Cloud cover automatic detection assessment for THEOS satellite images

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Abstract—The Earth observation optical image is considered as the excellent applicant to extract the Earth's surface information. Cloud cover is a spectacular problem for land surface analysis. False detection and analysis typically results for even small percentages of cloud cover. Therefore knowing the percentage of cloud in the image is constructive for the user to allow for selection of those images that contain an acceptable amount of cloud cover (and therefore error) for their application. This paper presents the algorithm for cloud cover assessment using ROI (region of interest) image classification based on histogram segmentation for THEOS satellite images. The objective is to accurately determine the percentage of cloud cover in the optical satellite image, which is improved from the existing algorithm developed. In addition the morphology structure element is used in the algorithm. A study on the appropriate shape and size of structure element is required and has been discussed in this paper.

Keywords—THEOS satellite image, Region of interest, Image segmentation, Histogram segmentation, Cloud cover, Structure element

I. Introduction

The cloud cover in satellite images obtained of the Earth's surface, e.g. Landsat and THEOS satellites, has always been the main concern for the ground receiving station and the end users. For the receiving stations, cloud cover is recorded as being one of the major meta data in the images archive, whereas for the users, cloud cover commonly represents unwanted information in the images [1]. As a consequence of the above problem, one of the possible approaches is to give information of the percentage of cloud cover of the image by using automatic cloud cover detection [2], then archiving this information with each individual image. This is a very useful process to enable users to select images that are appropriate for their application.

In this study, an automatic detection algorithm is developed to assess THEOS image's percentage of cloud cover.

The algorithm consists of three major stages. The first stage is the threshold histogram segmentation, the second process is dilation morphology and the third stage is ROI management for detection of cloud areas.

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The rest of the paper is organized as follows: Section 2 describes the specification of the THEOS satellite and it's images. Section 3 presents the ROI application information. Section 4 demonstrates the cloud automatic detection algorithm. Section 5 describes the results for the experiment of the proposed algorithm. The final section gives a conclusion and identifies future work.

II. THEOS images

A. THEOS specification

After many years of using remote-sensing data from many foreign satellite systems, in 2004 Thailand decided to acquire their own satellite for Earth observation, which was developed by Geo-Informatics and Space Technology Development Agency (Public Organization, GISTDA). The main payloads of THEOS are Panchromatic and Multispectral optical instruments [3]. The Panchromatic resolution is 2 meters, therefore the Multispectral is 15 meters with the blue, green, red and near infrared bands. The orbit type is circular sun-synchronous low earth orbit with an altitude of 822 km. The orbit period and inclination are 101 minutes and 98.7° respectively. The visibility area radius is more than 2,000 km with an access time of about 2 days with a 50° tilting angle [3].

B. THEOS image

Three satellite images have been used for this experiment to demonstrate the result of the proposed algorithm. All of them are THEOS satellite images in multispectral, which have been taken in different places around the world. For example, Fig. 1, is THEOS's image of an area of Chile on October 2008.

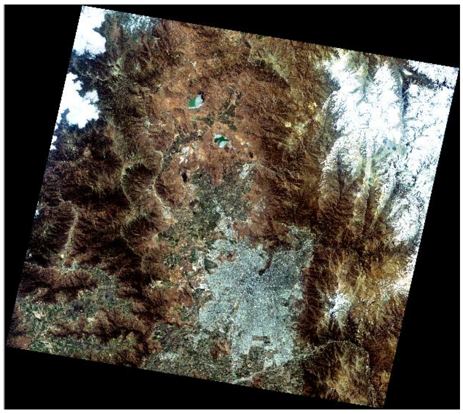


Fig. 1. THEOS multispectral image of Chile.

III. Region of Interest

ROI detection has been applied in many areas, such as telemedicine, remote sensing, web browsing, image database and video compression, etc. [4, 5, and 6]. Identification of the ROI of an image can be performed using a manual or automatic process. There have been many studies to develop automatic ROI detection by using image segmentation techniques [7, 8, 9 and 10]. A real satellite image can be very complex. Consequently, extraction of the required region of interest from within an image is very difficult using only one image segmentation technique. The solution is to use a combination of different image segmentation techniques to detect the region of interest effectively. There are many image segmentation methods, which are often based on basic properties of intensity values, discontinuity and similarity [11, 12, 13 and 14]. This paper proposes an automatic detection technique that can be used to detect the ROI of cloud cover in the satellite image.

IV. Cloud automatic detection algorithm

This section presents the ROI automatic detection algorithm based on histogram segmentation, which is used to identify clouds in the input image. The pixel values in an image can be represented by color histograms. The concept of histogram segmentation is classification of an image using thresholds. The thresholding is performed by considering each peak of the histogram and mapping to a particular region by the concept of different intensities matching to different regions [15]. This research has determined groups of cloud separate from the rest of the image. Each thresholding is separated manually based on the information of the image. Fig. 2 demonstrates the flow chart of the proposed algorithm. The process starts with retrieval of the input image, then conversion to gray scale. The next step is histogram segmentation using the thresholding. This automated algorithm identifies cloud pixels. Then it is applied to convert the image to binary, which is defining pixels of interest and not of interest.

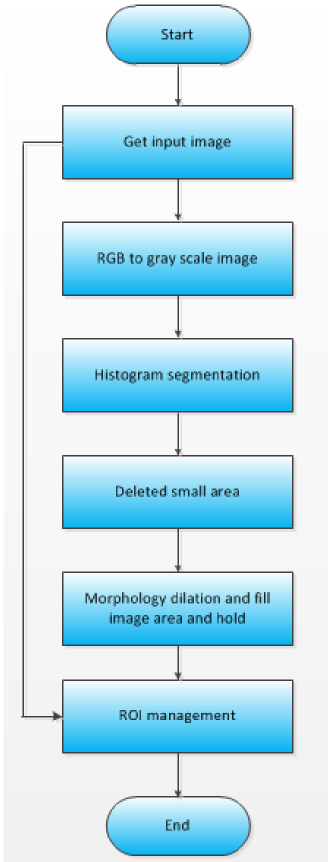


Fig. 2. ROI (cloud) automatic detection based on histogram segmentation algorithm.

The next step is to apply dilation morphology and fill the holes of the image to get the ROI mask, which is the area of cloud only. The final step is to apply the ROI mask to the original image to extract the ROI and calculate the percentage of cloud.

V. Experiment and results

The ROI (cloud) automatic detection process has been tested based on histogram segmentation techniques. The descriptions and results of each process are described as follows;

A. Gray scale image

For this experiment Fig. 1 has been used as an example for testing. The image is converted from color to gray scale. This process coverts the brightness of each pixel to a gray level, which usually consists of 256 levels [11 and 16]. There are many methods to make this conversion. A suitable method for each image depends on the nature of the input color image and the final expected result. Equation (1) shows the conversion of the color image to gray scale. *Igray* is the gray scale image, and *Ir*, *Ig* and *Ib* represent the image pixel value in red, green and blue channels respectively;

$$Igray = (Ir \times 0.3) + (Ig \times 0.59) + (Ib \times 0.11) \qquad (1)$$

B. Histogram segmentation

For the initial design, the threshold is calculated by the random selection of pixels for cloud and the identification of the appropriate group by human intervention. This sampling information is analyzed for statistical features such as the maximum, minimum and average values. The threshold is set based on these statistical features of each group for the example pixels. The statistical values from the first process are applied to the histogram image to compare the intensity range of each object. After obtaining the minimum and maximum intensity of each object, these thresholds (histogram thresholding set) are applied to the image. In this experiment, cloud pixels are replaced by the corresponding pixel value for that category (white color). Fig. 3 demonstrates the cloud cover areas in the example image.

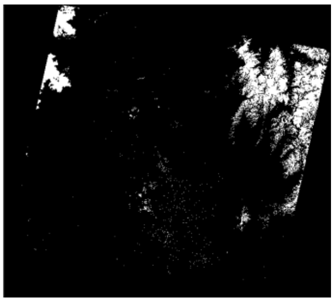


Fig. 3. Cloud only

C. Morphological dilation process

The mathematical morphology technique helps to connect areas, which are separated by smaller spaces than that of the structuring element used. This technique fills image regions and holes and enables a boundary line to be identified [17]. The dilation which is implemented using this method gradually enlarges the boundaries of regions of object. Fig. 4, demonstrates the ROI mask that represents areas of interest that are clouds.

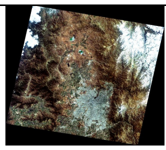
Fig. 4. ROI mask

The dilation operator has two data inputs. The first one is the image and the second one is the structure element. The appropriate size and shape of the structure element is important. A study of the structure element is described in the next section. The final step applies the ROI mask to the original image as shown in Fig. 5, which is cloud cover in the original image.

Other THEOS images have also been tested. Table 1 demonstrates the image size, cloud pixels and percentage of cloud cover in 3 images. There are 17.66 %, 5.52% and 3.03% of cloud cover in the test images number 1, 2 and 3 respectively.

Fig. 5. The output image: ROI (cloud) in the original image.

TABLE 1. The percentage of cloud in the THEOS image automatic detection by the proposed algorithm.

Image number	**Image size**	**Cloud pixels**	**Percentage of cloud in the image**
1.  Chile	37,523,345	628,446	17.66 %
2.  Marseille in France	39,867,558	2,199,990	5.52 %
3.  Nakonratchasima Thailand	53,749,720	1,629,596	3.03 %

The test results show that it is possible to detect the ROI (cloud) by using histogram segmentation. The results indicate that the proposed method is able to reach a comparable level qualitatively and quantitatively to manual assessment [2].

The accuracy of the proposed system has been examined by comparing the number of pixels between a manual process and the proposed automatic detection. The ROI images of both methods are compared by counting the number of different pixels, then using this number to find the percentage of pixels that are the same in ROIs from both detection methods. The result of the comparison for image number 1 is approximately 6.3% of difference.

VI. Morphology structure element study

The dilation technique which is implemented gradually enlarges the boundaries of regions of objects. The dilation operator has two data inputs. The first one is the image and the second is the structure element which is defined by size and shape [11]. A considerable amount of research has been performed on the morphology of the structuring elements [18 and 19]. The selection of structuring element size and shape depends on the geometric shapes that need to be extracted from the input image. For instance, for extracting shapes from geographic aerial images of a city, a square or rectangular element will provide good results [20].

For the morphology dilation and the morphology fill regions and holes, the structure element (SE) is the main parameter used in the morphological technique for image processing. Hence it is necessary to understand how the shape and size of SE affects the output image of the proposed ROI automatic detection system.

This research has investigated the shape and size of SE selection to find an appropriate method for the proposed system. Table 3 illustrates the test results of different shapes of SE changing the output images. The results show the percentage of difference between the ROI automatic detection and manual detection by using different SE. The ROI image from square, diamond and disk SE give similar results. However the line shape cannot detect some information in the ocean and land that have large regions with similar pixel values.

In addition four different sizes of the SE have been applied using the proposed system to test the effect on the resultant image as shown in table 4. There are four different sizes varying from 5x5, 10x10, 15x15 to 20x20 pixels. Table 4 shows the ROI images which are produced by the proposed system using the square shape of 4 different sizes. The results show that the ROI mask using size 3 gives the smallest percentage of difference between ROI automatic detection and ROI manual detection (3.33%).

TABLE 2. The percentage difference between the ROI automatic detection and ROI manual detection using different shapes of SE.

SE size	ROI image	Percentage difference
5 x 5		5.60 %
10x10		4.44 %
15x15		3.33 %
20x20		4.38 %

TABLE 3. The percentage difference between the ROI automatic detection and ROI manual detection using square shape in different sizes of SE

SE size	ROI image	Percentage difference
Square		10.27 %
Diamond		10.52 %
Disk		10.74 %
Line		11.48 %

VII. Conclusion and future work

The ROI automatic detection is a method to define the area of an image that contains information of interest; in this case it is cloud cover. This paper proposes an algorithm to detect cloud in THEOS satellite images and obtains the percentage of cloud cover by using ROI automatic detection technique based on histogram segmentation. The information obtained on the percentage of cloud cover in an image is useful for the user, allowing them to choose whether the image is acceptable for use in their application. This aids in reducing time consumption spent in satellite image preparation and image disqualification.

The system consists of three main parts; the first one is the threshold histogram segmentation. The second process is dilation morphology and the last process is ROI management for detection of cloud areas. The proposed algorithm can detect cloud cover automatically and give the percentage of the cloud cover in the image.

In addition the size and shape of the morphological structure element used has been found to affect the output image size. Therefore future work is how to identify smaller and specific ROI in an image, for example a rice paddy or specific patch of land**.**

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