

## GAP LINES REDUCTION FOR ENHANCED TEMPORAL LANDSAT ETM+ IMAGERY USING MORPHOLOGICAL OPERATIONS

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### Abstract:

The failure of the Scanning Line Corrector of ETM+2004 of Landsat7 in imposed systematic data gap lines on retrieved the correct satellite images and rejected the ability to provide continuous information in different scientific fields. While a many processing algorithms proposed to fill out this gap lines, utmost of these algorithms are just only valid through the homogeneous image regions. When there are applied to process the heterogeneous ETM+landsat7 images, returning image pixels and image features can't become correct and precise. In this study a gap filling algorithm has been proposed that is based on the morphologic operations of image. The operations used here are combination of the processes, dilation and erosion. The algorithm employs opening, closing morphologic operations of gap image methods to identify the properties and size the separated gap lines image for ETM+landsat7 images. Each band images has been passed through milt-image processing stages. The images that output of all stages are eight corrected images. Enhanced images are very clear and the gap lines completely disappear from all image bands. The algorithm succeeded in correction and filling gap lines for homogeneous and heterogeneous image areas.

**Keywords:-** Landsat7 , The Scan Line Corrector (SLC) ,Filling Methodology

### 1. INTRODUCTION

Landsat it is a series of satellites for the purpose of exploring the Earth's parts and for civil purposes, as well as monitoring the displacement of continents and beaches. Its images are used in surveying natural resources in countries and measuring terrestrial changes that may arise from natural erosion or be caused by human activity. NASA has launched since 1972[1]. The Landsat series of programs since its inception has given a lot of information about the surface of the earth. Through his accurate measurements, it became possible for scientists and researchers to obtain continuous information on urban growth, cities, agricultural irrigation,

desertification and deforestation, especially in tropical regions. Landsat images also gave important information about coral fields and ice fields in the North and South Poles and on the high mountains.

LandSat 7 is the 7 satellite of the Landsat platform. LandSat 7's primary target was commenced on April 15, 1999 and is to update the Global Archive of Satellite Imagery and looks like up-to-date images. The ETM+ sensor give 12 multispectral bands passes up each all region on Earth every 16 days ,with a narrow  $15^\circ$  field of vision [2].

The SLC is an electromechanical system at the board Landsat 7 ,destined to recompense for the forward action of the satellite during ETM+ scanning, has failed completely in May 31/ 2003 . wher the dismissil an ultimate result is that about 22% of scanned image data were misplaced [3,4]. This defect in the work of the ETM+ imaging system, which caused distortions in the images received from the ground, and these distortions are presented by a gaps in the form of diagonal lines extending from the left of the image to the right of it and in all the received images. the entire gap-line ranges from 11 to 14 pixels for all ETM+ spectral band images. Also, the gaps shift locations s barely with spectral bands, producing non-identical regions that have absenting pixels across all multi spectral bands with correct statistics in some bands and no information in others [4,5]. So, the images which gained before the failure of SLC are specific SLC-on images, and those acquired after the failure of SLC are specific SLC-off images[6]. In spite of the SLC failure produces, needless to say bad effect on Landsat 7 ETM+ Imagery. Fortunately, the ETM+ sensor scans 80% of spectral bands pixels perfectly, without any geometric and radiometric distortion[7].

Scientists and researchers have developed several techniques remove this defect form ETM + images to correct them and eliminates the scan gaps. Now listing some of the most important studies that dealt with this subject to remove lines of gaps form ETM+ SLC images:

Generally there are many studies that have been involved with the correction gap slc-off images .

Maxwell et al. (2007) inserted an method to fill the gaps mostly dependwd on a multi-scale segment paradigm. The conception of segmentation is to collection individual pixels into a sequence of equall size groups depending to their spectral and spatial characteristics [8].

Chen et al.(2011) suggested a deterministic approach indicated to as the Neighborhood Similar Pixel Interpolator NSPI , to promote the total performance of predicting heterogeneous regions. The NSPI supposes that

neighborhood pixels nearer to the un-scanned (gap) pixel share similar spectral similar and temporal patterns of modifications to the un-scanned pixel(s). By integrate the data provided by the neighborhood pixels the value of the missing pixels can be determined. the Results have proven that the NSPI gives far better continuous characteristics in contrast with previous techniques [9].

Hu (2011). usage imulti temporal images to remodel SLC-off ETM+ images by way of applying the Local Correlation Analysis approach (LCA) on simulated and actual SLC-off ETM+ images , then evaluate the effects with straitfy the LLHM technique on same e tested images. Visual and statistical indices indicated that the LCA method filled image and coincided well with the target image [10].

Zeng et al.(2013) suggested a weighted linear regression (WLR) algorithm compact in with Laplacian prior regularization to gain better missing pixels in SLC-off imagery. The WLR algorithm builds a linear regression paradigm between the corresponding pixels of multi-temporal images to fill the pluralilty of missing pixels. The Laplacian prior regularization method, is then applied to fill these gap pixels that cannot be absolutely recaptured by using WLR algorithm. where the inserted approach has been demonstrated to remode complicated landscapes strictly . However, its performance becomes limited when applied to complicated landscapes with large information gaps [2].

Salema S. Salman et al ,(2020)[11] , she embraced the criterion of correlation between satellite images to identifie spatially corresponding between images. where Three different multi temporal images were applied in filling the gaps , by use two algorithms. In the first algorithm, we got one image set free of any gaps when using three images of different times, while in the second algorithm, we got images set free of gaps depend ing on the images effecting from the first algorithm. Simulated and true SLC-off ETM+ compounds have been used to test the execution of the proposed system by comparing with the original information so as to test the resulting bands from the first and the second algorithms which are based on the correlation method .

In this study, a technique for removing gap lines from ETM + images acquired at 2004 was developed, where the temporal image fusion technique presented by Salema et.al. [11] Was used to remove the SLC gap as a first stage in removing the gap lines. However, this technique fails in some cases. Among these cases the ETM+ images in 6\5\2004 and 23 \6 \2004, as

applying this technique to ETM+ 2004 images removed a large part of the gaps, but it is not a complete removal. As the images resulting from the first stage of processing contain small line gaps that sometimes extend from the left ETM+ image side to the middle of the image plane, and the gap line width is rather small. Therefore, a vertical line processing technique has been used only in gap lines areas where there are small line gaps, by applying linear filtration using morphological techniques

## 2- GAP SCAN LINE FILLING METHODOLOGY

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In this study, ETM + images were taken for Baghdad and the southern regions of Iraq. These images were cropped after performing the registration process to obtain a complete geographical match of the band images captured from the landsat7 to the Earth during different time periods. The disadvantage of these images is the large distortion in them due to the defect that occurred in the imaging system, as all the spectral bands began to show gap lines. Unfortunately slightly slanting and distort the image from right to left of the images, these cropped images are shown in Figure (1). Where applying temporal filling gap algorithm [11] that uses three different temporal ETM+ images for each band in order to make an initial gap filling step: The gap-filled algorithm was efficient in processing many ETM + images and removing gaps lines completely. But in some cases, it did not succeed in completely removing the gaps, but after its implementation, a large proportion of the gap lines in the images were removed, but it left narrow gap lines and sometimes extended to the middle of the images. Where the obtaining ETM+ images that highly reduced gap lines, but containing some gap lines in the left of each band image see figure (1). Therefore, in this study as a second step: morphology filtration technology was adopted for the purpose of completely removing gap lines from the images processed in the first step. The proposed morphological algorithms will be used for the purpose of processing the resulting band images and filling the remaining gap lines and removing them completely. Where in the resulted images for the SLC-off 2004 ETM+ images the gap line width is not equal at left side and right side an algorithm was proposed to fill gab lines and correct pixels within narrow side and remove the gap lines. However, this algorithm is not effective for eliminating gap lines when the temporal technique is not used to reduce the width of the gap lines and reduce a large portion of them. This is because if this technique is applied to remove the gap lines directly without using any other technique before it, it will lead to the appearing a high

distortions in the resulting ETM+ images, because the lines of the gaps in the ETM+ images are thick, sometimes 11 to 14 pixels thick.

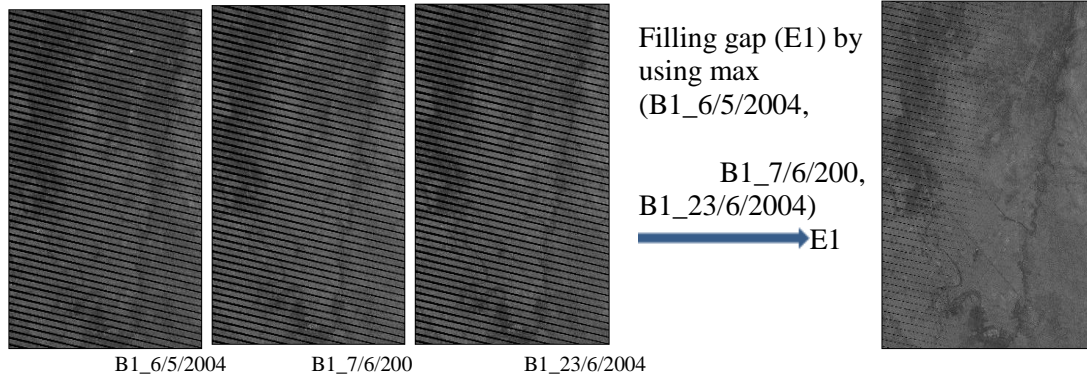


FIGURE 1: Filling gap (E1) by using max (B1\_6/5/2004, B1\_7/6/200, B1\_23/6/2004).

Therefore, in this study, morphology filtration technology was presented as an auxiliary technique aimed at removing any remaining lines from the first step processing technique (temporal algorithm) [11].

The applicability of filling in morphology has been tested until now across a maong of applications, which include the dilation, erosion, opening and closing methods [2]. the Dilation method is an operation that “grows” or “thickens” the objects orthe pixel of image in a binary image. The specific method and extent of this thickening is managed by a shape mention to as a structure element. The method of dilation will be described mathematically and algorithmically[12].

To implement dilation method of a binary image, it can be successively place the middle pixel of the structuring elements on each background pixel. where If any of the neighborhood pixels are foreground pixels, then the background pixel is replaced to foreground , the dilation method of image A by way of structuring element B is indicated as as AB. The mathematical definition of dilation method of A by B is defined as: [2,12]

$$AB = \{ (\bar{B})_x \cap A \neq \varphi \} \quad (1)$$

The dilation method of A by B is the set including of all the shape element original locations , where the reflected and translated B overlaps at least some part of A. while the Erosion method a foreground pixel just remnant a foreground pixel if the 1s in the structuring element ,are entirely contained inside the image foreground. If not, it will become a a background pixel [10].

$$AB = \{(\tilde{B})_z A\} \quad (2)$$

Opening method is the distinguish given to the morphological process of erosion followed by dilation with the equal structuring element. We mention the opening of A by using structuring element B as follow:

$$A \circ B = (A \ominus B) \oplus B \quad (3)$$

The universal impact of opening method is to removing small, separated objects from the foreground of an image, and checking them in the background. where It tends to smooth the contour of a binary object and breaks narrow joining regions in an object. while the Closing method is the name given to the morphological process of dilation method followed through erosion with the same structuring element. The closing method of set A through structuring element B is described as follow:

$$A \cdot B = (A \oplus B) \ominus B \quad (4)$$

Which is an dilation method of A through B and observed by intermediary of an erosion of the result by B, and It has a analogous geometric interpretation except that B is rolled on the outside of the boundary, while Closing additionally tends to smooth sections of contours however as opposed to opening[10].

### 3- THE PROPOSED ALGORITHM

Algorithm: The proposed morphological filtering methods to complete the gap SLC lines removal of the processed ETM+ images by applying Salema et.al method[11]:

**Input:** The ETM+ Eight bands images (I1-I8)// obtained by Salema et al. method[11]

**Output:** Free gap lines ETM+ bands images K) .

**The Steps:**

1- Calling band (I6 or I7) and converting into binary image (IB) to distinguish the points of gap-lines in the image and assign a zero to them, these images shown in fig (2: a). Note: I6 and I7 have the nature of its characteristics where the gap lines are very clear because the background of the image is more brightness than the rest of the other bands. Therefore, a simple ranking operation can be used to convert this band image into a binary image in which the gap values are zero. Then it will be considered as the locations of the zero values representing the gap lines locations in all the spectral bands to be processed in this algorithm.

2- Find the negative for the binary image IB to gat IN, see fig (2: b).

3- Calculate the number of gap (Ng) points in (IB): using matlab statement Ng=sum (sum (IB)).

4- Calculate the total number of image points (Nt) in (IB):  $N_t = M \times N$ ; where M, N represent number of row and number of columns of (IB).

5- Calculate points that do not represent gaps (Nn) in (IB):  $N_n = N_t - N_g$ .

6- Now to fill gaps to all eight bands let's do following steps:

- i. Calling band (Ii) that want to process and correcting the gap lines in it; where  $i=1, 2, \dots, 8$ , for example here will take  $i=1$ , i.e. take band image I1, see fig(2:c).
- ii. Multiply (I1) by (IB) to get a band that guarantees the gap points are equal to zero:  $J_0 = I_1 \times IB$ , fig (2: d).
- iii. Extend zero's lines on image I1 using matlab statement (strel, 13 pixels with theta 90o), then to filling gaps on I1 after extending lines, use one of the following methods:

A-  $J_E = \text{imdilate}(\text{strel}(I_1))$ , fig (2: e). Extract only the non-gaps part of the image (JE), using  $J_T = J_E \times I_N$ , fig (2: i). Finally addition of the gap line image J0 to the JT image gets the enhanced image without gaps:  $K_1 = J_0 + J_T$ . See fig(2: m).

B-  $J_E = \text{imclose}(\text{strel}(I_1))$ , fig(2: f).

$J_T = J_E \times I_N$ , fig (2: j).

$K_2 = J_0 + J_T$ . See fig(2: n).

Now a rebate stabs A and B, but for K2 image, gating from stab 2:

C-  $J_E = \text{imdilate}(\text{strel}(K_2))$ , fig(2: g).  $J_T = J_E \times I_N$ , fig (2: k).

$K_3 = J_0 + J_T$ . See fig(2: o).

D-  $J_E = \text{imclose}(\text{strel}(K_2))$ , fig(2: h).  $J_T = J_E \times I_N$ , fig (2: l).

$K_4 = J_0 + J_T$ , fig(2: p).

7- The resulting enhancement image bands without gaps lines are ( $K_i$ ,  $i=1, 2, 3, 4$ ) these represents the corrected images without gaps, for band (I1).

8- End.

#### 4- EVALUATION AND VALIDATION

The accuracy overall performance of correction algorithm of filled gab lines results will be quantitatively estimated by evaluating them with the actual ETM+ band images. Normalized mean square difference NMSD is a generally used measure for calculating the accuracy results using NMSD[13,14]:

$$NMSD = \frac{1}{N_t} \sum_{p=1}^{N_t} \left[ \frac{J_{mi}(p) - I_i(p)}{255} \right]^2 \quad (5)$$

Where  $N_t$  is the total number of image pixels  $I_i$  represents the image of the  $i$ -band and  $J_{mi}$ .

represents the enhancement image of the  $i$ -band by the  $m$  method where ( $m = 1$  to 4), and  $p$  is the pixel coordinates of the image in the  $i$ -band plane.

Now for comparison between the suggested four-gap filling methods, the normalized mean square error (NMSD) of the band images will be adopted with the images enhanced images using the four ways.

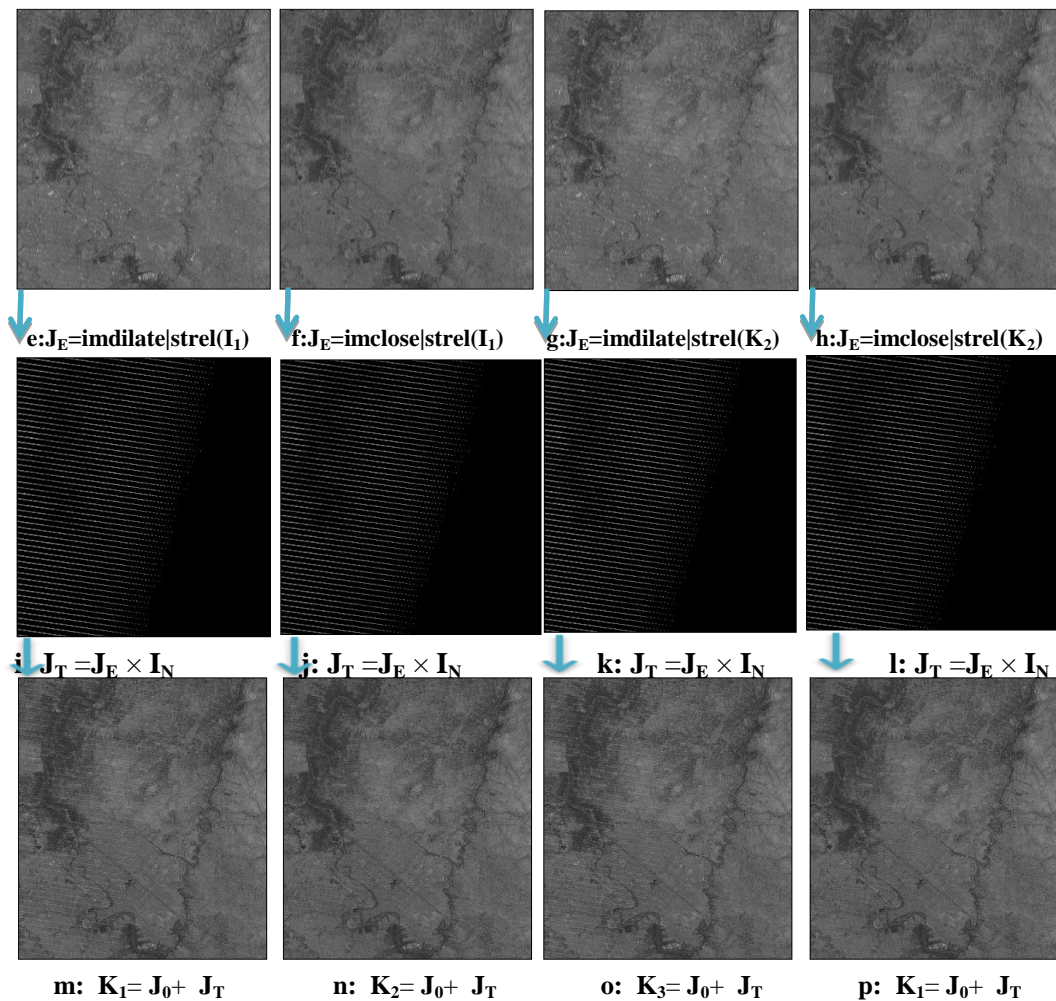


FIGURE 2: Demonstrates the algorithm steps of enhanced band images.



The amount of the normalized mean square error for non-gaps regions  $NMSD_{ng}$  will also be calculated between the image areas that do not represent the gap lines before and after the enhancement as the number of gaps points ( $N_g$ ) will be subtracted from the total number ( $N_t$ ) of image elements in order to determine the amount of the  $NMSD_{ng}$  only for the areas of the image that do not represent gaps.

$$NMSD_{ng} = NMSD \times EG \quad (6)$$

$$EG = \frac{N_t}{N_t - N_g} \quad (7)$$

Where  $N_g$ : is the number of gap lines points, The prediction error is usually represented by a smaller value by  $NMSD$  value, thus greater accuracy is expected.

## 5- IMPLEMENTATION RESULTS

Proposed algorithm has been built in using morphological image operations. The gap lines pixels are extracted using threshold method for the pixels that are less than specific threshold for  $I_6$  or  $I_7$  image. Mathematical operations with morphological image operations are used for the image arrays resulting from successive implementation stages of algorithm, in order to obtain the best correction image. The gap lines were closed and the missing pixels value are restoring completely after filling the gap with the correct elements using the morphological processing dilation and close techniques.

Table (1) shows  $NMSD$  and  $NMSD_{ng}$  calculations of enhanced corrected band images. The  $NMSD$  calculated between band image  $I_i$  and enhancement image  $J_{mi}$ . The values within table (1) have shown the difference between images as a result of filling gaps. The increase or decrease is not considered an effect on the quality of image, but only shows the change resulting from the gap-filling process. The mean of squared differences between the images was calculated to demonstrate the effect of gap filling. So,  $NMSD$  represent the amount of added information to fill the gap image lines.

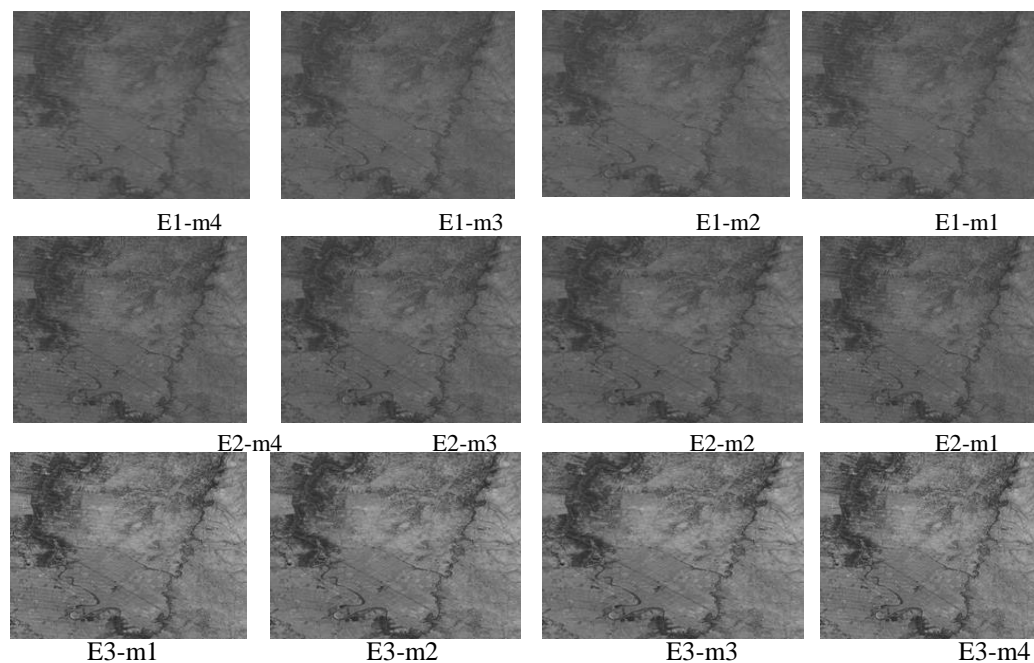
$NMSD_{ng}$  have been calculated for non-gap image region between bands image  $I_i$  and enhanced image  $J_{mi}$ . The values in table (1) indicate that  $NMSD_{ng}$  is the best mathematical method for calculating the effect of gap filling process. It was expected to give the lowest square-error ratio between images in non-gap areas. The values of  $NMSD_{ng}$  within table (1) indicate that the

process operations are efficient. This is the fact that inferred from  $NMSD_{ng}$  calculations of all the enhanced band images. The slight relative change or a zero error, so the change is limited for the gap area only and the  $NMSD_{ng}$  between the two images is nonexistent.

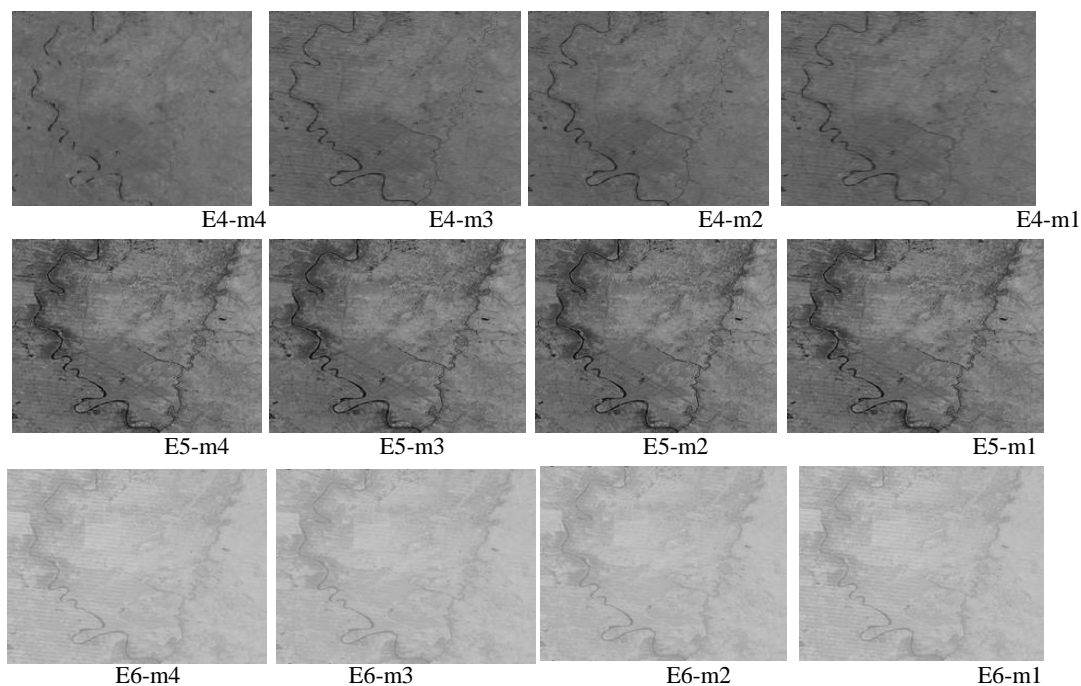
**TABLE 1:** Statistical  $NMSD$  and  $NMSD_{ng}$  calculations for the output enhanced images.

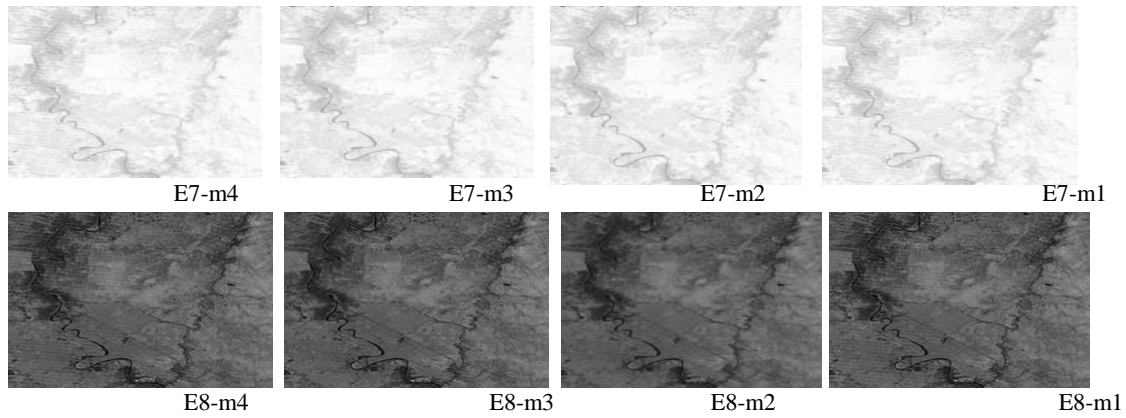
Enhanced Image (E=1,2,...8)	NMSD for the method(m=1,...4)				NMSD <sub>ng</sub> for the method(m=1,...4)			
	m=1	m=2	m=3	m=4	m=1	m=2	m=3	m=4
<b>E1</b>	0.0175	0.0069	0.0069	0.0175	0	0	0	0
<b>E2</b>	0.0266	0.0108	0.0108	0.0266	0	0	0	0
<b>E3</b>	0.0662	0.0278	0.0278	0.0662	0	0	0	0
<b>E4</b>	0.0315	0.0147	0.0147	0.0315	0	0	0	0
<b>E5</b>	0.0643	0.0295	0.0295	0.0643	0	0	0	0
<b>E6</b>	0.0265	0.0126	0.0126	0.0265	0	0	0	0
<b>E8</b>	0.0640	0.0282	0.0282	0.0640	0	0	0	0

Figures 3 and 4 shows that enhanced images for the methods (m=1,2,3 and 4) from the successive processing stages are clear images with the best obtained quality for all band images of SLC-off ETM+. Most of the black gap lines disappeared and most of missing values data were recovered where the image became very clear details.



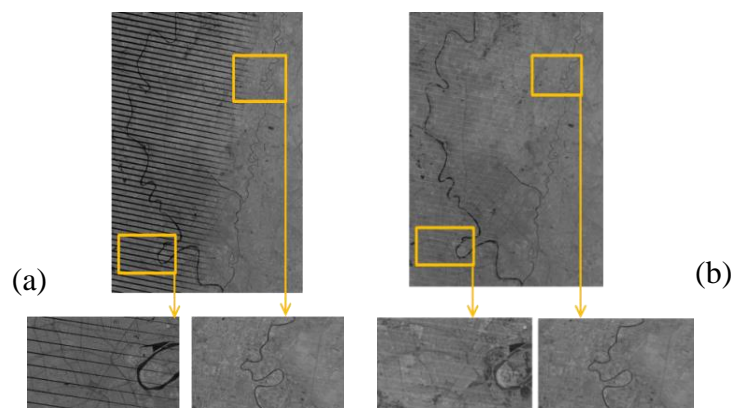
**FIGURE 3:** The final enhanced images for the bands 1,2 and 3 by applying temporal filling gap algorithm.





**FIGURE 4:** The final enhanced images for the band 4,5,6,7 and 8 applying temporal filling gap algorithm.

To find out the effectiveness of gap-filling process from the processed band image, small block images are extracted from the original and enhanced images band that is identical to the same location area on the earth's surface for E4 band image. The extractions is based on cutting block of size (360×249) pixel of I4 which is used for imaging vegetation, and make a comparison between the extracted block of original band image and enhanced image. As illustrated in figure (5), the image targets (soil, water and vegetation) remained confined to all its details without any significant change for the gab area and non-gab area for I4 and E4-m4 spectral band with corresponding to.



**FIGURE 1:** images illustration to small dedicated areas for gab area and non-gab area of E4 image band and the E4-m4 processed image. (a) Before gab-filling. (b) After gab-filling.

## 6- CONCLUSION:

From the results can be concluding the following points:

1. The algorithm achieved successful correction the gap pixels values at the left and right sides of the gap lines, where the estimated pixel value become closer to the right real values.
2. Evaluation of errors for the corrected images using NMSE gave values zero or close to zero, so all corrected images showed quantitative and qualitative enhancement.
3. Filling gab lines using proposed algorithm and correction pixels values dose not caused error for the non-gab image parts using correction algorithm.
4. Proposed algorithm is effective to get the positions of the best match in the bands image of the study area and make these images in the same place and area.

## 7- ACKNOWLEDGMENTS

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## اختزال فشل الماسح الضوئي للقمر الصناعي EMT+ بالاعتماد على صور ملتقطتة بأوقات زمنية مختلفة واستخدام عمليات المورفولوجيا

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### مستخلص البحث:

ان فشل الماسح الضوئي للقمر الصناعي EMT+ للعام 2004 أدى الى فقدان معلومات المنطقة الملتقطتة بواسطة القمر الصناعي، ولأجل استعادة المعلومات المختزلة والاستفادة منها في المجالات العلمية المختلفة، تم اقتراح العديد من الخوارزميات لمعالجة فشل الماسح الضوئي للقمر الصناعي EMT+ كانت ناجحة في استخلاص المعلومات في المناطق المتجانسة، لكن فشلت في استخلاص المعلومات في المناطق المتجانسة من الصور الفضائية. في هذه الدراسة تم اقتراح خوارزمية لملئ الفجوات الناتجة من فشل الماسح للقمر الصناعي EMT+ بالاعتماد على عمليات المورفولوجية . تستخدم هذه الخوارزمية عمليات الفتح والغلق لتحديد حجم الصورة وخصائص الصور EMT+ ، نتائج هذه الخوارزمية ثمانية صور مصححة .ان نتائج الصور الناتجة من هذه الخوارزمية خالية من الفجوات وتم استرجاع جميع المعلومات للمناطق المتجانسة وغير المتجانسة .  
الكلمات المفتاحية : لاندسات ( القمر الصناعي ) ، الماسح الضوئي ، طرائق المليء .