Detection of Clouds and Cloud Shadow in Satellite Images using Fuzzy Logic

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Abstract— **In satellite captured imagery clouds and cloud shadows are quite common. They sometimes aid information content and at others degrade it. Not only shadows but also the presence of clouds can tamper with the precious information that can be claimed from satellite images. Hence, detection of such elements is vital to claim the so lost or degraded information. The main aim of this paper is to provide an alternative methodology for estimation and detection of cloud and cloud shadow region in images. The proposed method takes advantage of the photometric invariance of $C_1C_2C_3$ color model and fuzzy thresholding.**

Index Terms—**Colour space models, Deriche edge detector, Fuzzy membership function, Morphology.**

I. Introduction

Satellite images find application in a wide range of areas like weather forecasting, climate studies, study of land cover, vegetation, topography etc. Capturing contaminant images is quite not yet possible. These contaminants may be in the form of clouds or cloud shadows, shadows of aerial objects etc. Presence of such elements might lead to problems in retrieval of atmosphere or surface information from satellite images. In order to claim the lost or degraded information detection of clouds and shadows in such images is quite important [1].

Some relevant work has been previously done in the area of cloud as well as cloud shadow detection. In [2], Simpson et al. proposed a method to detect cloud shadows using arbitrary viewing and illumination conditions. In [3], mathematical morphology was used harnessing the fact that clouds are brighter and shadows darker whereas in [4] SVM(Support Vector Machine) classifier was used. Reference [5] describes the use of HSI(Hue , Saturation, Intensity) color space and stationary wavelet transform for cloud detection.

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II. Methodology

This work has been derived by combining the two stage shadow detection model proposed in [6] with the thresholding techniques as proposed in [7] and [8]. Various steps involved are discussed in brief in this section.

A. Color Space Model

Invariant color models are models which are invariant to a specific set of parameters. Different color models are invariant and sensitive to different sets of parameters. This property of the color space models can be exploited to suit various applications. For instance, a model that is invariant to shadow or luminance can be used to detect shadows in real scene images or images of objects etc. Sensitivity of specific models towards shadow, material, geometry and highlights is shown in the Table I below. In the table R,G,B are red, green and blue color components respectively in RGB image; C_1,C_2,C_3 are first, second and third chrominance components respectively, o_1o_2 o_3 is the opponent color space. Y shows that the model is invariant to the corresponding parameters and N represents variance [9].

TABLE I. SENSITIVITY OF COLOR SPACE MODELS TO VARIOUS PARAMETERS

Model	Shadow	Geometry	Material	Highlights
RGB	Y	Y	Y	Y
$C_1C_2C_3$	N	N	Y	Y
$o_1o_2o_3$	Y	Y	Y	N

i. $C_1C_2C_3$ Color Space

A $C_1C_2C_3$ color space model as described in [6] is defined as follows:

$$C_1 = \tan^{-1}\frac{R}{\max(G,B)} \qquad (1)$$

$$C_2 = \tan^{-1}\frac{G}{\max(R,B)} \qquad (2)$$

$$C_3 = \tan^{-1}\frac{B}{\max(R,G)} \qquad (3)$$

Where, R,G,B are red, green and blue color components respectively in RGB image; C_1,C_2,C_3 are first, second and third chrominance components respectively. This color model was chosen for cloud shadow detection segment because of its property to suppress comparatively dull pixels (cloud and background) in the image [10].

B. Fuzzy Thresholding

As described in [6], [7], this is a great method for thresholding that overcomes a lot of misclassification problems of the state-of-art techniques. It assigns a degree of belief that a certain pixel is cloudy or not [11]. The key idea is to minimize fuzzy divergence value as in [7]. It is defined as the difference between actual and automatic/ideal threshold image. Membership value ($\mu(g_{ij})$) is given by gamma distribution and is calculated for each pixel and stored in a matrix for each threshold value (g=graylevel). It is defined as following (where, $0 \leq \mu(g_{ij}) \leq 1$ and, c = 1/256):

$$\mu_0 = \frac{\sum_{g=0}^{l} g.\text{count}\ (g)}{\sum_{g=0}^{l} \text{count}\ (g)} \qquad (4)$$

$$\mu_1 = \frac{\sum_{g=l+1}^{L-1} g.\text{count}\ (g)}{\sum_{g=l+1}^{L-1} \text{count}\ (g)} \qquad (5)$$

if $g_{ij} \leq l$ for background then,

$$\mu(g_{ij}) = \exp(-c.\ |g_{ij}-\mu_0|) \qquad (6)$$

if $g_{ij} > l$, for object (cloud/ shadow) then,

$$\mu(g_{ij}) = \exp(-c.\ |g_{ij}-\mu_1|) \qquad (7)$$

where, g=0,1,2...,255, count(g)=no. of occurrences of gray level g in the image, $g_{ij}=(i,j)^{th}$ pixel of the image, l=threshold value. One threshold satisfies only one condition which indicates the quantity of pixels belonging to background and cloud or cloud shadow.

C. Morphology

As described in [12], morphological operations primarily are of two types: erosion and dilation. Erosion is used for thinning any image element while dilation performs thickening. There are other morphological operations as well which are opening and closing. Opening is erosion followed by dilation. It can be used for the elimination of thin protrusions in an image thus smoothing it. Closing too performs smoothing of image but by fusing narrow furrows and eliminating small holes etc. It is dilation followed by erosion. Opening and closing have been used in order to eliminate isolated pixels.

D. Edge Detection

According to [13], any set of connected pixels which separates two disjoint regions is known as an edge. As described in, edge detection is used to segment images based on abrupt changes in intensity. Since, detection quality, unambiguity and accuracy is good in Deriche edge detector [14], it was used to determine cloud and cloud shadow edges.

E. Block Diagram

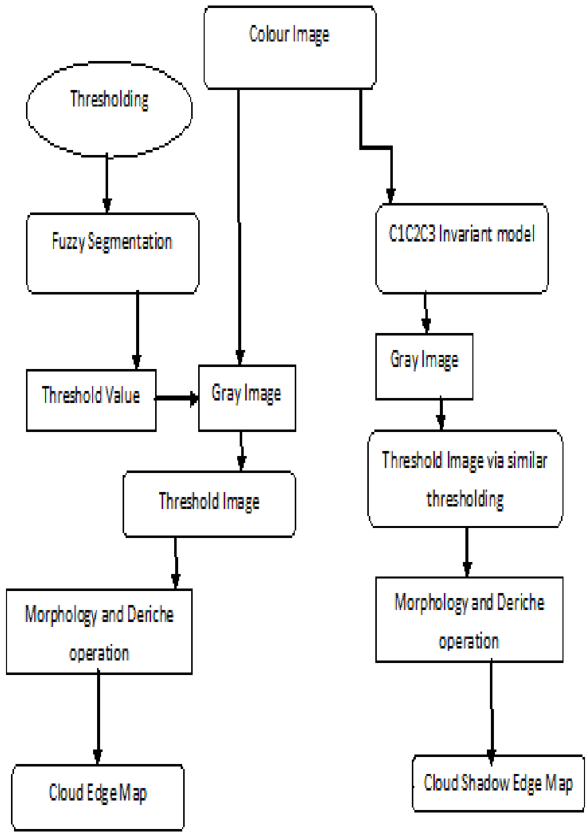

Fig. 1: Block diagram of the system

III. RESULT AND DISCUSSION

On application of algorithm to some satellite images, the results turned out to be satisfactory. Following are the experimental results on some cloud and cloud shadow images. Fig. 3 shows the results of cloud and cloud shadow estimation as applied to the original images in fig. 2. In the belowe results cloud and cloud shadow edges were effectively traced. Detected clouds in the images are enclosed with green boundary and shadows with pink boundary.

Fig. 2: Satellite images of Cloud and cloud shadow obtained from internet.

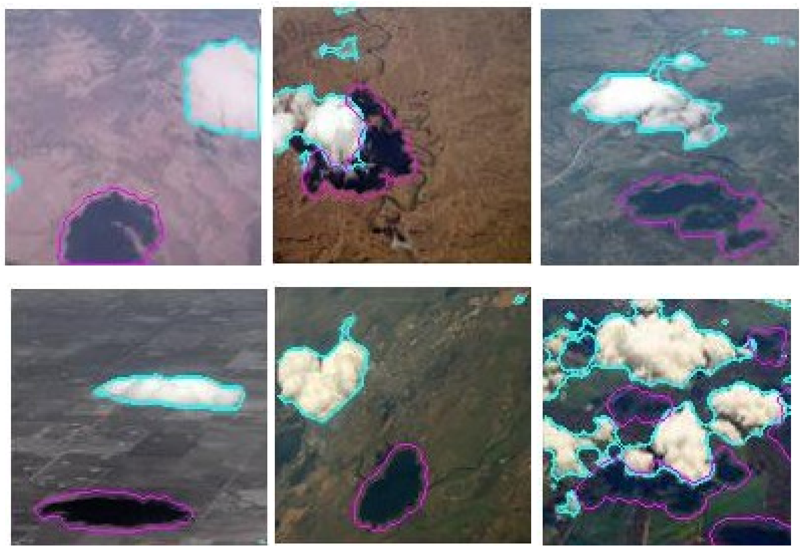

Fig. 3: Detected clouds (Green) and cloud shadow (Pink)

IV. CONCLUSION

The given algorithm was implemented on a few satellite captured images of cloud and cloud shadows, and the results were found to be appreciable and quite precise though minute misdetections are there. The system is can be enhanced to produce better, more accurate and precise results.

The shadow detection algorithm detects all shadows present in the images. Only images with clouds and their respective shadows have been tested. Although, detected shadows are accurate but for fine boundaries very good agreement with shadow borders is not seen, the algorithm needs to be modified for stereotype cloud shadows.

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