Cloud Region Segmentation from All Sky Images using Double K-Means Clustering

1st Semih Dinc
EagleView Technologies
semih.dinc@eagleview.com

2nd Randy Russell
Department of Chemistry
Auburn University at Montgomery
rrussell@aum.edu

3rd Luis Alberto Cueva Parra
Computer Science and Information Systems
University of North Georgia
Luis.CuevaParra@ung.edu

***Abstract*—The segmentation of sky images into regions of cloud and clear sky allows atmospheric scientists to determine the fraction of cloud cover and the distribution of cloud without resorting to subjective estimates by a human observer. This is a challenging problem because cloud boundaries and cirroform cloud regions are often semi-transparent and indistinct. In this study, we propose a lightweight, unsupervised methodology to identify cloud regions in ground-based hemispherical sky images. Our method offers a fast and adaptive approach without the necessity of fixed thresholds by utilizing K-means clustering on transformed pixel values. We present the results of our method for two data sets and compare them with three different methods in the literature.**

***Index Terms*—Cloud Region Segmentation, All Sky Images, K-means, Image Processing**

I. Introduction

An accurate record of the fraction and distribution of cloud is essential to atmospheric cloud research. However, the task of segmenting sky images to determine this vital information is often made difficult by the presence of tenuous cloud boundaries and semi-transparent cloud regions. [9]. The majority of published papers in the area can be categorized into two groups: 1) Traditional threshold-based methods that involve manual feature engineering, and 2) Modern deep learning based methods. Traditional methods mostly rely on extracting features (e.g. statistical, chromatic, or textural) from the original image and generating a gray level image that emphasizes distinctions between cloud and clear sky pixels [8]. They do not require large amounts of labelled data or long training times. However, most require the determination of a fixed threshold for parameters used in the segmentation. Modern deep learning methods avoid feature extraction and thresholding problems since they directly feed the original cloud image to a deep neural network to generate a corresponding segmentation image. Xie et al. Convolutional Neural Network (CNN) methods methods are commonly used (e.g. SegCloud [9]).

In this paper, we have experimented with two datasets containing ground-based sky images in RGB color space. Below, we describe details of each dataset. In first imageset (AUM ASC) RGB sky images were captured using a Moonglow Technologies video camera with a fisheye lens. The camera is mounted on the roof of the Ida Belle Young library tower on the AUM campus. Each JPEG image is a 720×480 pixel rectangle containing a central elliptical region corresponding to the sky. The second imageset The Singapore Whole sky IMaging SEGmentation Database (SWIMSEG) includes total of 1013 sky/cloud image patches and corresponding segmentation images. Each image has 600×600 resolution and was recorded between October 2013 to July 2015 in Singapore with the assistance of experts in Singapore Meteorological Services [1].

II. Proposed Method

In this study, we propose a non-parametric and efficient method for cloud region segmentation using whole sky RGB images. Our method of segmentation utilizes pixel clustering with regard to pixel proximity in two phases. As stated in several other studies such as [3] and [6], blue light is dominantly scattered in clear sky regions, which leads to a blue appearance to our eyes. On the other hand, in cloud regions, blue and red light are equally scattered by cloud particles, yielding a white or gray appearance to our eyes. We adopted the R/B ratio in our experiments as it generated more consistent results in our dataset.

The first K-means clustering divides pixels into 3 clusters: clear sky, indeterminate, and cloud. The intuition behind this idea is that some clear sky or cloud pixels can be unambiguously labeled in the first clustering, while some other pixels require closer examination. Then, in the second phase, we run another K-means passing only the indeterminate pixels to the algorithm to divide into two clusters. Similar to the first clustering, we start from approximate cluster centers and limit the number of iterations. Finally, all clear sky and cloud pixels are combined. A segmentation image is generated from labelled pixels.

Phase 1 and 2 of the system use only individual pixel values. The number of mislabelled pixels can be significantly reduced by utilizing the proximity information of pixels. We adopted a filtering approach from our previous work [2]. A 2D median filter was applied to the segmentation image to eliminate isolated and mislabelled pixels. Finally, the total cloud coverage is calculated by dividing the number of cloud pixels by the total number of pixels.

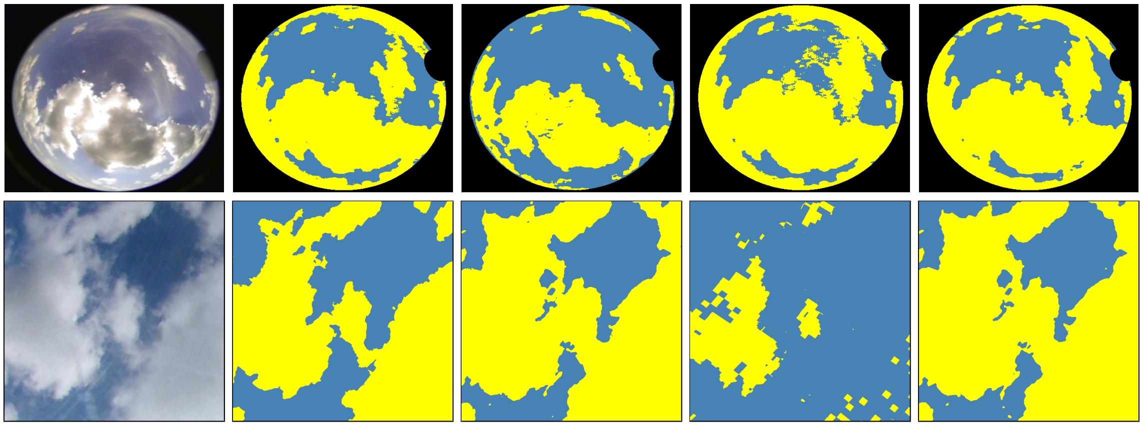

Fig. 1: Segmentation results. Top row ASC dataset. Bottom row SWIMSEG dataset. Columns from left to right, 1) original image, 2) Entropy based, 3) Otsu's, 4) Fixed Threshold, 5) Double K-means.

III. Experimental Results

We performed experiments on two different datasets and compared the results of the proposed method with three other methodologies that are commonly used to perform cloud region segmentation. The first method is a traditional binarization method called Otsu's Thresholding [7]. The second method is a well-known cloud identification method used by [5]. The last method is a baseline fixed threshold method that requires the tuning of threshold values on the R, G, and B color channels to determine the optimal threshold for a particular dataset [4]. In experiments, we compared the root-mean-square (RMS) error between the labelled cloud coverage and the cloud coverage estimated by methods. Table I shows average RMS error in two datasets.

In AUM ASC dataset, Otsu's method and the Entropy based method did not perform well. On the other hand, the fixed threshold method and the proposed method produced satisfactory results for all image types. In SWIMSEG dataset, the baseline fixed threshold method performs significantly worse than other methods. These results are somehow expected because the baseline method threshold values are carefully tuned for the ASC dataset, not the SWIMSEG dataset. On the other hand the proposed method performed well in both datasets because it is more generalized and does not require a parameter tuning step. Sample visual results are shown in Figure 1.

TABLE I: Average RMS Errors

	Kmeans	Otsu	Entropy	Baseline
AUM ASC	**0.105**	0.215	0.218	0.138
SWIMSEG	**0.087**	0.100	0.123	0.461

IV. Conclusion

Double K-means clustering has be shown to produce segmentation images suitable for determining cloud amount from color all sky images. The accuracy of the method is comparable to that achieved visually by experienced observers and is significantly greater than that produced by other simple segmentation methods. The method avoids having to find a threshold for segmenting the image and does not require supervision and training, so application to images obtained using a variety of cameras under differing sky conditions should be possible.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 2003740.

References

[1] Soumyabrata Dev, Yee Hui Lee, and Stefan Winkler. Color-based segmentation of sky/cloud images from ground-based cameras. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 10(1):231–242, 2016.

[2] Semih Dinc and Luis Alberto Cueva Parra. A three layer spatial-spectral hyperspectral image classification model using guided median filters. In *Proceedings of the 2021 ACM Southeast Conference*, pages 122–129, 2021.

[3] A. Heinle, A. Macke, and A. Srivastav. Automatic cloud classification of whole sky images. *Atmospheric Measurement Techniques*, 3:557–567, 2010.

[4] A. Kazantzidis, P. Tzoumanikas, A. F. Bais, S. Fotopoulos, and G. Economou. Cloud detection and classification with the use of whole-sky ground-based images. *Atmospheric Research*, 113:80–88, 9 2012.

[5] Qingyong Li, Weitao Lu, and Jun Yang. A hybrid thresholding algorithm for cloud detection on ground-based color images. *Journal of Atmospheric and Oceanic Technology*, 28:1286–1296, 10 2011.

[6] Charles N Long, Jeff M Sabburg, Josep Calbó, and David Pagès. Retrieving cloud characteristics from ground-based daytime color all-sky images. *Journal of Atmospheric and Oceanic Technology*, 23(5):633–652, 2006.

[7] Nobuyuki Otsu. A threshold selection method from gray-level histograms. *IEEE transactions on systems, man, and cybernetics*, 9(1):62–66, 1979.

[8] R. Tapakis and A. G. Charalambides. Equipment and methodologies for cloud detection and classification: A review. *Solar Energy*, 95:392–430, 9 2013.

[9] Wanyi Xie, Dong Liu, Ming Yang, Shaoqing Chen, Benge Wang, Zhenzhu Wang, Yingwei Xia, Yong Liu, Yiren Wang, and Chaofang Zhang. Segcloud: a novel cloud image segmentation model using deep convolutional neural network for ground-based all-sky-view camera observation. *Atmospheric Measurement Techniques Discussions*, pages 1–16, 2019.