CHAPTER 7

Automated Cloud Detection & Removal of Satellite Imagery

7.1 Introduction

A significant obstacle is the clouds in the satellite imagery while extracting information by satellite to a remotely sensed object on the earth. Various approaches have already developed with different result for detecting and removing clouds contaminated region from satellite imagery.

Satellite images are useful for identifying the changes that occur in the earth observation such as new settlement, change of river direction, land use for crop production and natural calorimetric. The major problem with these images is that the region below clouds cover is not covered properly by the satellite sensor. The image distortion occurs due to cloud cover of remotely sensed objects.

In this chapter an automated cloud detection and cloud removal (ACDCR) algorithm has been proposed. Detection of cloud in satellite imagery is done based on the pixel intensity (PI) value and cloud removal is done by merging the spatial details of one subject image and two reference images having same location. This process is applied for whole subject image to obtain a cloud-free image. To identify exact location of cloud contaminated region, cloud detection based on threshold value approach is introduced.

7.2 Threshold

Threshold is one of the methods used for image segmentation. It is useful in discriminating subject image from the reference image. By selecting an adequate threshold value T, the gray level image can be converted to binary image. The binary image should contain all of the essential information about the position and shape of the objects of interest of the subject image. The advantage of obtaining a binary image is that it reduces the complexity of the data and simplifies the process of recognition and classification. The most common way to convert a gray level image to a binary image is to select a single threshold value T for whole image and then apply the conditions for all the gray level values:

≤ T will be classified as black (0), and

> T will be white (1).

The crux of the segmentation problem becomes selecting the proper value for the threshold T. In this case the value of T is selected between cloudy and cloud-free modes.

7.3 Model of the Proposed Method

The objective is to identify clouds in a subject image and replace them from the reference images that are acquired at different periods of time. The workflow of the proposed technique for cloud detection and cloud removal from satellite imagery consists of the following steps; cloud detection, cloud removal and image reconstruction. In the first step an automated detection method is applied to detect the cloudy pixels from the subject image. In the next step, the detected clouds are corrected and removed using the reference image. In the last step of the proposed model image reconstruction is performed to fill out the missing information in the subject image and to produce a cloud-free image.

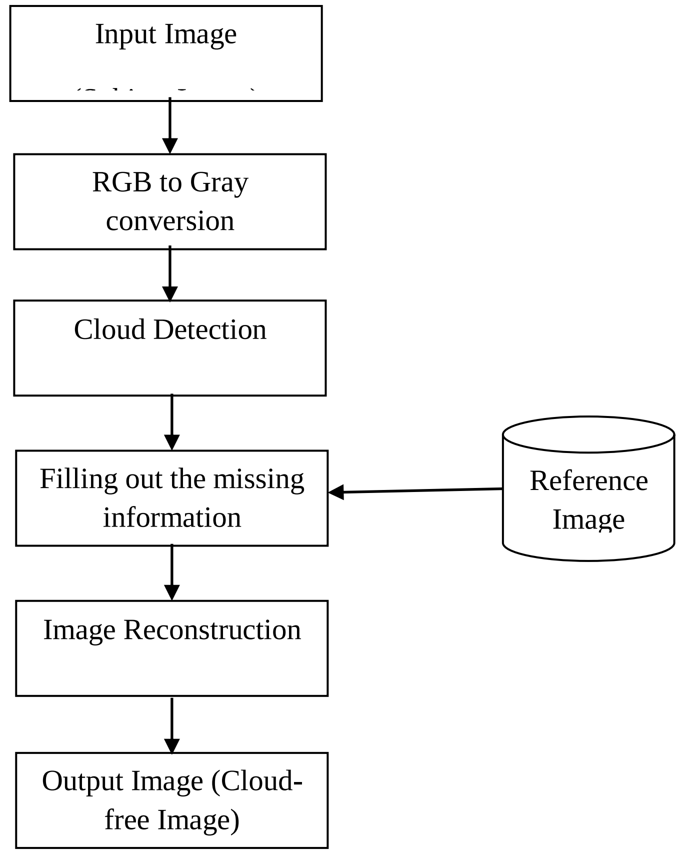

Fig 7.1: Workflow of the proposed method

7.4 Information Extraction

The aim is to extract correct information from earth by using satellite, various factors play an important role while extracting information by satellite. One of the factors is the presence of clouds in the satellite imagery. The following hypothesis is considered for the proposed method:

A significant increase of reflectance between two images of time series is related to the presence of clouds.

As the clouds are moving, clouds may not be present at the same coordinates in two different ortho-photos.

Clouds are generally much brighter compared to other object on earth.

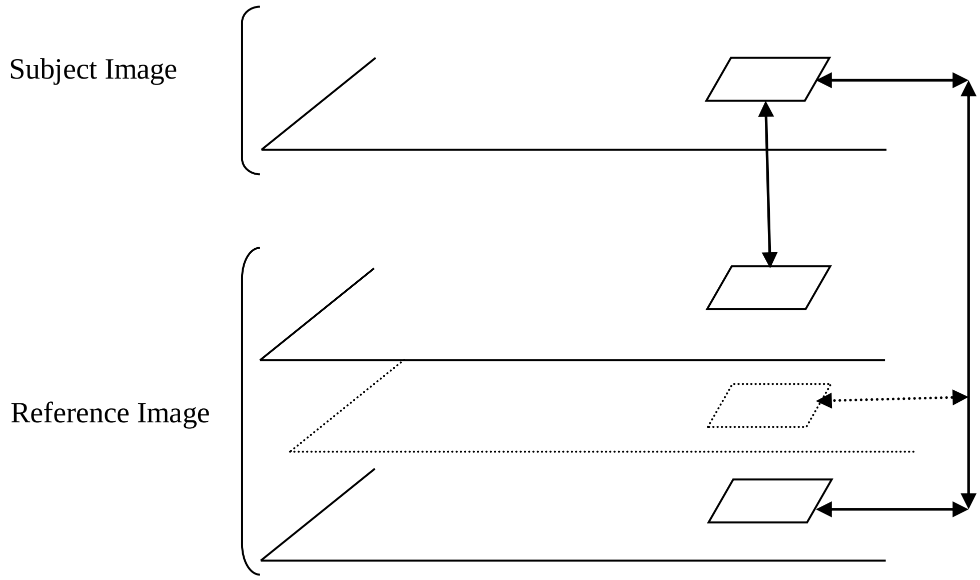

Fig 7.2: Pixel-to-Pixel Comparison

7.4.1 Colour Conversion

To detect the clouds in the target image the pixel intensity value needs to be calculated first. For the given Red Green Blue (RGB) target image it must be converted to any of the colour space for further processing. Here we choose the YIQ colour space conversion where the Y represents the Luma information, I & Q represents the chrominance information. The Y channel alone is used to find the average intensity value. The RGB to YIQ colour conversion is based on the following formula:

$$\begin{pmatrix} Y \\ I \\ Q \end{pmatrix} = \begin{pmatrix} 0.229 & 0.587 & 0.114 \\ 0.595716 & -0.274453 & -0.321263 \\ 0.211456 & -0.522591 & 0.311135 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

The major advantage of YIQ is that the gray scale information is separated from colour data. So the same signal can be used for both colour as well as black and white images.

7.4.2 Pixel-to-Pixel Correction

Pixel-to-Pixel mapping is the process of matching pixel of one image to another image so the same geographic area is positioned coincident with each other respectively. This type of correction is required when any changes occurred or part of the original image gets affected due to the presence of some obstacle while satellite is capturing the image. A reference image needs to be used to get rid of the geometrically corrupted area. The following figure shows the two images of same location at different time series.

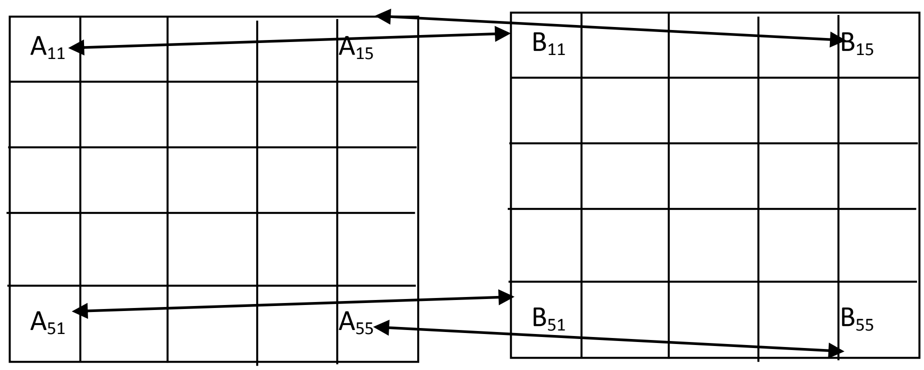

Fig 7.3: Pixel-to-Pixel image correction

7.5 Cloud Detection

The detection of clouds in satellite imagery in the proposed method is based on pixel intensity value. Initially a threshold value is set which is known as pre-defined threshold value. If the pixel value in the target image is lower than the pre-defined threshold value the pixel is marked as cloudy pixel. This process is repeated for each and every pixel in the target image.

Algorithm for Detecting Cloudy Pixel

The algorithm is based on the assumption that the pre-defined threshold value range between $T_i = 95$ to $T_i = 255$.

Algorithm:

if the DN of image > 95 & ≤ 255,

then the pixel is considered as cloudy pixel

place the cloudy pixel in the database.

DB1 = All the cloudy pixels in the image

Else. the pixel is considered as cloud-free pixel

place the cloud-free pixel in the database

DB2 = All the cloud-free pixels in the image.

7.5.1 Procedure of Cloud Detection Algorithm

In the proposed work, initially one target image (T_i) and two reference images (R_1, R_2) of different time interval having same geometric coordinates have been considered. The target image is taken as input image and the reference images (R_1, R_2) are referred from the data base. The DN (Digital Number) values are compared between the target image T (i, j) and the reference images R_1(i, j), R_2(i, j) respectively. If the DN of a particular pixel in (i, j) location of the target image is having value lower than 95, it is considered as cloudy pixel. After finding the cloudy pixel this particular pixel is replaced from the reference image having the minimum DN value. This process is repeated for all the pixels in the target image.

7.6 Cloud Removal

After detecting the cloudy pixel in the target image, it needs to be removed to get the information about the earth observation correctly. As the method is based on pixel-to-pixel comparison, the cloudy pixels are replaced and removed from the reference image by overwriting their spectral data from the data base which were stored in the cloud detection process.

7.6.1 Algorithm for Cloud Removal

Step1: Input the image as target image

Step2: Extract spatial information from reference images (R_1, R_2)

Step3: the cloudy pixel in the target image T (i, j) is compared with reference images R_1(i, j), R_2(i, j) respectively to get the best DN value.

Step4: The best DN value either from R_1(i, j) or R_2(i, j) will be replaced with T (i, j) using

$$T_F = T(i, j) \| R_1(i, j) \| R_2(i, j)$$

Step5: Merge the spatial details of three images to produce a cloud-free image

Step6: Repeat step 3 to step 5 for all the pixels in the target image.

The only requirement of the algorithm is that images should be captured at different time series so that they have different cloud cover patterns at different geometric positions.

The algorithm is quite simple to implement, First the images are converted to gray scale images & the intensity of pixel is calculated. Next a threshold value T_V = 95 is chosen as pre-defined threshold value. Then the threshold value is applied to the target image T_i to find the cloudy and cloud-free pixel. Finally the detected cloudy pixel in the target image T_i is removed & replaced with the data from another image of same location. This process is repeated for all the pixels in the target image.