_{GAP}(x,y)$ and $f_{EST}(x,y)$ correspond to the images from the gap-free image, image with gaps and the gap-filled image, respectively. The %MSE values show

the error percentage remaining in the images after the application of the gap-filling methods. We applied the %MSE to the entire reconstructed images and the selected regions of the reconstructed images.

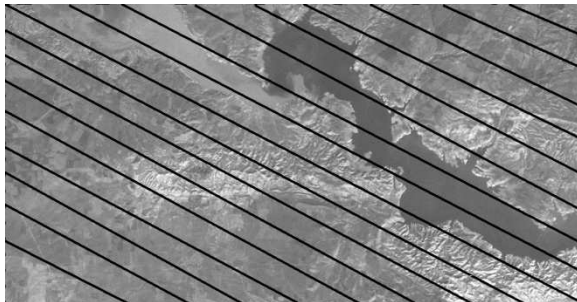


(C) Gap Filling With Suggested Linear Filling Method.
Figure 3- Examples Of Linear Filling Results,
(A) Original Lansat7 (Resolution=8461×7341 Pixel)
 Where: Image Format Is As Following:
 L71170035_03520091228_B10.Tif
 Llfpprrr_IIIYYYYMMDD_AAA.TIF
 LL=Landsat Sensor (LE For ETM+ Data; LT For TM Data)
 F= ETM+ Data Format (1, 2, Or G) (Character Omitted From TM File Name)
 Ppp = Starting Path Of The Product
 Rrr_Rrr = Starting And Ending Rows Of The Product,
(B) Segment From (A) Image (Resolution=1199×625 Pixel),
(C) Corrected Image Of (B) Image.

In fig4, the mean MSE was calculated. Linear filling was used to fill the gaps in the satellite data. Error estimates were made by calculating the mean absolute difference between pixels that existed in both the matched fill scene and the SLC-Off image. These error calculations were made on 30-meter data for every test scene, but due to processing constraints matched images for the thermal and pan bands were only created for one test scene each.



(A) Original Image Of Image Shown In Figure3-C (Auto Contrast Stretched Using Microsoft Picture Manager Ver2003.



(B) Gap Synthesized Using Mspaint Package, Black Line Width=6 Pixel.



(C) Black Lines Removing (Gap Filling) Using Proposed Method.

Figure 4- Examples of Linear filling results, MSE=0.65 and %MSE=1.33.

5. Discussion and Conclusion

In the current research work, for the gap-filling of the satellite data, a linear interpolation method to fill gap within SLC-Off satellite was proposed. The performance of this gap-filling method was evaluated quantitatively and visually with the numerical phantom dataset.

The fast and simple linear interpolation method gave as good results. The estimation time was shortened. We observed visual improvement in the reconstructed images.

The performances of both methods were deteriorated with the increased noise contamination in the satellite image.

However, we observed that the linear interpolation performed better for the low distortion ratio (i.e., MSE=0.65).

6. References

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