Ground-based Cloud Classification By Learning Stable Local Binary Patterns

Yu Wang, Cunzhao Shi, Chunheng Wang, Baihua Xiao

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Ground-based Cloud Classification By Learning Stable Local Binary Patterns

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Abstract—**Feature selection and extraction is the first step in implementing pattern classification. The same is true for ground-based cloud classification. Histogram features based on local binary patterns (LBPs) are widely used to classify texture images. However, the conventional uniform LBP approach cannot capture all the dominant patterns in cloud texture images, thereby resulting in low classification performance. In this study, a robust feature extraction method by learning stable LBPs is proposed based on the averaged ranks of the occurrence frequencies of all rotation invariant patterns defined in the LBPs of cloud images. The proposed method is validated with a ground-based cloud classification database comprising five cloud types. Experimental results demonstrate that the proposed method achieves significantly higher classification accuracy than the uniform LBP, local texture patterns (LTP), dominant LBP (DLBP), completed LBP (CLTP) and salient LBP (SaLBP) methods in this cloud image database and under different noise conditions. And the performance of the proposed method is comparable with that of the popular deep convolutional neural network (DCNN) method, but with less computation complexity. Furthermore, the proposed method also achieves superior performance on an independent test data set.**

Index Terms—**Local binary patterns, cloud classification, feature selection and extraction, texture image.**

I. INTRODUCTION

Clouds are the external reflection of the combined effect of atmospheric dynamics, heat, and hydrological cycle. They play an extremely important role on climate and the Earth's energy budget balance (Heinle et al., 2010; Liu et al., 2013). The volume, shape, thickness and composition of clouds indicate the condition of atmospheric motion, and monitoring these parameters has important implications for weather prediction, climate modeling, and flight service (Silva and Souza, 2013; Papin et al., 2002; Dev, et al., 2017). These uncertainties motivate researchers to study various characteristics of clouds, including cloud type, cloud height and cloud cover over the past years (Buch et al., 1995; Peura et al., 1996; Kazantzidis et al., 2012; Dev et al., 2016; Shiraishi et al., 2014; Lee and Mahmood, 2015).

Clouds are generally observed via three ways including space-based satellite observation, air-based radiosonde observation, and ground-based laser, visible light and infrared observations. Satellite images and aerial photographs are popular tools for monitoring the Earth's atmosphere (Shiraishi et al., 2014; Lee and Mahmood, 2015; Zhang and Xiao, 2014). Accurate satellite images with different spatial and temporal resolutions are widely utilized in large-scale surveys (Dev et al., 2016; Dev et al., 2017). For example, NASA's satellite has showed that 70% of the world's atmosphere is covered with clouds (Wylie et al., 2007). However, as Dev et al. (2016) and Dev et al. (2017) pointed out, satellite images cannot provide sufficient temporal and spatial resolutions for localized and short-term cloud analysis over a particular area, such as local weather prediction. In this case, small clouds may be easily overlooked, and low or thin clouds are easily confused because of their similar brightness and temperature (Heinle et al., 2010; Ricciardelli et al., 2008; Dybbroe et al., 2005). Although air-based radiosonde observation is advantageous in detecting cloud vertical structures, it is considerably costly, and less number of detection is difficult to meet the requirements of actual cloud detection.

The deficiencies of air-based radiosonde and space-based satellite observations have resulted in the popularity of ground-based whole sky images (Feister et al., 2010; Dev et al., 2016). It is commonly used to support satellite and radiosonde observation studies. These images are available at low cost and high resolution, and they offer accurate local cloud information (Dev et al., 2014; Dev et al., 2015a). Thus, ground-based whole sky images are now widely used in solar irradiance prediction (Fua and Cheng, 2013), local weather prediction, tracking contrails (Schumann et al., 2013), and attenuation of communication signals (Yuan et al., 2014). Over the years, a number of whole sky image models such as the Wide-Angle High-Resolution Sky Imaging System (WAHRSIS) (the data used in our study is obtained by this model) have been developed. See the detailed description in Dev et al. (2016).

Cloud base height, cloud cover, and cloud type are three important parameters for ground-based cloud observation (Roman, et al., 2017; Costa-Suros et al., 2013). In this study, we focus on the research of cloud types. The successful classification of cloud types can improve the precision of weather prediction and the understanding of climatic conditions. It also plays an essential role in meteorological studies. However, the recognition of cloud types at present mainly relies on artificial observation. The result is subjective and cannot satisfy the actual requirements of meteorological observations. The automatic classification of cloud types has become an urgent problem to be solved in this field. Several papers have been published on this subject.

In one prior study, Peura et al. (1996) adopted the basic physical information of clouds such as cloud outline to classify

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Y. Wang is with the State Key Laboratory of Management and Control for Complex Systems, Institute of Automation, Chinese Academy of Sciences, and with the University of Chinese Academy of Sciences, Beijing 100190 and with the School of Software, Shanxi University, Taiyuan 030006, China.

C. Shi, C. Wang and B. Xiao are with the State Key Laboratory of Management and Control for Complex Systems, Institute of Automation, Chinese Academy of Sciences, Beijing 100190, China.