Cloud Removal Approach based on Poisson Image Editing

VEENA.V.S, P G Scholar
Department of Electronics & Communication
TKM Institute of Technology
KOLLAM, INDIA
veenalekshmi94@gmail.com

ARUN KUMAR.G, Asst. Professor
Department of Electronics & Communication
TKM Institute of Technology
KOLLAM, INDIA
arunkumarg84@gmail.com

Abstract*—Optical satellite images, which are widely used for land surface studies are severely contaminated with cloud cover during day time. Sensors are not capable for capturing portions below cloud contamination. So an effective method to remove the impact of cloud is necessary to enhance the availability of remote sensing data for various land surface applications. As far as satellite images are of concern, thick clouds will completely obstructs the observation of landscape and the uneven illumination caused by thin clouds will limits the further processing of optical satellite images. In this paper, a new methodology for reconstructing cloud contamination in satellite images is introduced based on Poisson image editing. For this approach, multitemporal cloud contaminated satellite images are required with the assumption that in each image cloud cover change significantly over a short duration of time. Cloud contaminated region in multitemporal images are detected using a suitable cloud detection algorithm in frequency domain.Suitable cloud free patch for reconstructing cloud contamination in target image are selected from the available reference images. Selection of suitable cloud free patch is performed based on the quality assessment and amount of cloud cover present in multitemporal reference images.

***Index Terms*— Keywords- Multitemporal images, Optical satellite images, Poisson image editing, SSIM index.**

I. INTRODUCTION

OPTICAL satellite images are the main source of geophysical information. Sensors used to capture these images usually operate in the visible region of electromagnetic spectrum which provides high resolution images. To perform land surface studies the information provided by these types of images are highly useful. But cloud contamination is one of the common problems in the case of optical satellite images. Recent studies have proved that about 60% of land surface will be obscured by cloud cover during day time which leads to the limited usability of available satellite resource data. So an effective methodtoremovecloud contaminationis necessary to effectively utilize available satellite images for land surface studies.

Cloud cover in satellite images are necessary for measuringliquid water content presentin the atmosphere but at the same time it obstructs the observation of landscapes which limits the effective utilization of satellite image resource data. So cloud contamination in optical satellite images become a serious problem for various applications of satellite images like crop yield estimation, environmental monitoring, archaeological investigations and so on.

The aim of this paper is to reconstruct thick cloud contamination from satellite images by considering multitemporal reference images. A Poisson image editing algorithm is used to reconstruct thick cloud contaminated portions in satellite images. It optimizes the pixel intensity value of the cloud contaminated portion in target image based on gradient domain imaging.

A number of cloud removal approaches have been introduced in past few years for cloud free visualization of satellite images. It can be broadly categorized into three categories:

1. In-painting based
2. Multispectral based
3. Multitemporal based

In In-painting method [2], undetectable modifications are provided by smoothly propagating cloud free information from the boundaries of the cloud contaminated image inwards. Limitation regarding this method is that the cloud free patches are selected from the same image itself, which makes this method unsuitable for further applications. In multispectral[3] based approach, a predicted value iscalculated for the cloudcontaminated target pixel by considering pixel values of cloudy image and cloud free image of same place at different instants of time.

In this paper, a new methodology of cloud removal is proposed based on multitemporal approach. Multitemporal images are the images which are captured from same place but at different instant of time. For this paper cloud contaminated multitemporal satellite images are required with the assumption that in each image cloud cover change significantly over a short duration of time. Suitable cloud free patch from available reference image is selected based on the image quality and minimum amount of cloud rate in the reference images.

The remainder of this paper is organised as follows. Section II describes the new methodology of cloud removal based on Poisson image editing. Section III describes about the concept of multitemporal images .Section IV describes about the histogram specification.Cloudratecomputation technique used in this work is discussed in Section V. Section VI explains about the quality assessment technique and Section VII about the Poisson image editing algorithm. Section VIII presents the experimental results and discussion while conclusion is stated in Section XI.

II.METHODOLOGY

Figure 1 describes the methodology used for this work. Multitemporal cloud contaminated satellite images are required with the assumption that in each image cloud cover change significantly over a short duration of time. Suitable cloud free patch for reconstructing cloud contaminations in target image is selected from the available reference images. Selection of suitable cloud free patch is performed based on the quality assessment and amount of cloud cover present in multitemporal reference images. Quality of working region in reference images are computed using SSIM index. Finally, reconstruction based on Poisson image editing was performed to fill the missing data after removing the cloud contaminated portions.

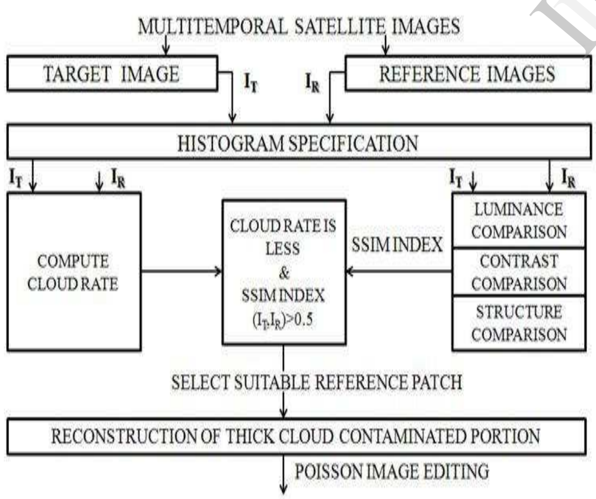

Figure 1:Basic block diagram

III. MULTITEMPORAL SATELLITE IMAGES

In remote sensing, image acquisition is an important pre-processing step. Remote sensing images are the representation of earth surface as viewed from the space and they may be of two types: analog images and digital images. Aerial photographs are analog images usually taken by some experienced analyst while the satellite images are digital and they provide real time transmission of remote sensed data to the ground station.

For the requirement of this work, cloud covered multitemporal satellite images are collected. Multitemporal images with cloud covers change insignificantly over a short period of time are collected. From those set of images, the image from which reconstruction of cloud contamination need to be performed is considered as target image and the remaining form the reference images.

IV.HISTOGRAM SPECIFICATION

Multitemporal satellite images are captured from same place but at different instant of time. Due to difference in solar radiance and atmospheric effects it is necessary to correct the brightness of all collected images.Histogram specification yields an output image with a specified histogram. It is an enhancement technique to improve visual appearance of the image. Three color channels of target and reference image are extracted. Histogram of the three channels of reference images were computed separately. It is then equalized with that of the target image. To intensity normalize all acquired images; histogram specification is applied to all reference images.

V.CLOUD RATE COMPUTATION

In optical satellite images, cloud contamination usually appears white in colour. The land areas usually have low frequency variations while cloud contamination has high frequency variations. To detect cloud contaminated portion within the satellite images, a frequency domain approach have been used. In this approach, an image in time domain

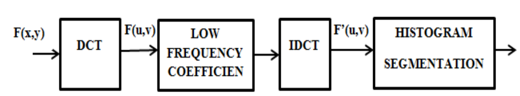

Figure 2:Cloud detection

F(x, y) is converted to frequency domain F (u ,v) using DCT. In DCT domain, the DCT coefficient located in the top left corner are significant. Reconstruction of image using only the low coefficient results in high quality reconstruction of original image. From the detected high frequency variation output, the cloud contaminated portions can be extracted using histogram segmentation. After detecting the cloud contaminated portions within the target and reference image, the cloud rate is calculated using the formula:

C = (Number of cloud contaminated pixels/Total number of pixels) *100 %(1)where, C is the cloud rate.

VI. STRUCTURAL SIMILARITY INDEX

In this paper, SSIM (Structural SIMilarity) index [4] is used to estimate the quality of working patch in reference image. SSIM index is a full reference image quality assessment metric which uses a full reference image for quality assessment. SSIM index estimates the quality of working patch by combining three components which characterize an image like luminance, contrast and structure.

Luminance comparison between target and reference image is given by,

$$L\ (I_T, I_R) = (2\mu_{IT}\ \mu_{IR}+C_1)/(\mu_{IT}^2+\ \mu_{IR}^2+C_1)\ (2)$$

Contrast comparison between target and reference image is given by,

$$C\ (I_T, I_R) = (2\sigma_{IT}\sigma_{IR}+C_2\ )/\ (\sigma_{IT}^2+\sigma_{IR}^2+C_2\ )(3)$$

Structure comparison between target and reference image is given by,

$$S\ (I_T, I_R) = (\sigma\ _{ITIR}+C_3)/(\sigma_{IT}\sigma_{IR}+C_3\ )(4)$$

Over all structural similarity is given by,

$$SSIM\ (I_T, I_R)= (2\mu_{IT}\ \mu_{IR}+C_1)\ (2\sigma_{IT\ IR}\ +C_2)\ /\ (\mu^2_{IT}+\mu^2_{IR}+C_1)\ (\sigma^2_{IT}+\ \sigma^2_{IR}+C_2) \qquad (5)$$

where μ_{IT} andμ_{IR} are the mean value of target and reference image. σ_{IT} and σ_{IR} are the standard deviation of target and reference image. $\sigma\ _{ITIR}$ are the co-variance coefficient. C_1 ,C_2 are constants to avoid instability.SSIM index value ranges between -1 (most dissimilar) to 1(most similar).

VII. POISSON IMAGE EDITING

Poisson image editing [7] is a seamless image blending algorithm. In this method, the reference image based on the lower amount of cloud rate and of better image quality is selected to reconstruct the thick cloud contaminated portion in the target image. The main concept is to stitch cloud free patch to the corresponding cloud contaminated patch. The image editing algorithm performs this task based on gradient domain imaging. Pixel intensity values underneath the cloud contaminated region have to be optimized using suitable iteration algorithm. In this methodology Poisson Jacobi iteration have been used to optimize the pixel intensity value underneath the cloud contamination.Reconstruction is based on gradient of the selected patches from reference image. V is the gradient of the patch selected from the reference image. Using V, we have to optimize the pixel intensities in the cloud contaminated regions. The reconstruction result is formulated as optimization equation as follows:

$$\min\ _f \iint_{\Gamma} |\nabla \mathbf{f\text{-}V}\ |^{\mathbf{2}}(6)$$

with boundary condition $f\,|\,\partial\Gamma = f^*\,|\,\partial\Gamma$

where, $\nabla = ((\partial/\partial x),(\partial/\partial y))$, is the gradient operator and can be calculated using finite difference method:

$$\partial f(x, y)/\partial x = f(x+1, y)-f(x, y)$$

$$\partial f(x, y)/\partial y = f(x, y+1)-f(x, y) \qquad (7)$$

Solution to equation (7) is the solution to the Poisson equation with Dirchlet's boundary condition.ie

$$\Delta f = \text{div V over } \Gamma \text{ with } f\,|\partial\Gamma = f^*\,|\partial\Gamma \qquad (8)$$

where,

$\Delta = (\partial^2/\partial x^2)+(\partial^2/\partial y^2)$ is the Laplacian operator

div $V=\partial V_1/\partial x+\partial V_2/\partial y$ is the divergence of vector field $V= (V_1,V_2)$

Second derivative can be calculated using finite difference method as:

$$\partial^2 f(x, y)/\partial x^2 = f(x+1, y) + f(x-1, y)-2f(x, y)$$

$$\partial^2 f(x, y)/\partial y^2 = f(x, y+1) + f(x, y-1)-2f(x, y) \quad (9)$$

Equation (6) and (8) are fundamentals for image reconstruction. They can be discretized as follows in a pixel grid:

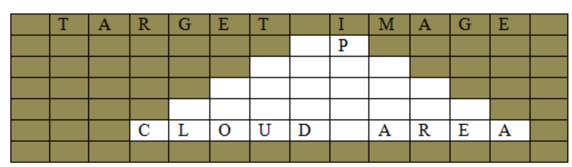

Figure 3: Pixel grid representation

In pixel grid representation shown above the pixel P is in cloud contaminated region. Let f(p) be the value of image function at P. The discretization equation to calculate pixel intensity in cloud contaminated region Γ is

$$\min \sum_{<p,q>\cap\Gamma\neq 0} (f\ (p)-f\ (q)-V_{pq})^2 \text{ with } f(s) = f^*(s) \text{ for all } s \in \partial\Gamma (10)$$

where,

q be one of the connected neighbors of pixel p.ie q € N_p

V_{pq} is the directional gradient

N_p is the pixel set of four connected neighbors of pixel P (top, bottom, right and left).

$|N_p|$ is the number of valid neighbors in N_p.

$$V_{pq=} (P_{Ri}(p)- P_{Ri}(q)) + (P_{Rj}(p)- P_{Rj}(q)) /2 \quad (11)$$

where, P_{Ri} and P_{Rj} represent neighboring patches in reference images I_{Ri} and I_{Rj}

Effect of reconstruction is similar to interpolation when the cloud contaminated region r contains pixel within the target image. Poisson interpolation provides a correction factor f ′ on r such that f=f′+g, where g is the selected reference patch and V is obtained by calculating gradient of source function g. The correction factor f′ is obtained by computing the vibrational difference among the known image intensity function f* and the source function g. Equation (17) can be generalized as

$$|N_p|\, f(p) \; - \sum_{f<p,\, q>\cap r\neq 0} f(q) = \sum_{q\in N_p \cap \partial r} f^*(q) + \sum_{q\in N} V_{pq} \text{for all } p \in r (12)$$

Effect of reconstruction is similar to extrapolation when the cloud contaminated region r contains pixel on the border of target image. The pixels on border lack neighborhood information can be calculated using

$$|N_p| f(p)-\sum_{q \in Nq \in N} f(q)=\sum V_{pq} \qquad (13)$$

Discrete Poisson solver can be used for linear system of equations. But the boundary of cloud contamination is irregular it requires Jacobi iteration. The iteration will continue until the solution converges. The execution time of algorithm depends on solver implementation.

VIII. RESULTS AND DISCUSSIONS

Optical multitemporal satellite images with cloud cover change significantly were collected and tested using MATLAB R2010a. Figure 2 shows the simulated results. Figure 2 (a) shows the cropped portion [size: 400 400] in target image. Figure 2(b-f) shows the corresponding portion in reference images which are the images of same place but at different instant of time. Cloud rate and SSIM index value of each reference images are mentioned below in each figure. Selected reference image based on lower amount of cloud rate and better SSIM index is shown in Figure 2 (g).Reconstructed result for thick cloud contaminated portion is as shown in figure 2(h).

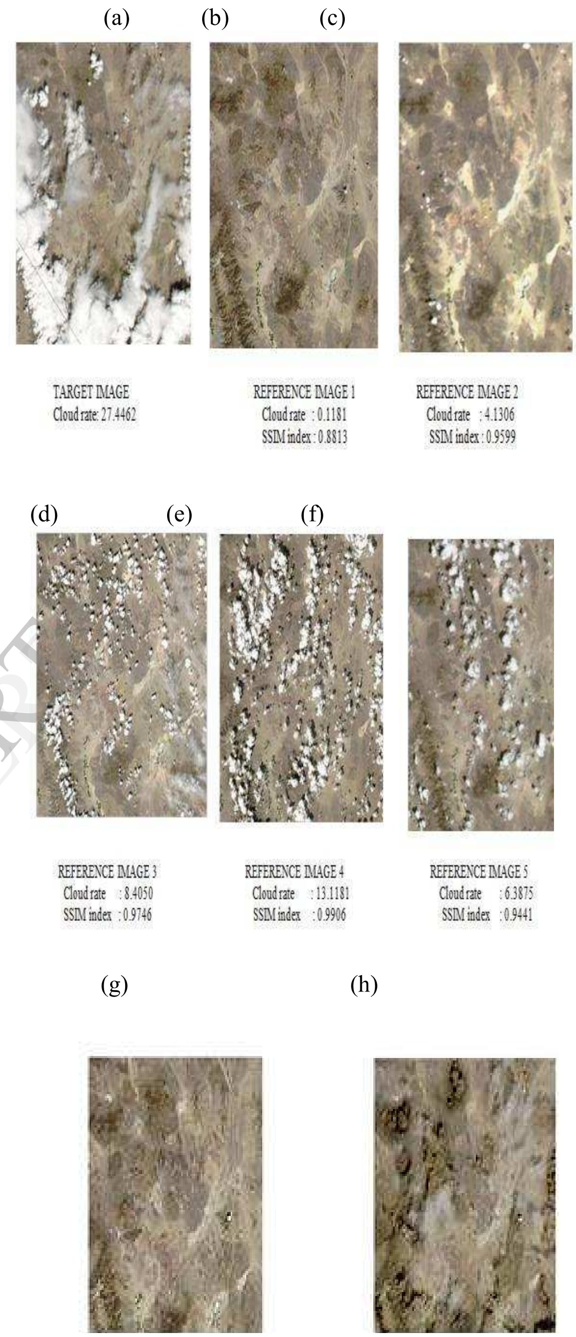

Figure 4: Results (a-h)

XI.CONCLUSION

In this methodology, a thick cloud removal technique is introduced to reconstruct cloud contamination in optical satellite images. Compared to previously existing cloud removal approaches this method provides much more cloud free visualization of satellite images so that various land surface studies are possible. From the Figure 4 (h), it is evident that the thick cloud contaminated portions are reconstructed effectively using the new methodology.

X.REFERENCES

[1] Chao-Hung Lin ,Po –Hung Tsai ,Kang- Hua Lai and Jyun-Yuan Chen,"Cloud removal from multitemporal satellite images using information cloning", *IEEE transactions* on *geoscience and remote sensing*, volume.51,no.1,pp.232-241,January 2013.

[2]A.Bugeau, M. Bertalmio, V. Caselles, and G. Sapiro, "A comprehensive framework for image inpainting", *IEEE transactions on Image Processing*, volume.19,no.10, pp.2634–2645, October 2010.

[3]Xiaolin Zhu, Feng Gao, Desheng Liu, and Jin Chen, "A Modified Neighbourhood Similar Pixel Interpolator Approach for Removing Thick Clouds in Landsat Images", *IEEE geoscience and remote sensing letters*, volume.9, no. 3, pp.521-525, May 2012.

[4] Z. Wang, A. Bovik, H. Sheikh, and E. Simoncelli, "Image quality assessment: From error visibility to structural similarity", *IEEE transactions on Image Processing*, volume. 13, no. 4, pp. 600–612, April 2004.

[5]Niveditta Thakur, Swapna Devi, "A New Method for Color Image Quality Assessment",*International Journal of Computer Applications*, volume.15, no.2, pp.10-17, February 2011.

[6]Bin WANG, Atsuo ONO, "Automated detection and removal of clouds and shadows from Landsat TM images", *IEICE TRANS.INF & SYST*, volume.E82-D, no.2, pp.453-460, February 1999.

[7]P. Perez, M.Gangnet, and A. Blake, "Poisson image editing," *ACM Trans. Graph.*, volume. 22, no. 3, pp. 313–318, July 2003.

[8] Dr. J. Satheesh Kumar, "Cloud Detection and Removal Algorithm Based on Mean and Hybrid Methods", *International Journal of Computing Algorithm*, volume. 02, Issue 01, pp.121-126, June 2013.

[9] M. Li, S. C. Liew, and L. K. Kwoh, "Producing cloud free and cloud shadow free mosaic from cloudy Ikonos images," in *Proc. IEEE International Geoscience and Remote Sensing Symposium (IGRASS)*, volume.6,pp. 3946–3948,July 2003.

[10] Mohamed. A. Berber and Soad F Gaber, "Clouds and shadows detection and removing from remote sensing images", *IEEE conference on Electrical, Electronic and Computer Engineering (ICEEC)*, pp.75-79, September, 2004.