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Cloud Detection and Removal Algorithm Based on Mean and Hybrid Methods

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Abstract - *S*atellite images are playing a major role in region structure planning, change detection which is used in defense for protection and also used for study and analysis of geographical structures of earth and space. Clouds are challenging issue in most of the satellite imaging based applications since appearance of cloud on input image will be treated as noise. Accurate detection and removal of cloud region either from an input image or from image acquisition is an important pre processing phase on most of the applications especially in remote sensing. Algorithms such as, Mean, Second Highest (SH) value, Modified Maximum Average (MMA) and Hybrid methods (combination of Mean and MMA) are widely in use for cloud detection and removal. The result of exiting methods shows that Mean and SH algorithm will be appreciable for removing less number of clouds which have less in brightness (low pixel values). However, MMA and Hybrid algorithms are used for removing more number of clouds in an image that have both less and high brightness (Low and High pixel values). This paper focuses new enhanced method for cloud removal. The result of proposed method shows that it is able to remove the clouds of both low and high brightness values without affecting quality of the images and it is also suitable for all types of satellite images.

Keywords: cloud, removal, mean, SH, satellite imaging.

I. INTRODUCTION

Remote sensing is an interesting field which plays a major role in economic development of the country. It is suitable for study and analysis of changes in the environment with higher impact on defense [1]. Remote sensing is closely related with satellite imaging where images are sensitive with resolution and other image features [14]. Images can be acquired by using different satellites such as ikonos, landsat, Quickbird and each satellite is used for different purposes like defense (change detection in regions), agriculture (for analysis of agriculture) etc [17]. Image quality is one of the most important factors in satellite images because every object in a satellite image is essential for accurate processing.

Quality of satellite image is always questionable when there is higher influence of clouds in an image. Presences of these clouds in satellite images are unavoidable during image acquisition and it also causes many problems in the study of satellite image based applications [3]. Removing cloud as a noise from an image will be helpful for better analysis of satellite imaging applications. Removal of cloud cover region is a challenging task because each region in satellite image is essential one [4][5]. Pixels in most of the cloud cover regions will have higher brightness than other pixels. These regions can be identified and removed by discriminating pixel resolution. Algorithms such as, Mean, Second Highest (SH) value, Modified Maximum Average (MMA) and Hybrid method which is combination of mean and MMA [1] are currently in use for cloud analysis and these algorithms are primarily based on pixel properties. Existing methods are more suitable for static images, small size images and less cloud cover regions. Development of new method is needed for most of the applications to improve the accuracy and better predictions [15]. This paper proposes a new method for cloud analysis which will overcome the drawbacks of existing methods [10][11].

Main aim of this research work is to remove low and high brightness clouds without losing quality of the images. Proposed method is designed in such a way that it will be applicable to all types of satellite images which are taken by using various satellites. Organization of this paper is as follows. Section II focuses on detailed methodology which includes various methods used for cloud analysis. Draw backs of existing methods and need for proposed method is also discussed in section II. Result and discussions are projected in Section III and section IV concludes the paper.

II. METHODOLOGY

Cloud region in an image can be discriminated from other objects based on intensity value of cloud pixels since those pixels will be high in resolution than other pixels [1] [2]. Each pixel in the image has separate pixel value. Cloud property of brightness is a basic property of most of the algorithms used for removing cloud cover region in an image. Several algorithms have already in use for detection and removal of cloud [13]. These algorithms may be either dependent or independent from type of cloud used for analysis. These clouds are generally categorized as high level, low level and middle level clouds with lesser or higher density. Development of better cloud segmentation algorithm which supports all types of cloud is still a challenging and interesting area for most of the researchers [6]. This section describes widely used cloud analysis algorithm and its implementation issues [7] [12].

(a) Mean

Mean based cloud removal is a traditional method which will detect and remove the cloud based on mean intensity value of cloud regions. The strength of mean based method is easy and simple to implement but major constraint of this algorithm is that this method is suggestible only for removal of less brightness clouds and it is not good for high or medium brightness clouds. Mean is a mathematical concept which is used for finding mean value of an array or a vector. Equation for calculating mean is,

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$$A = \frac{\text{Sum of the pixel values of the vector / array}}{\text{Sum of the total number of pixels in the vector / array}} \quad .. (1)$$

Calculated mean value will be used for removal of cloud by comparing mean value with respect to each pixel value of an image. Pixels which are lesser than mean value will be categorized as non cloud regions otherwise pixels will be considered as cloud cover region. This method is not an efficient one when an image has non cloud regions with higher pixel value than mean.

(b) Second Highest Value

Second highest value (SH) algorithm is another method used for cloud analysis. This method works based on calculating second highest values in each row of an image matrix. Each pixel of an image will be taken in a vector form and these vectors are sorted to find out second highest value. This value will be treated as threshold which will be used to compare with pixel resolution for discriminating cloud and non cloud regions. Pixel value greater than threshold is assumed as a cloud cover region and remaining pixel values are considered as cloud free region [2].

(c) Modified Maximum Averaging

Modified Maximum Averaging (MMA) will detect and remove cloud regions better than mean and SH methods. These algorithms will support only for low-level brightness clouds. MMA is one of the enhanced algorithms used to remove high brightness clouds. Procedure used for MMA algorithm is as follows;

i) First step is to assume image as a vector.
ii) Find mean for whole vector.
iii) The subset of the pixel is extracted by comparing pixel values to the mean value of an image [2].
iv) If the pixel value is higher than mean then eliminate the pixel values and remaining values of pixel is consider as cloud free region.
v) Repeat the process until entire cloud region has been detected.

(d) Hybrid Method

Mean, SH and MMA have number of drawbacks and implementation constraints. These methods are not accurate for removal of multi objects from an image. Development of hybrid method is needed to overcome constraints and drawbacks of existing algorithms. Hybrid method is a combination of mean and MMA. The process of hybrid method is to apply mean algorithm for finding the threshold. This threshold values will be used by MMA algorithm for cloud removal.

(e) Proposed Method

Proposed method is created based on the concepts of averaging pixel values. Mean can be calculated by considering average value of the pixels in an image. Threshold for cloud and non cloud regions can be classified by considering mean value either from row vector or from column vector. In image processing, images can be represented in numeric form of two-dimensional structure [8],

For example, consider an image with corresponding matrix 'A'.

$$Aij = \begin{bmatrix} a11 & a12 & a13 & \cdots & \cdots \\ a21 & a22 & a23 & \cdots & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix}$$

Where, 'i' and 'j' represents row and column of a matrix. Proposed method is based on fixing up of threshold value by calculating mean on both column and row wise vector. The formula for column wise mean is,

$$Aj = \frac{\sum j}{N} \quad .. (2)$$

Where, 'j' represents values of columns in the matrix and 'N' represents total number of columns in the matrix.

For example, If A is a matrix with 3 X 3 dimension,

$$\begin{bmatrix} 2 & 3 & 4 \\ 5 & 6 & 7 \\ 7 & 8 & 9 \end{bmatrix}$$

Its column wise mean is, 4.6667 5.6667 6.6667. The formula for row wise mean calculation is

$$Ai = \frac{\sum i}{M} \quad . \quad . (3)$$

Consider, A is a matrix of

$$\begin{bmatrix} 2 & 3 & 4 \\ 5 & 6 & 7 \\ 7 & 8 & 9 \end{bmatrix}$$

Its row wise mean is,
3
6
8

In equation (3), 'i' representing values of rows and 'M' refers total number of rows in the matrix. The above two equations are used to calculate mean to find out the cloud cover region in an image. The data flow representation of the proposed method is shows in figure 1.

The steps of the proposed method are as follows:

(i) Read an input image.
(ii) Image Colour Conversion:Convert RGB colour to Gray Scale colour.
(iii) Image Enhancement

Enhancement can be done by using Median filter for enhancing edges of the cloud cover region in an image.

(iv) Find mean value for an input image.
Both column wise and row wise mean are calculated by using equations (2) and (3).

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(v) Detection and Removal of cloud cover region.

Compare, the column wise mean value with each pixel in a matrix. If mean value is greater than pixel value, than eliminates that pixel values from the matrix and then remaining values are comparing with row wise mean value. If the pixel value of the matrix is lesser than the row wise mean than the values of pixels are taken for future computation.

(vi) Registration of image

Simple registration method is used for filling the holes in an image. The reference image is taken for registration. After removal of cloud, cloud regions should be filled by replacing respective pixels from reference image so as to avoid removal marks in processed image. Figure 1 shows flow of proposed cloud detection and removal method.

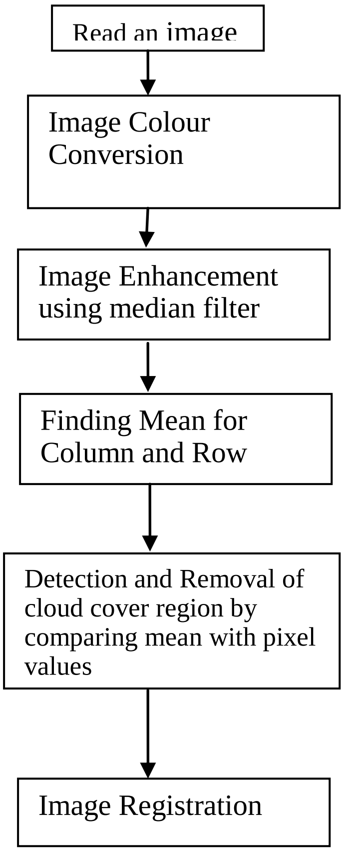


Figure 1. Data flow of the proposed method.

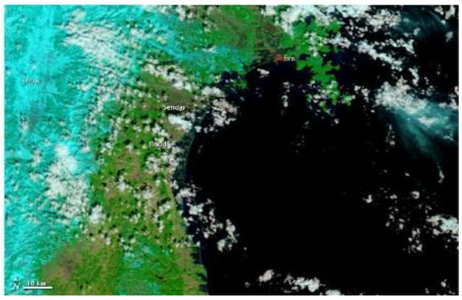
III. RESULTS AND DISCUSSIONS

a) Data Set Description

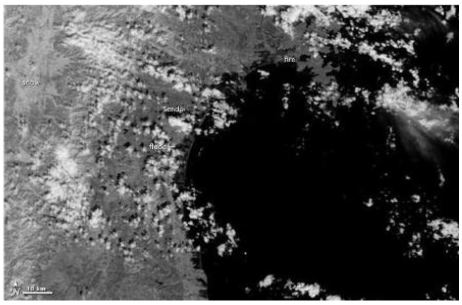
Images acquired from different satellites such as, MODIS, GeoEye's IKONOS satellite, aerial photos, Landsat, etc., are taken for testing the proposed method. The satellite image with interruption of cloud has been considered as an input image and an image without cloud disturbance is considered as a reference image.

b) Results and Discussions

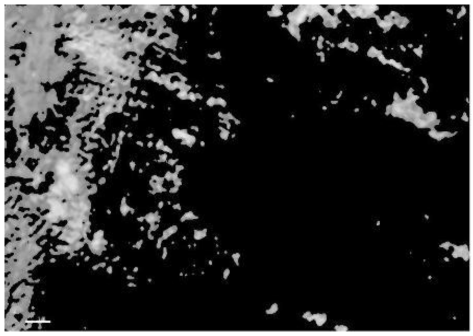
The performance of proposed method and other algorithms have been tested on the images collected from various satellites [16] [17]. Resulting images after removal of cloud using proposed method is visually better than other existing methods with less noise. Figure 2 shows the results of cloud detection and removal using proposed method. PSNR, MSE and Standard deviation are used for measuring strength of the algorithm. Table 1 shows PSNR, MSE and Standard deviation values of widely used methods [9].



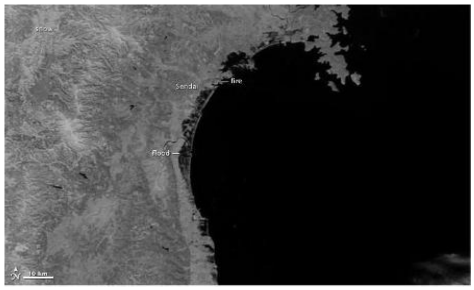
(a)



(b)



(c)



(d)

Figure 2. The Cloud Removal using Proposed method (a) Cloudy image (b) Gray Scale image (c) Cloud detection (d) Cloud Removal.

Performance of cloud removal algorithm have been accepted as an efficient when the standard deviation and PSNR values are high because clouds are having high pixel values than compare to other object values. Mean Square Error values obtained using proposed method is less compare with other methods.

Table 1. Comparisons of Hybrid, MMA, SH and Mean with proposed method.

Method	PSNR	MSE	Standard deviation
Column wise Mean	11.1095	4.7260e+003	52.5991
Row wise Mean	11.0891	4.9341e+003	52.5732
Mean	10.8451	5.5360e+003	48.0477
MMA	9.9213	5.5438e+003	47.7344
Hybrid	9.9219	5.5448e+003	47.7349
Second Highest	8.4561	6.5438e+003	46.6690

Table 1 illustrates that proposed method detect and removes clouds more accurately when compare to the other methods since standard deviation, PSNR and Mean Squared Error values for removal of cloud are better than existing methods. Figure 3 shows better PSNR value for proposed method.

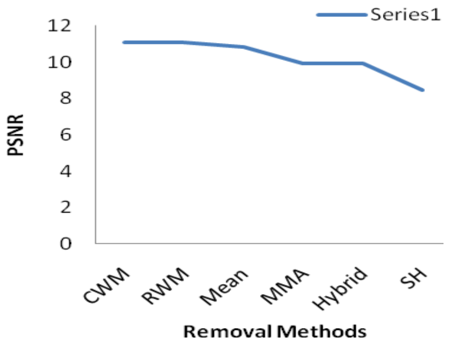


Figure 3. PSNR plot for cloud removal algorithms

IV. CONCLUSION

Cloud detection and classification plays an important role in the field of climate change detection and weather forecasting. This paper deals with detailed study comparison of existing cloud analysis methods such as Mean, Second Highest (SH) value, Modified Maximum Average (MMA) and Hybrid method. Merits and demerits of these methods have also been discussed. This paper proposes enhanced cloud analysis method for accurate detection of cloud and non-cloud regions. Mean at row vector and column vector have been considered for fixing threshold value for better segmentation of cloud cover regions. Enhanced algorithm also works better for removing tiny cloud regions which will be considered noise. Results of proposed method have been compared with existing method. Peak Signal to Noise Ratio (PSNR) and better Mean Squared Error (MSE) have been calculated where proposed method shows better results that existing methods.

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